Catfish Research Verification Trials in West Alabama Using Channel Catfish (*Ictalurus punctatus*) and Hybrid Catfish (*Ictalurus punctatus x Ictalurus furcatus)*

by

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Abstract

From 2010-2013 three management protocols were followed over 21 production cycles on three farms in west Alabama. The protocols were an owner defined multiple-batch Treatment A, an Extension defined single-batch Treatment B and a multiple-batch Treatment C. Data were analyzed to calculate yields, feed conversion ratios, cost of production and net returns.

Over three production cycles from Farm 1, Treatment A outperformed the two Extension recommended treatments (Treatments B and C) in terms of yield (13,156 to 10,780 and 6,121 lb/acre/year respectively), survival (91% to 87% and 51% respectively), feed conversion ratio (FCR 1.87 to 2.09 and 3.01 respectively), cost of production ($0.68, $0.73, and $1.08/lb respectively), and net returns ($122,789 to $95,419 and $2,810). Key to this outcome was the completion of three crops 2.75 years, compared to 3.58 and 3.67 years in the other two. Treatment A allowed the farmer to vary feeding rates and he chose to feed above the recommended daily feeding maximum and with high aeration Hp/acre no low dissolved oxygen levels were observed. Disease (*Edwardsiella tarda*) losses in Treatment C led to poor survival results. Farm 1 production cycles showed the importance of verifying Extension recommendations under commercial production conditions.

Over two production cycles from Farm 2, Treatment A performed best though Treatment C was close in terms of yield (5,384 to 5,191 lbs/acre/year respectively) compared to Treatment B at 4,261 lbs/acre/year, survival (58% to 42%, and 76% respectively). However the FCR (and cost of production) was best for Treatment B at 1.77 ($0.66/lb) compared to 2.59 ($0.75) and 2.60 ($0.75/lb) for Treatments C and A respectively. Treatment B also had the highest net

returns to land at $63,697 compared to Treatments C and A ($52,935 and $44,080 respectively). Farm 2 production cycles showed that there were advantages and disadvantages to the different treatments but all were profitable.

Over two production cycles from Farm 3, there were mixed results on which treatment was better. Treatment A performed better than Treatments B and C in terms of yield (4,631 to 4,619 and 4,143 lbs/acre/year respectively) and net returns to land ($50,312 to $43,811 and $37,723 respectively). In terms of survival and FCR Treatment B did better than Treatments A and C (survival 61% to 44% and 48% respectively; and FCR 2.22 to 2.62 and 2.42 respectively). In terms of production costs Treatments B and C did better than Treatment A ($0.73 and $0.75 to $0.82/lb produced respectively). It should be noted that in Farm 2 and Farm 3, the treatments with the highest survival rates were those having the highest levels of aeration (Hp/acre). This is in line with current Extension recommendations.

Based on these verification trials, some refinements Best Management Practices could be recommended, such as increasing the stocking density for hybrid catfish production, increasing the hybrid catfish feeding rate, and increasing aeration capacity and use for Channel and hybrid catfish production. Each of these recommendations has also been shown in this study to be profitable. This study confirmed again that we, that is researchers, producers and Extension personnel, must work together to gain the new insights that can improve catfish production management practices. Thorough good record keeping practices were used to perform this work and it would be a good tool to teach producers as a means to evaluate their own operations. This project allowed us to test new concepts toward making future recommendations that can lead to refined “best money making practices.”

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Chapter 1

Introduction

The groundwork laid to begin the birth of the commercial catfish industry began in the 1940's, with the research and leadership of Dr. Homer Swingle. Channel catfish (*Ictalurus punctatus*) were originally cultured along with many other finfish species for the purpose of stocking lakes, reservoirs and ponds of the U.S. and this is where the early research was focused. (Hargreaves 2002). Through research and "trial and error" techniques, Swingle discovered that a formulated feed was necessary to grow Channel catfish being raised for the purpose of commercialization. The realization that producing Channel catfish with a formulated feed and proper stocking rate (2,000 kg/ha), along with economic analysis to assess profit potential for commercial production of catfish, was perhaps the most valuable contribution to a fledgling commercial catfish industry.

As time went on, commercial catfish farming continued to grow as a result of growing interest from farmers and technical innovations developed to make production more efficient. Farmers fabricated feed blowers, harvesting equipment and early paddlewheels that could be driven by a tractor power take-off (PTO). Prior to the 1970s, Channel catfish were strictly being produced in a single-batch or one-crop system. The advantage to this type of production is a better feed conversion ratio (FCR) and uniformity in fish size. However, this production technique limited the farmer to producing one crop at a time. When the fish reached market size, the pond was drained and all fish were harvested at once. A major drawback of this approach was a restriction to seasonally producing fish and having to start over after each crop. At the same time, processing plants would receive a large volume at one time, potentially flooding the market and driving prices down (Engle and Pounds 1994).

Because of the limitations resulting from single-batch production, farmers began multi-batching, or stocking multiple sizes of catfish together in the same pond. In multi-batch production, fingerlings are added each spring to ponds that contain the previous year's crop of fish that are still too small to harvest (Tucker and Hargreaves 2004). The previous year's crop is harvested throughout the second year as those fish reach market size. In contrast, single-batch production involves stocking one size of fish in a pond, growing them to market size, and then completely harvesting all fish (Engle and Pounds 1994). Multiple-batch culture systems have become more popular because processors have access to market-size fish all year and having fish available in many ponds reduces cash flow problems that can occur from off-flavor (Engle 2003). Research has shown that feeding behavior of the smaller fish is not inhibited by feeding with the larger fish (Unprasert 2011). The smaller fish are able to consume the amount of feed needed for growth without interference from the larger fish. This multi-batch production system is currently the most widely used system in the catfish industry. It enables farmers to stock much higher densities (fish/acre) with some producers now stocking as many as 10-15,000 fish/acre. Research is currently being conducted using intensive aeration because it is still not known how high the stocking densities can go while still maintaining proper water quality, FCR, etc. (Torrans 2005).

Following these developments, research emphasis was placed on the many factors that make up successful catfish farming. We will briefly expound on each factor because they are the basis for our extension recommendations that are currently believed to be "best management practices" for Channel catfish production. Putting these practices into place and carefully documenting the results concerning production and economics allows Extension personnel to discern whether they work efficiently or if further refinement is needed. These factors include site selection, stocking/stocking density, feeding, water quality, aeration, fish health management and genetics.

Site selection

There are many important factors to consider when determining the suitability of an area for catfish culture. Soil characteristics, topography, temperature fluctuations, availability of water, and geographic location must all be taken into consideration (Lee 1991). The soil must be able to hold water, preferably with high clay content. Catfish culture is best suited in areas that have long periods of warm temperatures. Catfish ceased feeding when the water temperature gets below 45°F, and as a result stop growing. The southeastern portion of the U.S. is ideal for catfish culture because there are long periods of the year that have warm temperatures, hence a longer growing season for catfish. There are ponds greater than 15 acres still in production but current ponds being built are smaller (5-10 acres) because they are more conducive to managing higher stocking densities, cheaper to treat for disease/water quality issues, and more easily aerated.

Cropping Systems

A pond may be stocked in different ways. Single-batch stocking is just producing one crop at a time and then starting over again once the crop is completely harvested. Single-batch production of Channel catfish has been shown to convert feed more efficiently, grow faster, and have greater net yields than those raised in multiple-batch production (Tucker et al. 1994; Southworth et al. 2006b). Multiple-batch production involves growing fish of varying ages and sizes in the same pond. Fish are harvested periodically by seining with a selective size mesh, and then ponds are restocked with fingerlings without draining the pond. While it has shown to be more profitable if the fish can be sold without constraint, multiple-batch stocking enables the producer to have ponds with market size fish available at different times of the year as well as having more options if off-flavor is an issue (Tucker and van der Ploeg, 1999; Tucker et al. 2001). Multiple-batch catfish production results in higher gross yields and cash flow but smaller mean weights at the end of the growing season (Tucker et al. 1994). Because Channel catfish fingerlings can take as long as 18 to 24 months to reach market size (Engle and Valderrama 2001) in multiple-batch production, many farmers have begun stocking either larger fingerlings, to lessen the production time, or the faster growing Channel catfish (*Ictalurus punctatus)* x Blue catfish (*Ictalurus furcatus*) hybrid catfish (C x B) fingerlings. Once a farmer decides which type of cropping system works best for his/her particular operation, a stocking density (fish/acre) must be selected. Much has changed in the commercial catfish industry since Dr. Swingle's original recommendation of 2,000 Channel catfish/acre and maximum feeding rate of 30 lbs/acre (Swingle 1959). The current Extension recommendation, which is carried out in this research verification study, is to stock 6,750 catfish per acre. There are producers who stock less than this and there are producers in Arkansas stocking 10,000 fish/acre with intensive aeration (6.4 - 8.5 Hp/acre). All of these stocking densities can be profitable with proper management of other inputs and sufficient aeration horsepower.

Feeding

Channel catfish diets started out primarily relying on natural productivity in the ponds. Channel catfish fry in hatcheries were fed ground organ meat from slaughtered livestock as a supplement. Early diets prepared from soybean, peanut, and fish meals could yield approximately 1,000 kg/ha of Channel catfish production (Swingle 1957). These early diets contained ground ingredients that were extruded under low pressure and had poor water stability. It wasn't until around 1970 that the first floating pelleted catfish diet was developed from high pressure extrusion (Hastings, 1971). Feed not only represents the greatest variable production cost, it is the main determining factor in fish growth and water quality. At high densities a nutritionally complete feed is required. There is evidence that feeding Channel catfish feeds high in dietary protein reduces fattiness, increases processing yield, and improves FCR (Robinson and Li 1997; Hatch et al. 1998; Robinson and Li 1999a; Li et al. 2000; Li et al. 2001; Li et al. 2008; Li et al. 2010). Feeding a protein level as high as 36% has been shown to increase fillet yield but the much higher cost to the producer is not economically feasible. According to Jensen (1997), feed containing 32% protein plus all essential vitamins and minerals is adequate and the most economical feed for catfish production. Currently, catfish producers typically feed either a 28% or 32 % protein diet, although they grow equally well on diets containing lower levels of protein (Brown and Robinson 1989; Li and Lovell 1992; Robinson and Li 1999a, 1999b). For lower protein diets to be effective, it is assumed that Channel catfish need to be fed to satiation, which may negatively affect feed conversion, increase fat levels in the fish and expel waste in the form of undigested feed that may negatively affect water quality (Robinson and Li 1997; Boyd and Tucker 1998). There is evidence that feeding Channel catfish feeds high in protein reduces fattiness, increases processing yield and improves feed conversion which in turn reduces the levels of organic wastes being expelled into the culture system (Robinson and Li 1997). In a study comparing 4 different protein levels (28, 32, 36 and 40%) , the dietary protein levels had no effect on feed consumption, weight gain, feed conversion ratio, survival, or aeration time (Robinson et al. 2004). Carcass yield was lower for the fish fed the 28% diet, but difference in weight gain and growth levels were insignificant between the 28% and 32%.

Currently it is mainly a matter of preference by the producer as to which diet to feed. Based on economics alone, the 28% feed is cheaper (≈ $20-$30/ton less). Since processing plants currently pay by the pound and not by the fillet yield, most farmers in Alabama feed the 28% protein diet. The Extension recommendation for the research verification trial was to strictly feed a 32% feed. Research continues to develop better feeds that produce higher yields at the lowest possible cost to the producer. Gross average FCRs across the catfish industry (calculated as total feed fed divided by total weight of fish sold) are typically between 2.0 and 2.5, depending on farm size (USDA 2003).

Water quality

A catfish production pond is a closed system where all wastes remain in the system and must be processed biochemically. The water quality in the pond is the single most important factor that will determine the outcome of production. This is because every single variable: site, stocking density, feeding, aeration, and chemical treatment will affect the water quality parameters which in turn will affect the culture species in the pond. This presents serious challenges to the catfish producer. The maintenance of proper water quality is essential not only for survival but optimum health and growth of the catfish. The main water chemistry variables that catfish producers should be concerned with include alkalinity, hardness, pH, carbon dioxide, ammonia, nitrite, and chloride (Jensen 1997).

Aeration

In Channel catfish farming, when dissolved oxygen (DO) levels in the culture system become low, aeration is typically used on an emergency basis to prevent stress and/or the occurrence of fish mortality (Boyd 1979). By the 1980s, stocking and feeding rates were increasing in an attempt to increase yield. An increased incidence of low DO resulted. It was at this point that a need for the development of aeration technologies became vital. Early technologies were crude and inefficient.

The development and widespread adoption of the electric paddlewheel aerator was the single most important technical innovation responsible for the increase in production (Busch et al. 1984). Despite the use of high quality feeds and good feeding management, relatively little of the nutrient value of feed is converted to fish flesh. The remaining nutrients derived from fish wastes stimulate excessive phytoplankton growth. High rates of phytoplankton metabolism cause pronounced diurnal fluctuations in dissolved oxygen concentrations, dissolved carbon dioxide concentrations, and pH (Boyd 2006; Boyd 2009). Such fluctuations cause stress in fish resulting in reduced fish growth rates, poor feed conversion, and reduced resistance to disease (Brunson et al. 1994). It has been shown that feed conversion rates and feed consumption decreases as DO levels go down (Torrans 2005). Due to the fact that catfish feed more aggressively in warmer temperatures because of higher metabolic needs, farmers feed at their highest rates from spring until early autumn and therefore may need to aerate every night (Boyd and Tucker 1998).

Evidence has shown that increasing the amount of aeration in a pond (Hp/acre) enables a producer to increase production and yields and improve FCR. Increased aeration allows higher feeding rates and decreases the frequency and magnitude of oxygen depletion events (Hollerman and Boyd 1980). Producers typically start aeration when dissolved oxygen levels reach between 2 and 4 ppm. Torrans demonstrated that maintaining DO levels of 3 ppm or greater is preferred but is not always possible. When DO concentrations drop below 2.5 ppm, fish performance begins to decline (Torrans 2005).

Fish health management

Fish health management in culture systems is a continuous multidisciplinary approach because it involves all aspects of the species being produced and the production environment in which they are produced. Nutrition, physiology, genetics, water quality, and disease are all aspects included in the area of fish health management. The producer must properly manage all of these factors to maintain healthy fish. Prevention is the goal a producer should strive for by providing adequate nutrition, maintaining good water quality and DO levels, and stocking appropriately to avoid overloading the carrying capacity of the culture system. Even under the best conditions, problems will sometimes still arise and early detection of the problem is a must. It could be a low DO issue, a water quality issue, or a disease/parasite issue. No matter what the problem, the producer must be knowledgeable enough to implement a solution to the problem. Contacting the local fish health specialist or aquaculture Extension specialist for help is highly recommended if the producer does not know what the problem is or how to solve it.

Genetics

The culture performance of several strains of catfish was evaluated through research in the 1970s and 1980s. These findings were not representative of a "stock improvement" program for commercially produced catfish. Only recently have there been significant strides from a research standpoint in the development of potentially superior strains of catfish. In order to increase production in the catfish industry, scientists discovered a genetically superior species of catfish by crossing the female Channel catfish, with the Blue male catfish *I. furcatus* (C x B hybrids, Dunham and Masser 2012). C x B hybrids generally grow faster, are more resistant to certain diseases, and survive better than Channel catfish (Dunham et al. 1990, 2008; Wolters et al. 1996; Bosworth et al. 2003; Li et al. 2004). Improvements in C x B hybrid fingerling production technologies have allowed dramatic recent increases in commercial C x B hybrid catfish production. Over twenty years ago, C x B hybrid technology was not economically feasible because the two species seldom mated with one another. Advances in artificial spawning and fertilization techniques, however, have improved fry production and made it economically feasible (Dunham and Masser 2012).

C x B hybrid catfish fingerlings are raised specifically for the food fish market. Market size for hybrids is typically 1.5 to 2.0 lbs and hybrids will easily reach market size (from fry to 1.0 - 2.0 lbs) in 1 to 2 years. Intensive systems have produced C x B hybrids (large fingerlings (8 - 10 inch) to market size (1.5-2.0 lbs) in less than one year. Research has demonstrated that C x B hybrids grow faster in the second season of production (Li et al. 2004; Li et al. 2014; Bosworth et al. 2004; Dunham et al. 2008).

C x B hybrid catfish are more resistant to certain diseases than other species of ictalurids. Research has shown that they are resistant to *Edwardsiella ictaluri* (Wolters et al. 1996*)* which causes enteric septicemia of catfish (ESC) as well as *Flavobacterium columnare* which causes columnaris (Arias 2012). These are two of the most detrimental diseases in the catfish industry. Blue catfish are more tolerant to low levels of dissolved oxygen (Torrans et al. 2012). This important trait in catfish production was genetically inherited by the C x B hybrids. As a result, yield is increased by reducing the amount of stress that often leads to disease, thus improving survival rates (Dunham et al. 1983).

C x B hybrid catfish perform better in intensive, densely stocked systems. In general, they grow faster than Channel catfish in both single and multiple-batch culture. Research has shown the reason C x B hybrids grow faster is because they start feeding earlier in the spring and feed conversion in C x B hybrids averages 10-15% better than in Channel catfish. Under good culture conditions, C x B hybrids display as much as a 25% increase in growth rate compared to genetically inferior strains (Dunham and Masser 2012). Feed conversions on commercial farms have averaged 10-15% better than channels (Dunham et al. 1990, 2008). Li et al. (2004) in a comparison of C x B hybrids and Channel catfish reported that C x B hybrid catfish consumed more diet, gained more weight, and had higher net production and survival when compared to Channel catfish. Green and Rawles (2010) reported that net yields, as well as individual weights were higher for C x B hybrid catfish when compared to Channel catfish and for fish fed a full ration or restricted ration.

C x B hybrids are easier to catch with a seine because, like their Blue catfish parent, they stay in the middle of the water column (Chappell 1979; Dunham et al. 1982; Dunham and Argue 1998). While this behavioral trait makes it easier to catch them with a seine, inevitably all the fish will not be caught. A grading sock is attached to the seine to allow only fish in the size range the market demands to remain caught. The rest of the smaller fish should "escape" to be seined at a later time after they reach market size. One of the few negative drawbacks attributed to hybrids is the susceptibility of the fish to become stuck in the sock or net. Unlike Channel catfish, the Blue catfish has a high arch from the head up to the dorsal fin. The head of the fish goes through the net but the dorsal fin becomes stuck. This problem can be eliminated by constructing nets that are customized specifically for hybrids. These negative harvest issues affect yield because when the seiners fail to harvest all of the fish, C x B hybrids can quickly become oversized for processors due to their fast growth rate. These larger fish will continue to consume feed that is not needed for growth and can cannibalize smaller fish. This negatively affects FCR, survival, and inevitably yield. When these larger fish finally go to the processor, the producer will be penalized with a much lower price if he has oversized fish.

It is anticipated by researchers and demonstrated by producers that the hybrid catfish is and will continue to take the catfish industry to a new level by intensifying the way catfish are raised. The last published data concerning the percentage of catfish operations producing C x B hybrids was 21.2%, but the percentage is continuing to grow (USDA 2010).

Chapter 2

Production and economic verification of an intensively aerated hybrid catfish farm in west Alabama

Abstract

From 2010 to 2013 a research verification program was implemented to evaluate production practices on an intensively aerated hybrid catfish farm in west Alabama. This program tracked production practices, input costs and product sales from stocking through harvest for three production cycles. This farm used intensive aeration (~10 HP/acre) to produce market sized C x B hybrid catfish. For each production cycle, three management treatments were implemented, including a single-batch (Treatment A), a multiple-batch (Treatment B), and a farmer-controlled program (Treatment C) as well as other pond size, stocking, aeration and algal management criteria mutually agreed upon between producer and research/Extension personnel.

Conclusions indicated variable production results from crop cycle to crop cycle, even within the same treatment, and financial results will vary accordingly. Results revealed net annual yields of 6,121 lbs/acre/year to 13,156 lbs/acre/year, survival (range = 51% - 91%) and feed conversion ratios (range = 1.87 - 3.01) were significantly different due to high mortality levels due to *Edwardsiella tarda* in Treatment C.

Enterprise budgets were developed for all Treatments A, B and C revealing incomes above variable cost of $16,086/acre, $15,223/acre, and $351/acre, respectively, and net returns to land of $15,543/acre, $14,680/acre, and $351/acre, respectively. On an annual basis the net

returns for Treatments A, B and C were \$5,652/acre/year, \$4,100/acre/year, and \$96/acre/year, respectively.

Introduction

The long term trend in U.S. fish and seafood consumption is increasing, though from 2004 to 2013 per capita consumption decreased from 16.6 to 14.5 lb per person per year (Hanson and Sites 2013). U.S. farm-raised catfish is among the most consumed fish in America. However, in 2012 escalating catfish feed and fuel prices were not sufficiently matched by increases in fish selling prices resulting in overall negative net returns to U.S. catfish producers (Hanson and Sites 2013). Prices received by producers in 2012 averaged \$0.967 per pound, 18% less than the 2011 average price of \$1.177 per pound. A result of these difficulties there was a 13% decrease in the number of U.S. catfish operations and an 8% decrease in the number of production acres. In order for the U.S. catfish industry to compete it will have to develop more efficient technologies and management strategies, such as the adoption of hybrid (C x B) catfish, increasing aeration rates and better feed management. An aquaculture research verification program can test these developments and strategies in commercial-scale ponds and verify if the recommended practices do result in increased yields, fish survival, lower production costs and improved financial returns or make changes to existing recommendations as necessary.

Aquaculture research verification programs are designed to demonstrate and test Extension recommended practices, which are research based, on commercial-scale operations (Engle et al. 2004). In Arkansas, research verification trials have been conducted on row crops since the early 1980s when they were initially used to evaluate and identify cotton production refinements and over time have resulted in increased state yields (Kaliba and Engle 2005). Over the last thirty years a number of row crop research verification programs have been established to evaluate their production practices. In 1993, Arkansas conducted the first pilot catfish research verification program (Engle 2007). Following the success in Arkansas, the U.S. Department of Agriculture's Southern Regional Aquaculture Center funded a major research verification trial in five states on major aquaculture species in 1997 (Engle 2007). Research verification programs can be extremely valuable to industry and Extension personnel as they work together to document practices and results to develop improved standard operating procedures and best management practices (Kaliba and Engle 2005). Catfish research verification programs test whether current Extension recommendations can produce profitable yields and also provide useful information such as the cost of production, identification of research needs and updating of Extension recommendations.

Most commercial catfish farmers in Alabama and other states currently raise Channel catfish. However, there are a number of U.S. producers that have been successfully raising C x B hybrid catfish. Research at several institutions has confirmed that C x B hybrid catfish have faster growth, better feed conversion, higher dress-out percentage, higher fillet yield, higher tolerance to low oxygen conditions, and increased resistance to certain types of diseases (Dunham et al. 2008; Dunham and Masser 2012). Disadvantages to using C x B hybrid catfish also exist, particularly the higher cost of fingerlings and problems harvesting fish with existing gear optimized for Channel catfish. Other logistical difficulties can also occur, such as the need for evolved management that can synchronize the faster fish growth requiring more frequent harvesting with the daily processing plant requirements and their numerous independent producers having fish that should/could be harvested. When this dynamic is not well managed processors can receive a large number of fish that are not of the optimal size (too large) and result in additional labor intensive and expensive hand processing.

The negative effects of low dissolved oxygen (DO) on catfish production and the positive effects of nightly aeration have been documented for decades (Andrews et al. 1973; Carlson et al. 1980; Hollerman and Boyd 1980; Dunham et al. 1983; Lai-fa and Boyd 1988; Buentello et al. 2000; Torrans 2005). In recent years, a number of farmers in Alabama, Mississippi, and Arkansas have been moving towards increasing aeration in their production ponds to enhance production and improve fish health, survivability and feed conversion (Bott et al. 2014; Recsetar 2014). The basic premise is that maintaining higher minimum dissolved oxygen levels than in the past by increasing *and using* additional horsepower per acre of aeration will produce these positive production results and financial outcomes. Farmers have been achieving this goal by placing more aerators in their ponds.

It is well established that increased aeration and proper oxygen management can allow higher feeding rates and increased production of catfish under intensive and semi-intensive conditions (Torrans 2005; Torrans 2008; Torrans 2011; Torrans et al. 2012). In a Mississippi pond production study with Channel catfish, Torrans (2005) reported that feed consumption was reduced in a low oxygen treatment (2.5 mg/L) by 6% relative to a high oxygen treatment (5 mg/L). In a second trial, where an even lower oxygen treatment (1.5 mg/L) was utilized, feed consumption was reduced by 45% compared to the higher oxygen treatment and reduced average fish weight (31% less) and net production (54% less) were reported (Torrans 2005). Green and Rawles (2011) reported higher consumption of feed in both Channel catfish and C x B hybrid catfish reared at high versus low DO concentrations in a 234-d pond production study in Arkansas.

C x B hybrid catfish are known to withstand lower DO concentrations better than Channel catfish, (Dunham et al. 2008) yet maintaining higher levels of aeration provide the fish with a more optimum environment in which to grow and enhances overall fish health (Torrans 2005). Not only do the fish feed more aggressively, but reduced total ammonia-nitrogen (TAN) and un-ionized ammonia levels may result from higher aeration rates (Torrans 2008; Boyd 2009). The objectives of this research verification study were to evaluate catfish Best Management Practices (BMP's) for single-batch and multiple-batch catfish production systems on a commercial catfish operation using C x B hybrid catfish and intensive aeration rates. Since 1991, the study farm (61 acres) has steadily increased its aeration rate from one Hp/acre to an average exceeding 10 Hp/acre (Figure 1). While the benefits of increased aeration have been explored at length in research settings, few studies have attempted to verify this benefit on actual commercial farms. In addition to the Extension treatment recommendations, the farmer was allowed to choose a pond and use his own practices allowing for a comparison of Extension recommendations to producer management protocols.

Farm 1 is a commercial catfish farm in Hale County, Alabama and has been raising catfish since 1989 when Channel catfish were stocked in a one acre pond. In 1998 he obtained his first C x B hybrid catfish fingerlings and was able to produce 10,000 lbs/acre in the pond he stocked. Over the course of the next nine years, he converted exclusively to C x B hybrid catfish on his 61 water acre farm. He is also an advocate of intensive aeration. Since C x B hybrid catfish perform well in intensive production, this producer has seen the benefits of intensively aerating his ponds based on his production performance over the years.

During the course of this study, Farm 1 was able to complete 3 complete production cycles in comparison to Farms 2 and 3 (see Chapter 3) where only 2 production cycles were completed.

Materials and Methods:

A complete aquaculture research verification management plan was developed in detail with Alabama Cooperative Extension System (ACES) personnel, Auburn University (AU) aquaculture faculty and cooperating Alabama catfish producers. It was implemented on selected commercial catfish farms in west Alabama. The protocol developed was modeled after earlier verification studies conducted at UAPB (Engle et al. 2004) and AU (Engle 2007) with some modifications to accommodate participating producers and taking into account available resources. Catfish producers agreed to manage verification ponds according to project criteria and recommendations for a minimum of three complete production cycles using three treatment protocols in three different ponds for a project total of nine pond production cycles (3 per pond).

Management Protocols

In order to compare our recommendations to the current practices of the industry, three treatments were assigned to the participating producer. Treatment A was a control treatment pond managed according to the owner's historical protocols for the farm which were characterized by use of multiple-batching, hybrid catfish, high feeding rates and intensive aeration. Treatment B was a single-batch approach managed according to Extension protocols and Treatment C was a multiple-batch approach managed according to Extension protocols. Table 1 provides management recommendations for Farm 1.

The ponds from Farm 1 selected for the study were similar in size (Treatment A, B, and C were 7.9, 6.5, and 8.0 acres, respectively). At the beginning of the study, pond catfish inventories were "zeroed out" by seining each pond three times with a fingerling seine to remove fish left from the prior production cycle. Each of the three verification ponds was equipped with at least 8 horsepower per water surface acre at the beginning of the study. Aerators were operated with automatic monitoring systems (Aercon, Newbern, AL) with aerators programmed to shut off when DO levels were above 4.5 ppm.

Treatment A was stocked at a rate of 7,161 hybrid catfish/acre. Extension guidelines for stocking Treatment B and Treatment C allowed no more than 6,750 hybrid catfish/acre. Fish were sampled at stocking and harvest events. Fingerlings were sampled from the live haul truck, graded and tabulated to produce a closer estimate of actual fingerling sizes stocked than the usual industry practice. Food fish harvests were sampled for similar data.

Fish were fed a 32% crude protein commercial catfish ration (Alabama Catfish Feed Mill, Uniontown, AL) seven days a week during the peak feeding season (April/May-September/October). Feeding during the off-peak season (October/November-March/April) followed protocols already available from Extension literature that use thermal ranges (Lovell et al. 1989, Li and Robinson 2008). Feed was offered as a percent of satiation determined at seven day intervals. Feed rate adjustments were made every month from November through February, every 2 weeks when temperatures were between 60-73°F and every 7 days during the peak feeding season (May-September). For illustration, on day 1 of the 7 day cycle, fish were fed patiently to satiation and that quantity was recorded. For the next 6 days, fish were fed up to 90% of the satiation quantity determined on day 1. On day 8, fish were fed again to satiation, the quantity recorded and for the next 6 days fish were fed up to 90% of this satiation quantity. A maximum feeding rate of 150 lbs/acre/day was allocated for treatments B and C and the producer (Treatment A) was allowed to exceed 150 lbs/acre/day. Feeders with digital scales were utilized in the daily feeding program and scales were calibrated periodically as necessary. ACES personnel worked with the producer to develop an easy to use feed collection data form, which was picked up and reviewed regularly (Appendix 1).

Diuron use was permitted only as a means of algae control and was used according to label. Granulated copper sulfate was used in lieu of aqueous copper sulfate to control aquatic vegetation. Use of copper sulfate as a general algae bloom thinning treatment was not permitted in Treatments B and C, with the exception of blue green algae. Blue green algae that became "wind-rowed" or accumulated in corners of ponds were treated as soon as possible. Dominant blue-green algae blooms, as indicated by microscopic evaluation, were treated according to the recommendations of ACES personnel. The farmer was encouraged to maintain minimum chloride concentrations above 100 ppm in all study production ponds.

Fish disease management followed established protocols. Health problems were reported to the fish disease specialist (Bill Hemstreet) at the Alabama Fish Farming Center (AFFC) in Greensboro, AL. Feeding during a fish health problem was based on recommendations from the AFFC fish disease specialist. Samples of fish were either brought to the AFFC by the farmer or collected on site by ACES personnel. During a fish health problem, the farmer estimated mortality every day, and also kept records of treatments that were applied.

As fish reached the targeted harvest weight in study ponds, normal procedures were followed by the farmer cooperator to schedule the pond for harvest with the processor. Treatment B pond (single-batch) was harvested completely and the pond was again "zeroed out" before the beginning of the next production cycle when fingerlings were re-stocked. Multi-batch ponds (Treatments A and C) were partially harvested throughout the production cycle and fingerlings were stocked before the previous crop had ended. At the end of the study, ponds were "zeroed-out" with fingerling seines following the last harvest. Throughout the study, monthly data sheets with feed and management records were collected from the farm by ACES personnel and any issues were discussed and resolved as soon as possible. All chemical use and tractor aeration use (tractor hours) were recorded by the producer. Stocking and harvesting events were monitored by ACES personnel. Approximately two hundred pounds of food fish were sampled at each harvest event. Economic and production data on expenses for fingerlings, feed, electrical, and chemicals were tracked throughout the study. Aerator use readings were recorded weekly.

Pond water was sampled on a weekly basis to measure temperature, ammonia nitrogen, pH, and nitrite nitrogen. Total alkalinity, total hardness, and chloride were monitored on a monthly basis. Total ammonia-nitrogen (TAN) was analyzed according to Nessler's method (APHA et al. 1989), whereas nitrite was measured according to (Parsons et al. 1985). Total alkalinity (acidimetry), chloride (mercuric sulfate method), and total hardness (ethylenediamenetetraacetic acid titration) were measured according to standard methods (Eaton et al. 2005). All water quality analyses were conducted at the AFFC.

Economic methodology

Production data and associated operating (variable) costs were taken directly from farmer records compiled for the research verification program and entered into spreadsheets that kept track of specific expenditures as they occurred. Records were collected weekly and monthly, depending on the type of data, and frequent visitation by Extension personnel allowed record keeping questions or obstacles to be quickly answered or solved. At the end of each production cycle receipts and feed costs were calculated based on average fish and feed prices received or paid for during the production cycle time period. All receipt and expenditure data were condensed by line item categories into a summarized enterprise budget format that calculated sales, itemized variable costs, income above variable cost (an indicator of short term profitability), fixed costs, total costs, and net return above all costs (an indicator of long term profitability). This was done for each production cycle within each of the three treatments as well as for an overall combined three production cycle summary for each treatment.

Specific parameters measured for total cost of production calculation included quantity and price of fish sold and quantity and price of purchased inputs: namely feed, fingerlings, chemicals, electricity, fuel, harvest/transport, management/labor, and interest on operating costs. Fixed costs included depreciation on the pond and machinery, land taxes, and interest on pond construction costs. No land charges were included, so, a net return to land was calculated for comparison's sake between all production cycles and treatments in this research verification program.

Results

Production Cycle 1

A summary of the production data is found in Table 2. The production period for Treatment A cycle 1 was much shorter (0.83 years) than for cycle 1 in Treatment B (1.42 years) and Treatment C (1.33 years) and can be attributed to harvest of 1.91 lb fish compared to 2.56 and 2.60 lb fish in the latter treatments. The level of aeration in cycle 1 for each treatment was 8.86, 9.23, and 9.28 Hp/acre for Treatments A, B, and C, respectively. Overall, harvest sized fish survival ranged from 83 - 95% for cycle 1 in the three treatments. Net yield for cycle 1 was highest in Treatment B (14,659 lbs/acre) compared to Treatments A (11,762 lbs/acre) and C (12,653 lbs/acre). Net feed conversion ratios (FCR) were 2.02, 2.93, and 2.60 for Treatments A, B, and C, respectively. Cycle 1 fish size distribution at harvest revealed that close to 50% or higher of fish were between 1.5 and 3.0 lbs at harvest for all three treatments (Table 3). However, in Treatment B, 44% of the fish were larger than 3.0 lbs.

Water quality sampling showed total alkalinity (133.9 - 165.2 mg/L) and total hardness (138.46 - 213.8 mg/L) values that are typical of west Alabama catfish ponds (Table 4). Total ammonia nitrogen reached 14.5 mg/L in Treatment B in November of 2010 and began to gradually diminish until harvest. Total ammonia nitrogen never exceeded 3 mg/L in Treatment A. Total nitrite nitrogen also spiked twice in Treatment B but chloride levels were maintained at adequate levels. Water temperatures throughout the study fluctuated normally for pond water temperatures typically encountered in catfish ponds in west Alabama (Figure 2).

Treatment A produced $105,306 in catfish receipts (sales) with $66,317 in total costs (variable plus fixed costs) resulting in a net return above all costs of $38,989, or $4,935/acre or $5,946/acre/year (Table 5). Treatment B, Cycle 1 produced $107,253 in catfish sales with a total cost of $90,447 resulting in a net return of $16,806 or $2,586/acre or $1,821/acre/year (Table 5). Treatment C, Cycle 1 produced $113,411 in catfish sales with a total cost of $84,498 resulting in a net return of $28,914 or $3,614/acre or $2,717/acre/year (Table 5).

Production Cycle 2

In Cycle 2, all three treatments were harvested over the course of the same time period of 1.33 years (Table 2). Cycle 2 aeration levels in Treatment B and Treatment C were raised to 10.77 and 10.63 Hp/acre, respectively. Treatment C, Cycle 2 experienced a massive catfish die off due to a combination of *Edwardsiella tarda* and high ammonia resulting in low survival (25%). Treatment A and Treatment B had survivals of 86% and 95% for Cycle 2, respectively. Cycle 2 net yield was again higher in the single-batch treatment (Treatment B 13,956 lbs/acre) than in Treatment A (11,762 lbs/acre) and was only 3,034 lbs/acre in Treatment C due to the mass mortality event. Net FCR in Treatment A and B, Cycle 2 was 2.22 and 1.78, respectively, and 4.93 in Treatment C cycle 2, again due to the large mortality event. Samples of size distribution at harvest revealed that the single-batch treatment (Treatment B) once again produced the largest number of fish of suboptimal size with 44% of the fish ranging in size from 0.5 - 1.5 lbs.

During production Cycle 2 total alkalinity (133.0 - 187.9 mg/L) and total hardness (109.6 - 165.5 mg/L) measurements were similar to those attained in Cycle 1 (Table 4). Total ammonia nitrogen peaked at close to 13 mg/L in Treatment C, November 2011, which coincided with the mass mortality event, observed in conjunction with an *Edwardsiella tarda* infection. The highest levels of nitrite nitrogen (> 1.6 mg/L) were also observed in Treatment C (Table 4). Winter temperatures were slightly higher in production Cycle 1 than in production Cycle 2 (Figure 2).

Treatment A, Cycle 2 produced $108,571 in catfish sales with a total cost of $75,251 resulting in a net return of $33,320, or $4,218/acre or $3,171/acre/year (Table 5). Treatment B, Cycle 2 produced $102,688 in catfish sales with a total cost of $55,932 resulting in a net return of $46,756 or $7,193/acre or $5,408/acre per year. Treatment C, Cycle 2 produced $32,468 in catfish sales with a total cost of $51,323 resulting in a net return of $-18,855 or $-2,357/acre or $-1,772/acre/year.

Production Cycle 3

In Cycle 3, the production period for Treatment A was longer (1.33 years) than for Treatment B (0.83 year) and Treatment C (1.00 year) (Table 2). Aeration Hp/acre levels remained at the same level as in Cycle 2. Treatment A, Cycle 3 had 93% survival. Treatment B, Cycle 3 had some mortality due to a toxic algae die-off in September of 2012 resulting in a lower survival (79%). As in Cycle 2, Treatment C, Cycle 3 experienced high mortality rates due to high ammonia levels and *Edwardsiella tarda* resulting in low survival (45%). Treatment C had lower ammonia levels and a slightly better survival than that found in Cycle 2 (25 %). Net yield was highest for Treatment A, Cycle 3 at 12,441 lbs/acre and Treatment B and Treatment C, Cycle 3 were 9,979 lbs/acre and 6,758 lbs/acre, respectively. Samples of size distribution at harvest revealed that Treatment A and Treatment B had virtually the same (28% and 29%) percentage of suboptimal size fish ranging from 0.5-1.5lbs. Treatment C, Cycle 3 had the highest percentage of fish ≥ 3.0 lbs at 29%.

During production Cycle 3 total alkalinity (117.3 - 201.9 mg/L) and total hardness (104.2 - 182.3 mg/L) measurements were similar to those attained in production Cycles 1 and 2 (Table 4). Total ammonia nitrogen peaked at 13 mg/L in Treatment C, which coincided with the mass mortality event observed in conjunction with an *Edwardsiella tarda* infection. The highest levels of nitrite nitrogen (>5.0 mg/L) were also observed in Treatment C (Table 4). The water temperatures throughout the study fluctuated normally for pond water temperatures typically encountered in catfish ponds in west Alabama.

Treatment A, Cycle 3 produced $111,332 in catfish sales with a total cost of $60,852 resulting in a net return of $50,480 or $6,390/ acre or $4,804/acre/year. Treatment B, Cycle 3 produced $75,080 in catfish sales with a total cost of $43,223 resulting in a net return of $31,858 or $4,901/acre or $5,905/acre/year. Treatment C produced $64,646 in catfish sales with a total cost of $71,894 resulting in a net return of $-7,249 or -$906/acre or -$906/acre/year.

Summary of 3 Production cycles

Because it is sometimes difficult to completely separate production cycles due to multiple-batches within the same pond and incomplete harvests, another accurate and informative way of analyzing the production and economics is to look at the combined three production cycles for each treatment over the course of the three year study. Treatment B produced the highest net yield (38,594 lbs/acre) but Treatment A resulted in the highest annual net yield (13,156 lbs/acre/year) as well as highest survival rate (91%) and lowest net FCR (1.87). The overall net return for the combined three cycles for Treatment A was $122,789 or $15,543/acre or $5,652/acre/year or $0.41/lb and a total cost of production of $0.68/lb (Table 7).

Treatment B produced the second most pounds over the three production cycles (261,487 lbs) and because the pond was smaller than Treatment A's pond size the production per acre was greater (40,229 lbs/acre or 11,237 lbs/acre/year). Treatment B's overall average fish size harvested was 2.3 lbs and 0.4 lb greater than the average fish size in Treatment A. Survival in Treatment B was 4% less than in Treatment A (87%), and survival in Treatment C was 40% less than Treatment A (due to high ammonia levels and severe disease losses). Net FCR was higher for Treatments B (2.09) and Treatment C (3.01) than for Treatment A. These latter measures as well as a significant amount of weigh backs during Treatment B cycle 2 (6,064lbs) were the differences in production that led to reductions in the net return for Treatment B ($95,419 for 3 cycles which was more than $27,000 less than Treatment A's net return for 3 cycles) and led to a much lower net return for Treatment C ($2,810 for 3 cycles which was almost $120,000 less than Treatment A's three production cycle net return). The annual net returns for the three treatments were $5,652/acre/year, $4,100/acre/year, and $96/acre/year, respectively) (Table 7).

Discussion

Aquaculture research verification programs are useful in determining whether Extension recommendations developed based on research are effective when applied to a commercial farm production setting. While there have been several successful catfish research verification trials, few have addressed intensively aerated ponds using C x B hybrid catfish. The catfish industry has been steadily increasing the number of acres in hybrid catfish production for good reason

(USDA 2003; USDA 2010). Data obtained through this study has revealed that farmers can indeed make a profit by raising C x B hybrid catfish under intensively aerated production conditions in single and multiple-batch systems.

There has been little published literature concerning the production and economics of commercial catfish farms raising C x B hybrid catfish and using intensive aeration (Green and Rawles 2011). Engle et al. (2007) reported net yields of 6,263 - 7,569 lbs/acre for hybrid catfish in Alabama in a multi-state verification study. In the same study, survivals and net FCRs ranged from 64 -86% and 1.56 - 2.1, respectively. In Engle's (2007) verification project report, the cost of hybrid catfish production from the Alabama trials ranged from $0.51 to $0.83/lb of production and net returns to land and risk ranged from $-444 to $1,644/acre. In this study, conducted thirteen years after the Engle 1997 effort, enterprise budgets had a range of production costs from $0.68 to $1.08/lb of hybrid catfish production (no adjustment for inflation), and the net returns herein ranged from $117 to $5,181/acre/crop or put on an annualized basis $96 to $5,652/acre/year. Unfortunately, the Engle study did not provide information on water quality or disease loss events, and we know in this work that Treatment C had severe losses due to high ammonia levels and *E. tarda* outbreaks and accounted for the low value in the range of net returns.

C X B hybrid catfish in prior published research verification studies were not grown in intensively aerated ponds. This farm utilized intensive aeration (>5 Hp/acre) on his farm and gradually increased his aeration level over the past 10 years because the farmer saw its positive effect on catfish production (Figure 1). This was not a study on aeration, but it should be noted as a contributing factor in the observed production and economics of Farm 1. Data from the present study reported net yields ranging between 2,276 and 14,115 lbs/acre with high aeration rates ranging from 8.86 - 10.77 Hp/acre. While production and yield were high, with the exception of the pond that experienced high levels of disease in years 2 and 3, compared to traditional pond culture they were not as high as reported by Recsetar (2014) in ponds supplied with 6.4-8.5 Hp/acre stocked with Channel catfish and C x B hybrid catfish in Arkansas. Recsetar (2014) reported yields ranging from 15,165 - 21,054 kg/ha (13,497-18,738 lbs/acre) for hybrid catfish and 13,195 - 15,632 kg/ha (11,744 - 13,912 lbs/acre) for Channel catfish, albeit with higher initial stocking densities of 10,000 head/acre. The stocking density employed in our study (6,750 head/acre) is quite conservative given the high aeration rate utilized by the farmer, particularly for the single-batch production treatment but this farm has historically stocked ponds at this stocking density. Fish farmers in Arkansas and Mississippi utilizing intensive aeration are stocking at much higher densities (Recsetar 2014, Dr. Travis Brown, USDA-ARS Stoneville National Warmwater Aquaculture Research Station, personal communication, February 8, 2015). It is likely that farmers in Alabama utilizing intensive aeration could increase production their stocking density, as has been confirmed by the University of Arkansas at Pine Bluff research verification program (Recsetar 2014).

Another observation from this research trial is that harvesting fish when they reach a minimally acceptable harvest size allowed by the processor had a positive, beneficial production and financial effect on the study farm. For instance, when fish reached approximately 2.0 lbs, the fish could be harvested and another crop stocked. If fish are grown to 2.5 lbs, the next production cycle's initiation is delayed. As we saw in this work, Treatment A grew three complete crops of fish in 2.75 years compared to Treatment B and Treatment C that required 3.58 and 3.67 years, respectively, and had larger fish at harvest than in Treatment A (1.9 lbs compared to 2.3 lbs). Thus, a lesson learned here is to harvest fish as soon as possible, but we must keep in mind that this is not always possible because the processor controls when the fish are harvested. It is possible that the high mortalities in Treatment C may have been avoided if the fish had been harvested earlier. Also, the quality of the seining job determines how well the producer controls his inventory. Especially with C x B hybrids, if market size fish are missed and stay in the pond for another season, or longer, the fish will become too large and the producer will get paid a lesser rate or no pay at all for the oversize fish.

Other methods farmers are utilizing to increase the availability of aeration to catfish include the use of split-pond production systems and in-pond raceways (Tucker and Kingsbury 2010; Brown et al. 2011, Park et al. 2014). In these intensive production systems, fish are confined in smaller areas where aeration, feeding and other aspects of production can be managed more efficiently. These type systems have a major advantage in inventory control because a complete harvest is possible. In split-pond systems, fish are confined in a relatively small section of the pond with all aerators in close proximity while the water treatment zone is devoid of aeration to allow anaerobic processes to process waste. However, both the split pond and in-pond raceway systems have initial capital investment costs that can be too expensive for many farmers. By simply adding additional aerators to ponds, production can be intensified without spending the amount of money necessary to convert an existing pond to a split-pond or an in-pond raceway system while raising fish at production rates comparable to these systems and higher than traditional pond culture.

When the data is evaluated over the course of the three production cycles, the owner defined multi-batch Treatment A outperformed the Extension recommendation treatments in terms of net yield/acre/year, survival, net FCR, and net return. Treatment B (single-batch) produced the highest net yield. Three entire crops were produced in the Treatment A pond in less than three years, compared to 3.58 and 3.67 years in the Treatment B and Treatment C, respectively, in which Extension recommendations were followed (Table 2). The farmer attributed the improved performance of his Treatment A to being able to feed above the maximum feeding rate of 150 lbs/acre, the level to which the other two treatments were restricted. During peak feeding season, a feeding rate of 200 lbs/acre/day (224 lbs/acre/day max) was often exceeded in this pond. The farmer also indicated that due to the intensive aeration available on his farm his DO levels rarely dipped below 4.5 mg/L throughout the entire study period (2010 - 2013). This is an instance in which the farmer, using his own feeding protocol, outperformed the ponds with a daily feed restriction, as outlined in the research verification protocol developed by Extension personnel. Thus, this provides an example of why recommendations derived from research data should always be verified under real world production conditions and further highlights the value of research verification programs.

Chapter 3

Production and economic verification of two commercial Channel catfish farms in west Alabama

Abstract

From 2010 to 2013 a research verification program was implemented to evaluate production practices on two farms (Farm 2 and Farm 3) using traditional production practices to raise Channel catfish in west Alabama. This program tracked production practices, input costs and product sales from stocking through harvest for three production cycles. For each production cycle, three management treatments were implemented, including a single-batch (Treatment A), a multiple-batch (Treatment B), and a farmer-controlled program (Treatment C). Pond size, stocking, aeration and algae management criteria mutually agreed upon between producer and research/Extension personnel were tracked for each production cycle.

Conclusions indicated that there was a variable production result from crop cycle to crop cycle, even within the same treatment, and financial results will vary accordingly. Two production cycles were completed for these operations and Farm 2 results showed Treatment A performed better from a production stand point. This treatment had the highest net and annual yields at 18,845 lbs/acre and 5,384 lbs/acre/year. Survival rates for Treatments A, B and C was 52%, 42%, and 76%, respectively. Treatment C had the highest net return to land ($52,935and profit margin at $0.34/lb.) However, Treatment B had the lowest cost of production at $0.66/lb compared to 0.75/lb for Treatments A and C. Farm 2 had net yields ranging from 5,131 to 11,016 lbs/acre. FCRs ranged from 1.4 to 3.1 and survival ranged from 39% to 100%. Study

results for Farm 2 indicated advantages and disadvantages for each treatment but they all showed a profit.

Farm 3 net returns were highest for Treatment B at $43,811, profit margin at $0.36/lb and the lowest cost of production at $0.73/lb. Treatment B had a higher survival rate at 61% compared to 44% and 48% for Treatment A and Treatment C, respectively. Likewise, Treatment B had the better FCR at 2.2 compared to 2.6 and 2.42 for Treatment A and Treatment C. For Farm 2 and Farm 3 treatments with the highest survival rates were also the treatments with the highest levels of aeration (Hp/acre).

Introduction

Catfish farming is the largest segment of the U.S. aquaculture industry. In 2008, 510 million pounds of food size Channel catfish were produced. This constituted an overall value of $410 million (USDA 2010). Catfish production has decreased in the last several years. In 2014 approximately 300 million pounds of catfish were processed in the U.S., down 10% from 2013 (Hanson and Sites 2014). The projection for 2015 is approximately 330 million pounds but is dependent on feed prices not climbing (average $484/ton in 2014 for 32% protein) and fingerling suppliers being able to meet the demand of producers.

Feed costs for catfish farmers in the U.S. have risen dramatically in the last several years and now average more than $400 per ton. Feed comprises 55-58% of cost to produce a pound of catfish, thus it is critical that farmers adopt feeding and management strategies which maximize feed performance in terms of cost per unit of gain. Research verification programs are management programs in which research based recommended production management protocols are applied in a timely manner on a commercial scale. While there have been two previous research verification trials in west Alabama, but because production, competition and cost environments have changed so dramatically, growers find themselves in uncharted waters. Catfish research verification programs serve to verify and refine current Extension recommendations and costs of production. In addition, they help identify research needs, update Extension recommendations, and develop interdisciplinary management strategies for maximizing profit while promoting sustainability of the industry.

Material and Methods

In order to compare existing Extension recommendations to current practices of the catfish industry, three management protocols or treatments were developed to raise Channel catfish. Treatment A is a control treatment pond managed according to the producer's historical protocols for the farm. Treatment B is a single-batching system managed according to Extension protocols and Treatment C is a multiple-batching system managed according to Extension protocols. Table 8 provides the recommended and required management protocols for the two farmer cooperators.

Two Channel catfish producers in west Alabama collaborated on this project from 2010 to 2013. Farmer 2 (note: Farm 1 was discussed in chapter 2 of this thesis) owns 660 acres of water with 50 Channel catfish ponds in Hale County, Alabama and has been producing catfish commercially since 1967. Farmer 3 owns 420 acres of Channel catfish ponds in Dallas County, Alabama and began raising catfish in 1983.

Farm 2 ponds selected for the study were similar in size, ranging from 8.3 - 15.7 acres. At the beginning of the study, pond catfish inventories were "zeroed out" by seining each pond three times with a fingerling seine to remove fish left from the prior production cycle. The three verification ponds were equipped with 1.11, 1.91 and 2.41 horsepower per water surface acre at the beginning of the study. Aerators were operated with automatic monitoring systems (Royce, New Orleans, Louisiana) with aerators programmed to shut off when DO levels were above 3.8 ppm. Farm 3 ponds ranged in size from 5.9 - 9.6 acres and inventories were also "zeroed out" at the beginning of the study. The three study ponds were equipped with 2.08, 3.39 and 2.86 horsepower per water surface acre at the beginning of the study. Aerators were operated with automatic monitoring systems (In-situ, Fort Collins, Colorado) programmed to shut off when DO levels were above 4.0 ppm.

Production Practices on Farm 2 and Farm 3

Production practices for Farm 2, Treatment A used the farm owner's traditional production and management practices and was the 'control' treatment to which the other treatments were compared. The Treatment A pond was stocked with 7,759 Channel catfish per acre. Extension guidelines for Treatment B and Treatment C required pond stocking to be no more than 6,750 Channel catfish/acre (Table 8). Farm 3 followed the same production practice guidelines and stocking rates.

Stocking and harvesting events were monitored by ACES personnel. Fingerlings were sampled from the live haul truck, graded and tabulated to produce a closer estimate of actual fingerling sizes stocked than the usual industry practice. Food fish harvests were sampled in a like manner.

Fish were fed a 32% crude protein commercial catfish ration (Alabama Catfish Feed Mill, Uniontown, AL) seven days a week during the peak feeding season (April/May-September/October). Feeding during the off-peak season (October/November-March/April) followed protocols already available from Extension literature that use thermal ranges (Lovell et al. 1989, Li and Robinson 2008). Feed was offered as a percent of satiation determined at seven day intervals. Feed rate adjustments were made every month from November through February, every 2 weeks when temperatures were between 60-73°F and every 7 days during the peak feeding season (May-September). For illustration, on day 1 of the 7 day cycle, fish were fed patiently to satiation and that quantity was recorded. For the next 6 days, fish were fed up to 90% of the satiation quantity determined on day 1. On day 8, fish were fed again to satiation, the quantity recorded and for the next 6 days fish were fed up to 90% of this satiation quantity.

A maximum feeding rate of 150 lbs/acre/day was allocated for Treatment B and Treatment C and the producer (Treatment A) was allowed to exceed 150 lbs/acre/day. Feeders with digital scales were utilized in the daily feeding program and scales were calibrated periodically as necessary. ACES personnel worked with the producer to develop an easy to use feed collection data form which was picked up and reviewed regularly (Appendix 1).

Diuron use was permitted only as a means of algae control and was used according to label. Granulated copper sulfate was used in lieu of aqueous copper sulfate to control aquatic vegetation. Use of copper sulfate as a general algae bloom thinning treatment was not permitted in Treatment B and Treatment C, with the exception of blue green algae control. Blue green algae that became “wind-rowed” or accumulated in corners of ponds were treated as soon as possible. Dominant blue-green algae blooms, as indicated by microscopic evaluation, were treated according to the recommendations of ACES personnel. The farmers were encouraged to maintain minimum chloride concentrations above 100 ppm in all study production ponds.

Fish disease management followed established protocols. Health problems were reported to the fish disease specialist (Bill Hemstreet) at the Alabama Fish Farming Center (AFFC) in Greensboro, AL. Feeding during a fish health problem was based on recommendations from the

AFFC fish disease specialist. Samples of fish were either brought to the AFFC by the farmer or collected on site by ACES personnel. During a fish health problem, the farmer estimated mortality every day, and also kept records of treatments that were applied.

As fish reached the targeted harvest weight in study ponds, normal procedures were followed by the farmer cooperator to schedule the pond for harvest with the processor. The Treatment B (single-batch) pond was harvested completely and the pond was again "zeroed out" before the beginning of the next production cycle when fingerlings were re-stocked. Multi-batch ponds (Treatment A and Treatment C) were partially harvested throughout the production cycle and fingerlings were stocked before the previous crop had ended. At the end of the study, ponds were "zeroed-out" with fingerling seines following the last harvest. All chemical use and tractor aeration use (tractor hours) were recorded by the producer. Stocking and harvesting events were monitored by ACES personnel. Approximately two hundred pounds of food fish were sampled at each harvest event. Economic and production data on expenses for fingerlings, feed, electrical, and chemicals were tracked. Aerator use readings were recorded weekly.

Pond water was sampled on a weekly basis to measure temperature, ammonia nitrogen, pH, and nitrite nitrogen. Total alkalinity, total hardness, and chloride were monitored on a monthly basis. Total ammonia-nitrogen (TAN) was analyzed according to Nessler's method (APHA et al. 1989), whereas nitrite was measured according to (Parsons et al. 1985). Total alkalinity (acidimetry), chloride (mercuric sulfate method), and total hardness (ethylenediamenetetraacetic acid titration) were measured according to standard methods (Eaton et al. 2005). All water quality analyses were conducted at the AFFC.

Economic methodology

Production data and associated operating (variable) costs were taken directly from producer records compiled for the research verification program and entered into spreadsheets that kept track of specific expenditures as they occurred. Records were collected weekly and monthly depending on the type of data and frequent visitation by Extension personnel allowed record keeping questions or obstacles to be quickly answered or solved. At the end of each production cycle receipts and feed costs were calculated based on average fish and feed prices received or paid for during the production cycle time period. All receipt and expenditure data were condensed by line item categories into a summarized enterprise budget format that calculated sales, itemized variable costs, income above variable cost (an indicator of short term profitability), fixed costs, total costs, and net return above all costs (an indicator of long term profitability). This was done for each production cycle within each of the three treatments as well as for an overall combined two production cycles for each treatment.

Specific parameters measured for total cost of production calculation included quantity and price of fish sold and quantity and price of purchased inputs: namely fingerlings, feed, chemicals, electricity, fuel, harvest/transport, management/labor, and interest on operating costs. Fixed costs included depreciation on the pond and machinery, land taxes, and interest on pond construction costs. No land charges were included, so, a net return to land was calculated for comparison's sake between all production cycles and treatments in this research verification program.

Results

Farm 2 Production Cycle 1

A summary of the production data is found in Table 9. The production period for Treatment C was shorter (1.67 years) than for cycle 1 in Treatments A (1.83 years) and B (1.92 years). Average fish size at harvest was comparable for Treatment A and Treatment C at 1.97 and 1.99 lb fish compared to 2.62 lb fish in Treatment B. Survival was highest in Treatment C at 63% followed by Treatment A at 62% and Treatment B at 39%. Net and annual yields were highest for Treatment A (8,277 lbs/acre and 4,523 lbs/acre/year) followed by Treatment C (7,153 lbs/acre or 4,293 lbs/acre/year) and Treatment B (6,586 lbs/acre or 3,430 lbs/acre/year, respectively). Net feed conversion ratios (FCR) were 3.09, 2.04, and 2.65 for Treatments A, B, and C, respectively. Cycle 1 fish size distribution at harvest revealed that 43% or higher of fish were between 1.5 and 3.0 lbs at harvest for all three treatments and 29% or higher were between 0.5 and 1.5 lbs for all three treatments (Table 10). Only around 10% were > 3.0lbs at harvest for all three treatments.

Water quality sampling revealed total alkalinity (103 -155 mg/L) and total hardness (103 - 124 mg/L) measurements to be typical for west Alabama catfish ponds (Table 11). Treatment B had an ammonia nitrogen spike (8.5) in April 2012. Total ammonia nitrogen peaked at 9 mg/L in Treatment C in June 2011 and gradually diminished until harvest in August 2011. Total ammonia nitrogen never exceeded 4.6 mg/L in Treatment A. Water temperatures throughout the study fluctuated within normal pond water temperatures typically encountered in catfish ponds in west Alabama (Figure 3).

Treatment A produced $87,324 in catfish receipts (sales) with $63,541 in total costs (variable plus fixed costs) resulting in a net return above all costs of $23,783, or $2,643/acre or $1,444/acre/year (Table 12). Treatment B produced $96,041 in catfish sales with a total cost of $74,887 resulting in a net return of $21,154 or $1,347/acre or $702/acre/year. Treatment C, produced $67,876 in catfish sales with a total cost of $47,479 resulting in a net return of $20,398 or $2,458/acre or $1,472/acre/year (Table 12).

Farm 2 Production Cycle 2

In Cycle 2, Treatments A and C were harvested at 1.67 and 1.83 years, respectively. Treatment B was significantly shorter at 0.83 years (Table 9). Cycle 2 aeration levels remained the same in all three treatments. Treatments A had a survival rate of 100% followed by Treatment C (89%) and Treatment B was much lower at 47%. Cycle 2 net yield and annual yield was lowest in the single-batch Treatment B (5,131 lbs/acre or 3,072 lbs/acre/year). Treatment A produced 10,567 lbs/acre or 6,328 lbs/acre/year and Treatment C produced yields of 11,016 lbs/acre or 6,019 lbs/acre/year, respectively. Net FCR in Treatments A and C, were 2.22 and 2.55 and respectively, and 1.21 in Treatment B (Table 9). Samples of size distribution at harvest revealed that there were large numbers of suboptimal size fish with 46% and 43% in the 0.75 - 1.25lb range in Treatments A and B and 24% and 25% in the 1.5 - 3.0lb range (Table 10). Treatment C had the most optimal size fish distribution with 48% in the 1.5 to 3.0 lb range but also had 30% that were < 1.5 lbs (Table 10).

During production Cycle 2 total alkalinity (93 - 101 mg/L) and total hardness (95 - 101 mg/L) measurements were similar to those attained in Cycle 1 (Table 11). Treatment B, total ammonia nitrogen reached a cycle high of 8.5 in April of 2012 but dropped significantly by the next week. The highest levels of nitrite nitrogen (1.7 mg/L) were observed in Treatment C but there was sufficient chloride to prevent brown blood disease. Winter temperatures were slightly higher in production Cycle 1 than in production Cycle 2 (Figure 3).

Treatment A produced $88,270 in catfish sales with a total cost of $68,973, resulting in a net return of $20,297, or $2,255/acre or $1,350/acre/year (Table 12). Treatment B produced

$97,225 in catfish sales with a total cost of $54,682 resulting in a net return of $42,543 or $2,710/acre or $3,265/acre per year. Treatment C produced $102,922 in catfish sales with a total cost of $70,385 resulting in a net return of $32,537 or $3,920/acre or $2,142/acre/year.

Farm 2 Summary of 2 Production cycles

It is difficult to completely separate production cycles due to multiple-batches within the same pond and incomplete harvests. Another accurate and informative way of analyzing the production (Table 13) and economics (Table 14) is to look at the combined two production cycles for each treatment. Over the course of the three year study, Treatment B produced the most pounds for the two production cycles (196,942 lbs), but had a much lower net yield (11,717 lbs/acre or 4,261 lbs/acre/year) and the lowest survival (42%) over the three treatments. The high production (lbs) was a result of this pond being much larger (15.7 acres) than Treatments A (9.0 acres) and Treatment C (8.3 acres) pond size therefore, more fish were stocked (217,398 head). The overall net return for the combined two cycles for Treatment A was $44,080 or $4,898/acre or $1,399/acre/year or a profit margin of $0.25/lb produced. The total cost of production was $0.75/lb (Table 14).

The overall average fish size harvested for Treatment B was 2.16 lbs even though it had the shortest production period (2.75 years). The larger average fish size is most likely due to the lower survival. FCR was lowest for Treatment B (1.67) but the average daily feeding rate for this pond was almost half (28 lbs/acre/day) as much as Treatments A and C (57 and 59 lbs/acre/day respectively). Despite the lower survival rate, the net return for Treatment B was positive at $63,697 for 2 cycles, $4,057/acre and $1,475/acre/year and a profit margin of $0.32/lb produced. The total cost of production was $0.66/lb (Table 14).

Treatment A (176,795 lbs) produced the highest net yield over the course of two production cycles (18,845 lbs/acre or 5,384 lbs/acre/year) and had the highest survival (76%). The average fish size at harvest was 1.94 lbs and net FCR was 2.59. The net return for Treatment C was $52,935 or $6,378/acre or $1,822/acre/year and a profit margin of $0.34/lb produced. The total cost of production of $0.75/lb (Table 14).

Farm 3 Production Cycle 1

A summary of Farm 3 production data is in Table 15. The production period for Treatment B cycle 1 was longer (2.33 years) than for cycle 1 in Treatment A (1.67 years) and Treatment C (1.67 years). Average fish size at harvest was comparable for Treatment B and Treatment C at 2.27 and 2.21 lbs, respectively compared to 1.63 lbs in Treatment A. The level of aeration used in Treatments A, B and C ponds was 2.08, 3.39, and 2.86 hp/acre, respectively. Survival was highest in Treatment A (99%) followed by Treatment B (73%) and Treatment C (62%). Net yield for Treatment A and Treatment C was comparable (9,887 and 9,161 lbs/acre, respectively) while Treatment B was higher (11,687 lbs/acre). Net feed conversion ratios (FCR) were 2.49, 2.01, and 2.09 for Treatments A, B, and C, respectively. Cycle 1 fish size distribution at harvest revealed that 56%, 66% and 49% of Treatments A, B and C, respectively were in the 1.25 to 1.5 lb range, while only 1%, 10% and 3% fell into the > 3.0 lbs range at harvest (Table 10).

Water quality sampling showed total alkalinity (103 – 107mg/L) and total hardness (102 - 141 mg/L) measurements that are typical of west Alabama catfish ponds (Table 11). Total ammonia nitrogen reached 9.2 mg/L in Treatment A during September of 2010 and converted to NO_2 in October 2010. Water temperatures throughout the study fluctuated normally for pond water temperatures typically encountered in catfish ponds in west Alabama (Figure 3).

Treatment A, produced $106,443 in catfish receipts (sales) with $70,801 in total costs (variable plus fixed costs) resulting in a net return above all costs of $35,642, or $3,713/acre or $2,223/acre/year (Table 16). Treatment B, produced $77,375 in catfish sales with a total cost of $45,194 resulting in a net return of $32,181 or $5,454/acre or $2,341/acre/year (Table 12). Treatment C produced $72,936 in catfish sales with a total cost of $42,933 resulting in a net return of $30,003 or $4,286/acre or $2,567/acre/year (Table 16).

Farm 3 Production Cycle 2

In Cycle 2, all three treatments were harvested over the course of approximately two years (1.92 - 2.17 years, Table 15). Cycle 2 aeration hp levels remained the same for all three treatments (2.08, 3.39, and 2.86 Hp/acre). Treatment A experienced a massive catfish die off due to a spike in nitrite nitrogen resulting in poor survival (27%). Treatments B and C had survivals of 52% and 35%, respectively. Net yield was comparable in Treatments A and B (7,864 and 7,941 lbs/acre) and Treatment C was slightly lower at 6,182 lbs/acre. Net FCR in Treatments A, B, and C was 2.79, 2.52, and 2.86, respectively. Sample size distributions are not available because the farmer cooperator did not notify Extension personnel of harvests in time to take sample weights.

Total alkalinity (133.0 - 187.9 mg/L) and total hardness (109.6 - 165.5 mg/L) measurements were similar to those attained in Cycle 1 (Table 11). Total ammonia nitrogen peaked at 10.3 mg/L in Treatment A. Nitrite nitrogen levels spiked in August of 2012 resulting in a significant fish die-off. The producer assumed the mortality was due to *Aeromonas hydrophila* without having water quality checked first. He treated the pond with copper sulfate which further deteriorated water quality in the pond. The pond had low chloride levels and did not buffer the effects of high NO_2 that resulted from the decomposition of dead fish. Salt was added the following week to raise chloride levels. These water quality issues led to poor survival (27%) in Treatment A. Winter temperatures were slightly higher in production Cycle 1 than in production Cycle 2 (Figure 3).

Treatment A produced $93,123 in catfish sales with a total cost of $78,454, resulting in a net return of $14,669 or $1,528/acre or $704/acre/year (Table 16). Treatment B produced $54,500 in catfish sales with a total cost of $42,869 resulting in a net return of $11,631 or $1,971/acre or $1,027/acre per year. Treatment C, produced $48,754 in catfish sales with a total cost of $41,033 resulting in a net return of $7,720 or $ 1,103/acre or $552/acre/year.

Farm 3 Summary of 2 Production cycles

Because it is difficult to completely separate production cycles due to multiple-batches within the same pond and incomplete harvests, another accurate and informative way of analyzing the production (Table 17) and economics (Table 18) is to look at the combined three production cycles for each treatment. Over the course of the three year study, Treatment A produced the most pounds for the two production cycles (183,088 lbs or 17,751 lbs/acre), produced the highest annual net yield (4,631 lbs/acre/year), yet it had the lowest survival (44 %) and the highest gross FCR (2.44). The overall net return for the combined two cycles for Treatment A was $199,566 or $20,788/acre or $5,428/acre/year or a profit margin of $0.27/lb of fish produced. The total cost of production was $0.82/lb (Table 18).

Treatment B produced the second most pounds over the two production cycles (120,986 lbs) and because the pond acreage (5.9 acres) was less than that of Treatment A (9.6 acres) the production per acre was greater (19,629 lbs/acre, Table 17). Survival in Treatment B was the highest of the three treatments at 61% and the FCR was 2.22. The overall net return for the combined two cycles for Treatment B was $43,811 or $7,426/acre or $1,747/acre/year or a profit margin of $0.36/lb of fish produced (Table 18). The total cost of production was $0.73/lb of fish produced.

Treatment C produced the least pounds over the two production cycles (111,642 lbs) and with the 7.0 acre pond acreage the production per acre was less (15,949 lbs/acre, Table 17). Survival in Treatment C was low at 48% but Treatment A was lower at 44%. Treatment B had the highest survival at 68%. The FCR for Treatment C was 2.42. Overall net return for combined cycles for Treatment C was $37,723 or $5,389/acre, $1,468/acre/year or a profit margin of $0.34/lb of fish produced. The total cost of production was $0.75/lb of fish produced (Table 18).

Discussion

Aquaculture research verification programs are useful in determining whether Extension recommendations developed through research are effective when applied to a commercial farm production setting. The trials allow farmers to gain confidence in Extension recommendations and foster more rapid adoption of new production technology. However, the returns from such investments should be large enough to justify the cost of on-farm trials (Kaliba and Engle 2005). Extension personnel monitor various production parameters and make management recommendations to the producer on a regular basis.

While there have been several successful catfish research verification trials, the need for applying new management ideas and new technologies still exist and continued efforts to improve overall production and lower costs of production are needed. Engle (2007) reported that the Alabama research verification trial (1996-2000) stocked 5 ponds in west Alabama. Two ponds were stocked with Channel catfish and three ponds were stocked with C x B hybrids. The Channel catfish ponds were stocked at 4,855 and 5,469 head/acre. Net yield for the Channel catfish ponds was reported as 3,811 and 6,503 lbs/acre/year. Harvested weights ranged from 5,241 to 10,749 lbs/acre. This stocking density proved to be profitable for the Channel catfish ponds. The stocking rates recommended for this study were significantly higher, 6,750 Channel catfish/acre, and harvest rates ranged from 5,602 to 12,032 lbs/acre for the Channel catfish. Engle (2007) reported that the survival rates for Channel catfish were 56% and 55%, respectively. Data obtained in this study has confirmed that farmers can make a profit raising Channel catfish using current Extension recommended production practices in single and multiple-batch systems.

During the research verification trials in Arkansas (1993 - 1996) the recommended Extension protocol was to stock 15,000 to 16,500 fish/ha (6,073 to 6,680 fish/acre) and implement a minimum aeration rate of 2 Hp/ha (0.8 Hp/acre). The results of the trial encouraged farmers to reduce stocking rates to 15,000 fish/ha and increase aeration to a minimum of 2.5 Hp/ha of paddlewheel aeration to increase production and be more profitable (Heikes 1997).

There has been a lot of literature published on the production and economics of commercial catfish farms raising Channel catfish. Catfish research publications have reported data concerning fingerling stocking sizes, single or multiple-batch cropping systems, stocking rates, nutrition, feed conversion ratios, water quality, genetics and fish health management. The key to least-cost production is to balance the use of inputs, their associated costs, and yield production to achieve economic efficiency within the farm’s overall business and management model.

Single-batch production of Channel catfish has been evaluated extensively by many researchers (Engle and Pounds 1994; Pomerleau and Engle 2003; Southworth et al. 2006a, 2006b, 2009). Southworth et al. (2006b) reported that high stocking rates of catfish in single-batch production with satiation feeding and sufficient aeration can result in high net yields of fish with no increase in FCR over those obtained at lower densities. Tucker et al. (1994) also obtained yields that ranged from 3,881 to 7,254 kg/ha (3,463 to 6,474 lbs/acre) at a stocking density of 11,120 fish/ha (4,500 fish/acre) and from 5,177 to 11,214 kg/ha (4,621 to 10,009 lbs/ace) at a stocking density of 19,770 fish/ha (8,000 fish/acre) in their single-batch treatments. Pomerleau and Engle (2003) stocked fingerlings (6.7cm) in single batch at rates of 50,000, 100,000, and 150,000 fish/ha (20,243, 40,485, and 60,728 fish/acre). Net yields in their study increased as stocking density increased. Green and Engle (2004) raised fish in single-batch production at a stocking rate of 11,155 fish/ha (4,516 fish/acre) to weights of 1.17 kg/fish (2.58 lbs) at 210 days with net yields of 3,062 to 8,355 kg/ha (2,733 to 7,457 lbs/acre). Engle and Pounds (1994) reported that single-batch stocking strategies maximize net returns above variable cost, but multiple-batch stocking is lower risk to the producer and can better meet financial obligations because of a more steady cash flow.

In this study, the single-batch ponds were stocked at rates of 6,750, 6,922, and 8,821 fish/acre, respectively for Farms 1, 2 and 3. Farm 1 which produced the C x B hybrid catfish had a mean annual net yield of 10,780 lbs/acre/year over 3 production cycles. Farms 2 and 3 which produced Channel catfish had very similar results with mean annual net yields of 4,261 and 4,619 lbs, respectively over two production cycles. The results from this study demonstrate that single-batch cropping for both Channel catfish and C x B hybrids (Chapter 2) was profitable for these particular producers.

Farm 1 (Chapter 2) produced annual net yields of 10,000 lbs/acre or greater for all 3 production cycles. Farm 1 stocked larger fingerlings (80 lbs/1000) than Farm 2 and 3 (60 and 50 lbs/1000 fingerlings) respectively, had much higher aeration rates (10.26 Hp/acre versus 1.91 and 2.22 Hp/acre), and had much higher survival (87% versus 42 and 61% for Farms 2 and 3 respectively. Farm 1 also had a net return above all of $95,419 ($14,680/acre and a profit margin of $0.36/lb of fish produced). Farm 2 had a net return above all costs of $95,419 ($14,680/acre and a profit margin of $0.36/lb of fish produced) and Farm 3 had a net return of $43,811 ($7,426/acre and a profit margin of $0.36/lb of fish produced). This study demonstrated that single-batch production is profitable for both the production of C x B hybrid catfish and Channel catfish.

Most catfish farms (76%) use a multiple-batch production system in which ponds contain both newly stocked fingerlings and carryover fish, whereas only 31% of producers use single-batch production that was previously discussed (USDA 2010). Like single-batch, multiple-batch production has been extensively evaluated by researchers (Tucker et al. 1994; Engle and Valderrama 2001; Southworth et al. 2009; Nanninga and Engle 2010 and Engle et al. 2011). Southworth et al. (2009) evaluated production results from treatments of different densities of stockers and found little difference among the different stocking densities. Engle and Valderrama (2001) found percent survival of fingerlings to be higher when larger fish were understocked. Tucker et al. (1994) found lower survival of fingerlings in multiple batches as stocking densities increased. The survival of fingerlings when understocked in multiple batches tends to be lower than when stocked in single-batch production (Southworth et al. 2006b). This held true in the case of Farm 3 in which Treatment B had a higher rate of survival than the two multi-batch treatments. Farm 2 had the opposite result in that Treatment B had the lowest survival of the three treatments (42%).

In this study there were two multiple-batch treatments per farm (Treatments A and C). One was an Extension based multi-batch (Treatment C) and the other was a producer or “owner” based multi-batch treatment (Treatment A). The two treatments were implemented to compare the current Extension recommendations to different producer management practices. For Farm 2 over 2 production cycles, Treatment C was the most successful of the three treatments producing a net yield of 18,845 lbs/acre, an annual net yield of 3,725 lbs/acre/year, a net FCR of 2.6 and a 58% survival rate. Farm 3 Treatment B was the most successful of the three. The net yield over two production cycles was 16,629 lbs/acre, annual net yield of 4,619 lbs/acre/year, net FCR of 2.2 and a 61% survival rate. From an economic perspective, Farm 2 Treatment C had an income above variable cost of $71,966 and a net return of $68,963 ($8,309/acre and a profit margin of $0.36/lb of fish produced). Farm 3 had an income above variable cost of $41,266 and a net return of $37,723 ($5,389/acre and a profit margin of $0.34/lb of fish produced).

In the case of the two commercial channel catfish farms in the study, overall, the multiple-batch Extension treatment had the highest average survival rate (71%), the highest annual yield (5,404 lbs/acre/year) and the highest profit margin of $0.35/lb of fish produced. The single-batch Extension Treatment B was second in performance with a 52% survival rate, the highest FCR rate of the three treatments (1.95), annual net yield of 4,543 lbs/acre/year and profit margin of $0.35/lb of fish produced.

Results from these verification studies verify current Extension recommendations are profitable. However, we continue to learn ways to improve the catfish industry through improvement on management practices. Research and collaboration with good cooperators, like those who participated in this study, are vital to such studies, as they implement the practices and, importantly, keep good records! These types of records allow researchers to review BMPs to test the changes in management and new technologies, allowing us to refine and develop new BMPs.

Chapter 4

Summary and Conclusions

This study demonstrated that current Extension recommendations are profitable. It demonstrated that single-batch as well as multiple-batch stocking can be profitable, with both C x B hybrid and Channel catfish. The verification trial confirmed that C x B hybrids produced with intensive aeration outperformed Channel catfish produced without intensive aeration. This observation is based on the fact that three crops of C x B hybrids were produced in the 3 year study as opposed to only two crops in 3 years (4.25 years for Farm 3 Treatment B) from the Channel catfish operations. Farm 1 was able to have higher net returns, despite the fact that C x B hybrid fingerlings and feeding was more costly because the additional crop in the three year period more than made up for these additional costs.

It can be concluded from this study that there are many different and profitable ways of producing catfish. It can also be concluded that different methods of management work better for different producers. Commercial catfish farming is not solely about production. Economic profitability is a very important aspect of every business and it is not any different for agriculture and aquaculture businesses. Some producers are able to successfully produce catfish in single-batch crops, but it may not be economically feasible for other producers because of the "one-time pay off" as opposed to a more steady cash flow that may result from multiple-batch cropping systems.

Comparing the two Channel catfish operations (Farms 2 and 3), Treatment A average net returns showed the difference between Farm 2 and Farm 3 was small (Table 19). In Treatment B the average net return was greater for Farm 2 than Farm 3 (Table 20). Treatment C Farm 2 had higher net returns than Farm 3 (Table 21).

The Extension recommendation regarding stocking in a single-batch or multiple-batch system should be determined by taking a look at the overall position of the producer as our results show both can be profitable. The Extension specialist should take the time to discuss the pros and cons of each stocking system before making a recommendation. Everyone has different situations, whether it be a matter of finances or otherwise. Just as every pond is different, so is every farming operation. So, even if an Extension recommendation is verified as being profitable, that doesn't mean it is the best approach for every producer.

The processing plants play a huge role in the overall profitability of individual catfish operations. Farms 1 and 3 were directly and negatively impacted by the processing plant not being able to purchase their market sized fish on a timely basis. Secondly, the custom harvesting process, whether they are independent or part of the processing company, also directly and negatively impacted these producers by their poor seining efforts. This resulted in the producer having over-sized fish when the processor and harvester were able to return to these farms and harvest more fish. Oversized fish is a burden to processors and they pay a much lower price for fish when they are big and sometimes the processors will not accept them at all.

How does the U.S. farm-raised catfish industry get to a place where both producers and processors profit without creating sacrifices for the other? Courtwright (2013) spoke of a merit-based purchasing remedy where the processor pays a certain price or buys fish strictly based on the quality of the product. I believe this would be a beneficial change to the U.S. catfish industry because it would raise the standards at which our producers raise the fish and it would raise the standard of product that the processor is making available to the consumer. Requiring higher standards for color, flavor, fillet yield and appearance might seem daunting to the producer at first, but marketing a higher grade product would make the U.S. catfish industry more competitive with foreign catfish imports as well as with other fish species competing in the same market place such as tilapia and salmon.

The purpose of this study and others preceding verification studies is for researchers, producers and Extension specialists to learn from each other. By utilizing not only current BMP guidelines but new and innovative future methods in verification trials, we will continue to improve not only the methods of management and production, but also improve our collective ability to maintain better records for analysis. Additionally, these studies enable producers, researchers, processors, and consumers to better communicate their issues, needs and solutions. The production variables set forth in the BMPs used in this study were both productive and profitable, yet there will always be more to be learned and room for improvement.

Based on the results from these verification trials, there could be some refinements to the initial BMP put forth for this study (Table 22). First, the stocking density for hybrid catfish production could be increased above the 6,750 initially proposed. Secondly, for the hybrids the feeding rate could be increased above the 150 lbs/acre/day initially proposed. Third, high aeration rates in hybrid catfish production were confirmed as a means to increase production. It is now proposed that the new BMP should state that increasing aeration rates to a minimum of 3 **-** 4 Hp/acre for Channel catfish could help increase production. Each of these recommendations has also been shown in this study to be profitable. These types of improvements, no matter how slight or insignificant they seem, are necessary to enable the catfish industry to move forward and become not only a more profitable industry, but a sustainable one that will continue for future generations.

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Table 1. Recommended / required management protocols for (Farm 1) an intensively aerated C x B hybrid catfish farm in west Alabama to follow for three complete production cycles in the research verification program, 2010 - 2013.

Management description (treatments):	
Treatment A: multiple-batch, owner defined	
Treatment B: single-batch, extension recommendations	
Treatment C: multiple-batch, extension recommendations	
Pond size, acre	6 - 15
Aeration, Hp/acre	5 - 6
Stocking, head/acre	6,750
Feed protein level, %	32
Maximum feeding rate, lbs/acre/d	150[1]
Chemicals allowed	Diuron, copper sulfate, salt, potassium permanganate, hydrated lime, lime slurry, citric acid

[1]MBO Treatment A was not limited to 150 lbs/acre/d

Table 2. Production data for three treatments (A=Multiple-Batch, Owner defined; B=Single-Batch, Extension defined; C=Multiple-Batch, Extension defined) from three production cycles at (Farm 1) an intensively aerated C x B hybrid catfish farm in west Alabama, 2010 - 2013.

	Treatment A (MBO)			Treatment B (SBE)			Treatment C (MBE)		
	Cycle 1	Cycle 2	Cycle 3	Cycle 1	Cycle 2	Cycle 3	Cycle 1	Cycle 2	Cycle 3
Pond size (acre)	7.9	7.9	7.9	6.5	6.5	6.5	8.0	8.0	8.0
Production Period (year)	0.83	1.33	1.33	1.42	1.33	0.83	1.33	1.33	1.00
Head stocked/acre	6,754	6,856	7,872	6,750	6,775	6,871	6,834	7,015	6,875
Average weight at stocking (lbs/1000)	69	91	62	71	77	91	51	99	91
Aeration (HP/acre)	8.86	8.86	8.86	9.23	10.77	10.77	9.28	10.63	10.63
Total harvested (lbs)	96,611	99,606	102,139	98,397	94,209	68,881	104,077	29,787	59,308
Total harvested (lbs/acre)	12,229	12,608	12,929	15,138	14,494	10,597	13,006	3,723	7,414
Weighbacks (lbs)	1,374	1,077	1,333	656	6,064	2,290	281	284	390
Net Yield (lbs/acre)	11,762	11,975	12,441	14,659	13,956	9,979	12,653	3,034	6,758
Net Yield per year (lbs/acre/yr)	14,115	8,981	9,354	10,347	10,467	12,023	9,490	2,276	6,758
Average weight at harvest (lbs)	1.91	2.13	1.77	2.56	2.25	1.95	2.60	2.14	2.40
Survival (%)	95	86	93	88	95	79	83	25	45
Total feed fed (lbs)	187,849	209,774	138,202	279,463	161,608	184,821	263,083	119,661	157,624
Total feed fed/acre (lbs/acre)	23,778	26,554	17,494	42,994	24,863	28,434	32,885	14,958	19,703
Average daily feeding rate (lbs feed/acre/day)	78.12	54.52	36.01	83.09	51.05	93.79	67.53	30.71	53.94
Gross FCR	1.94	2.11	1.35	2.84	1.72	2.68	2.53	4.02	2.66
Net FCR	2.02	2.22	1.41	2.93	1.78	2.85	2.60	4.93	2.92

Table 3. Harvested catfish size distribution (%) results from fish sampled at harvest for three different production cycles and for three different treatments (A=Multiple-Batch, Owner defined; B=Single-Batch, Extension defined; C=Multiple-Batch, Extension defined) at (Farm 1) an intensively aerated C x B hybrid catfish farm in west Alabama, 2010 – 2013.

Fish Size Range	Treatment A (MBO)			Treatment B (SBE)			Treatment C (MBE)		
	Cycle 1	Cycle 2	Cycle 3	Cycle 1	Cycle 2	Cycle 3	Cycle 1	Cycle 2	Cycle 3
0.0 – 0.75lbs	2.0	0	0	0.3	1.1	0.5	5.0	1.0	0
0.75 - 1.25 lbs	11.0	5.0	9.0	2.3	26.0	11.0	32.0	11.0	4.0
1.25 - 1.5lbs	16.0	5.0	20.0	4.3	18.0	17.0	16.0	4.0	7.0
1.5 - 3.0lbs	62.0	68.0	69.0	64.0	45.0	59.0	41.0	60.0	67.0
3. - 4.0lbs	5.0	8.0	1.0	16.0	6.0	10.0	5.0	15.0	16.0
> 4.0lbs	3.0	13.0	0	12.0	5.0	3.0	1.0	11.0	6.0

Table 4. Monthly total ammonia nitrogen (TAN) (mg/L), total nitrite nitrogen (NO_2-N) (mg/L), chlorides (mg/L), total alkalinity (mg/L) and total hardness (mg/L) in research verification ponds during three different production cycles for three treatments (A=Multiple-Batch, Owner defined; B=Single-Batch, Extension defined; C=Multiple-Batch, Extension defined) at (Farm 1) an intensively aerated C x B hybrid catfish farm in west Alabama. Values represent the mean ± standard deviation of values.

	Treatment A (MBO)	Treatment B (SBE)	Treatment C (MBE)
Production Cycle 1			
TAN	1.18 ± 0.40	4.83 ± 3.33	2.52 ± 1.84
NO_2-N	0.30 ± 0.26	0.44 ± 0.65	0.26 ± 0.03
Chloride	100.50 ± 17.16	96.54 ± 19.02	69.78 ± 15.40
Total Alkalinity	165.20 ± 23.48	140.96 ± 25.71	133.85 ± 29.16
Total Hardness	213.81 ± 75.20	154.65 ± 36.73	138.46 ± 40.73
Production Cycle 2			
TAN	1.25 ± 0.87	1.79 ± 1.48	3.71 ± 2.81
NO_2-N	0.13 ± 0.04	0.44 ± 0.49	0.22 ± 0.24
Chloride	123.04 ± 16.78	114.33 ± 14.59	94.27 ± 22.83
Total Alkalinity	187.91 ± 44.16	133.0 ± 23.51	149.33 ± 31.22
Total Hardness	165.50 ± 35.42	114.35 ± 21.11	109.56 ± 22.45
Production Cycle 3			
TAN	1.65 ± 0.82	1.04 ± 0.41	5.53 ± 3.69
NO_2-N	0.20 ± 0.11	0.57 ± 0.12	0.57 ± 1.41
Chloride	126.43 ± 5.16	111.0 ± 22.20	107.50 ± 23.32
Total Alkalinity	201.86 ± 16.20	117.30 ± 22.43	145.10 ± 28.58
Total Hardness	182.29 ± 4.82	104.20 ± 27.94	124.80 ± 27.95

Table 5. Summary enterprise budgets for three treatments and three production cycles at (Farm 1) an intensively aerated C x B hybrid catfish farm in west Alabama, 2010 - 2013 (Multiple-batch MB, Single-batch SB, Owner O, Extension E).

	Treatment A (MBO)			Treatment B (SBE)			Treatment C (MBE)		
	Cycle 1	Cycle 2	Cycle 3	Cycle 1	Cycle 2	Cycle 3	Cycle 1	Cycle 2	Cycle 3
Pond Size, acre	7.9	7.9	7.9	6.5	6.5	6.5	8.0	8.0	8.0
Pounds Harvested	96,611	99,606	102,139	98,397	94,209	68,881	104,047	29,787	59,308
Production Period, year	0.83	1.33	1.33	1.42	1.33	0.83	1.33	1.33	1.00
1. Gross Receipts									
Catfish sales[1]	105,306	108,571	111,332	107,253	102,688	75,080	113,411	32,468	64,646
2. Variable Costs									
Feed[2]	35,647	44,262	34,895	56,181	30,675	20,951	49,986	25,248	39,799
Labor & Management	5,828	5,828	5,828	4,795	4,795	4,795	5,902	5,902	5,902
Fingerlings	7,470	8,470	7,587	6,143	6,540	8,659	7,654	9,091	10,663
Harvest and transport[3]	4,831	4,980	5,107	4,920	4,710	3,444	5,202	1,489	2,965
Diesel (aerators, tractors)	566	483	106	1,587	240	177	233	158	0
Aeration Electrical	5,433	4,446	2,011	7,819	2,920	1,270	5,951	2,810	2,875
Chemicals	868	522	0	1,986	1,293	0	2,690	1,914	3,634
Interest on Operating Capital	4,245	4,829	3,887	5,840	3,582	2,751	5,433	3,263	4,609
Total Variable Costs	64,887	73,821	59,422	89,271	54,756	42,046	83,050	49,875	70,447
3. Income Above Variable Cost	40,419	34,749	51,909	17,982	47,932	33,034	30,361	(17,407)	(5,801)
4. Fixed Cost									
Land charge (not included)	0	0	0	0	0	0	0	0	0
Pond and Machinery depreciation	561	561	561	462	462	462	568	568	568
Taxes (land)	177	177	177	146	146	146	179	179	179
Interest on Equipment/Mach. Purchases	691	691	691	569	569	569	700	700	700
Total Fixed Costs	1,429	1,429	1,429	1,176	1,176	1,176	1,447	1,447	1,447
5. Total Costs	66,317	75,251	60,852	90,447	55,932	43,223	84,498	51,323	71,894
6. Net Returns to Land	38,989	33,320	50,480	16,806	46,756	31,858	28,914	(18,855)	(7,249)

[1]Catfish sales receipts based on $1.09/lb
[2]Feed prices taken from industry average during each production cycle: Cycle 1: $380/ton; Cycle 2: $422/ton, and Cycle 3: $505/ton.
[3]Harvest and transport cost based on $0.05/lb of fish

Table 6. Three Cycle Summary of Production data at (Farm 1) an intensively aerated C x B hybrid catfish farm in west Alabama, 2010 - 2013.

	Treatment A (MBO)	Treatment B (SBE)	Treatment C (MBE)
Pond size (acre)	7.9	6.5	8.0
Production Period (year)	2.75	3.58	3.67
Head stocked/acre	21,482	20,397	20,724
Average weight at stocking (lbs/1000)	74	80	80
Aeration (HP/acre)	8.86	10.26	10.21
Total lbs harvested (lbs)	298,356	261,487	193,142
Total lbs harvested /acre (lbs/acre)	37,767	40,229	24,143
Weighbacks (lbs)	3,784	9,010	955
Net Yield (lbs/acre)	36,178	38,594	22,445
Net Yield per year (lbs/acre/yr)	13,156	10,780	6,121
Average weight at harvest (lbs)	1.9	2.3	2.3
Survival (%)	91	87	51
Total feed fed (lbs)	535,825	524,043	540,368
Total feed fed/acre (lbs/acre)	67,826	80,622	67,546
Average daily feeding rate (lbs feed/acre/day)	72	59	51
Gross FCR	1.80	2.00	2.80
Net FCR	1.87	2.09	3.01

Table 7. Summary enterprise budgets for combined three production cycles and three treatments at (Farm 1) an intensively aerated C x B hybrid catfish farm in west Alabama, 2010 - 2013.

	Treatment A (MBO)			Treatment B (SBE)			Treatment C (MBE)		
	$	$/acre	$/lb	$	$/acre	$/lb	$	$/acre	$/lb
Pond size (acres)	7.9			6.5			8.0		
Pounds Harvested	298,356			261,487			193,142		
1. Gross Receipts									
Catfish sales	325,208	41,166	1.09	285,021	43,849	1.09	210,525	26,316	1.09
2. Variable Costs									
Feed	114,805	14,532	0.38	107,808	16,586	0.41	115,033	14,379	0.60
Management & Labor	17,484	2,213	0.06	14,385	2,213	0.06	17,705	2,213	0.09
Fingerlings	23,527	2,978	0.08	21,341	3,283	0.08	27,409	3,426	0.14
Harvest and transport	14,918	1,888	0.05	13,074	2,011	0.05	9,657	1,207	0.05
Diesel (aerators, tractors)	1,156	146	0.00	2,004	308	0.01	390	49	0.00
Aeration Electrical	11,891	1,505	0.04	12,009	1,847	0.05	11,636	1,454	0.06
Chemicals	1,390	176	0.00	3,279	504	0.01	8,238	1,030	0.04
Int. on Operating Capital	12,962	1,641	0.04	12,173	1,873	0.05	13,305	1,663	0.07
Total Variable Costs	198,131	25,080	0.66	186,073	28,627	0.71	203,372	25,422	1.05
3. Income Above Var. Cost	127,077	16,086	0.43	98,947	15,223	0.38	7,152	894	0.04
4. Fixed Cost									
Land charge (not included)	0	0	0	0	0	0	0	0	0
Pond and Machinery Depr.	1,684	213	0.01	1,385	213	0.01	1,705	213	0.01
Taxes (land)	531	67	0.00	437	67	0.00	528	67	0.00
Int. - Pond Constr. Costs	2,073	262	0.01	1,706	262	0.01	2,100	262	0.01
Total Fixed Costs	4,288	543	0.01	3,528	543	0.01	4,342	543	0.02
5. Total Costs	202,419	25,623	0.68	189,602	29,169	0.73	207,715	25,964	1.08
6. Net Returns to Land	122,789	15,543	0.41	95,419	14,680	0.36	2,810	351	0.01

Table 8. Recommended / required management protocols for (Farm 2 and Farm 3) west Alabama catfish farmers producing Channel catfish to follow for two complete production cycles in the yield verification program, 2010 - 2013.

Management description (treatments):	
Treatment A: multiple-batch, owner defined	
Treatment B: single-batch, extension recommendations	
Treatment C: multiple-batch, extension recommendations	
Pond size, acre	6 - 15
Aeration, Hp/acre	5 - 6
Stocking, head/acre	6,750
Feed protein level, %	32
Maximum feeding rate, lbs/acre/d	150[1]
Chemicals allowed	Diuron, copper sulfate, salt, potassium permanganate, hydrated lime, lime slurry, citric acid

[1]MBO may exceed 150 lbs/acre/d

Table 9. Production data for three treatments (A=Multiple-Batch, Owner defined; B=Single-Batch, Extension defined; C=Multiple-Batch, Extension defined) from two production cycles at (Farm 2) a Channel catfish farm in west Alabama, 2010 - 2013.

	Treatment A (MBO)		Treatment B (SBE)		Treatment C (MBE)	
	Cycle 1	Cycle 2	Cycle 1	Cycle 2	Cycle 1	Cycle 2
Pond size (acre)	9	9	15.7	15.7	8.3	8.3
Production Period (year)	1.83	1.67	1.92	0.83	1.67	1.83
Head stocked/acre	7,111	8,406	6,751	7,092	6,024	6,822
Average weight at stocking (lbs/1000)	58	46	53	68	58	53
Aeration (HP/acre)	1.11	1.11	1.91	1.91	2.41	2.41
Total harvested (lbs)	78,209	98,586	108,986	87,956	62,272	94,424
Total harvested (lbs/acre)	8,690	10,954	6,942	5,602	8,625	11,376
Weighbacks (lbs)	299	16,465	1,518	2,963	172	1,838
Net Yield (lbs/acre)	8,277	10,567	6,586	5,131	7,153	11,016
Net Yield per year (lbs/acre/yr)	4,515	6,340	6,584	6,157	4,292	6,008
Average weight at harvest (lbs)	1.97	1.27	2.62	1.69	1.99	1.88
Survival (%)	62	100	39	47	63	89
Total feed fed (lbs)	229,908	211,376	210,800	114,231	157,534	232,764
Total feed fed/acre (lbs/acre)	25,545	23,486	13,427	7,276	18,980	28,044
Average daily feeding rate (lbs feed/acre/day)	38	39	19	24	31	42
Gross FCR	2.94	2.14	1.93	1.3	2.53	2.47
Net FCR	3.09	2.22	2.04	1.21	2.65	2.55

Table 10. Harvested catfish size distribution (%) results from fish sampled at harvest for two different production cycles and for three different treatments (A=Multiple-Batch, Owner defined; B=Single-Batch, Extension defined; C=Multiple-Batch, Extension defined) at (Farm 2 and Farm 3) Channel catfish farms in west Alabama, 2010 – 2013.

		Farm 2 Cycle 1			Farm 2 Cycle 2	
Size range	Treatment A	Treatment B	Treatment C	Treatment A	Treatment B	Treatment C
< 0.75	6.0	1.0	0.0	4.0	14.0	0.0
0.75 - 1.25	28.0	29.0	18.0	47.0	43.0	15.0
1.25 - 1.50	15.0	12.0	21.0	15.0	9.0	15.0
1.50 - 3.0	44.0	43.0	53.0	24.0	25.0	48.0
3.0 - 4.0	5.0	8.0	8.0	7.0	4.0	15.0
> 4.0	2.0	7.0	0.0	3.0	5.0	7.0
		Farm 3 Cycle 1			Farm 3 Cycle 2	
Size range	Treatment A	Treatment B	Treatment C	Treatment A	Treatment B	Treatment C
< 0.75	3.0	1.0	2.0	*	6.0	2.0
0.75 - 1.25	39.0	19.0	34.0	*	44.0	34.0
1.25 - 1.50	19.0	26.0	11.0	*	15.0	11.0
1.50 - 3.0	37.0	40.0	38.0	*	30.0	38.0
3.0 - 4.0	1.0	10.0	3.0	*	3.0	3.0
> 4.0	1.0	4.0	12.0	*	2.0	12.0

*extension personnel not notified of harvests resulting in no sample size distribution

Table 11. Monthly total ammonia nitrogen (TAN) (mg/L), total nitrite nitrogen (NO_2-N) (mg/L), chlorides (mg/L), total alkalinity (mg/L) and total hardness (mg/L) in research verification ponds during three different production cycles for three treatments (A=Multiple-Batch, Owner defined; B=Single-Batch, Extension defined; C=Multiple-Batch, Extension defined) at (Farm 2 and Farm 3) two Channel catfish farms. Values represent the mean ± standard deviation of values.

	Trt A MBO Farm 2	Trt A MBO Farm 3	Trt B SBO Farm 2	Trt B SBO Farm 3	Trt C MBE Farm 2	Trt C MBE Farm 3
Production Cycle 1						
TAN	1.48 ± 0.55	2.73 ± 2.04	1.27 ± 0.99	2.76 ± 1.03	4.76 ± 1.19	2.75 ± 1.54
NO_2-N	0.13 ± 0.13	0.53 ± 0.08	0.06 ± 0.05	0.34 ± 0.23	0.65 ± 1.59	0.24 ± 0.18
Chloride	43 ± 27	20 ± 14	52 ± 24	46 ± 38	61 ± 24	100 ± 32
Total Alkalinity	105 ± 52	131 ± 26	103 ± 20	116 ± 19	124 ± 32	99 ± 25
Total Hardness	141 ± 52	96 ± 40	102 ± 20	106 ±40	155 ± 64	127 ± 51
Production Cycle 2						
TAN	1.33 ± 0.60	2.04 ± 1.52	1.33 ± 1.00	3.16 ± 1.41	1.78 ± 1.07	3.54 ± 2.50
NO_2-N	0.12 ± 0.11	0.08 ± 0.06	0.08 ± 0.15	0.23 ± 0.34	0.12 ± 0.15	0.18 ± 0.15
Chloride	48 ± 21	33 ± 28	47 ± 10	39 ± 35	73 ± 22	54 ± 29
Total Alkalinity	97 ± 17	109 ± 29	101 ± 23	118 ± 28	93 ± 20	94 ± 27
Total Hardness	95 ± 15	100 ± 52	104 ± 19	76 ± 33	101 ± 15	91 ± 32

Table 12. Summary enterprise budgets for three treatments and two production cycles at (Farm 2) a Channel catfish farm in west Alabama, 2010 – 2013 (Multiple-batch MB, Single-batch SB, Owner O, Extension E).

	Treatment A (MBO)		Treatment B (SBE)		Treatment C (MBE)	
	Cycle 1	Cycle 2	Cycle 1	Cycle 2	Cycle 1	Cycle 2
Pond Size, acre	9.0	9.0	15.7	15.7	8.3	8.3
Pounds Harvested	78,209	98,586	108,986	87,956	62,272	94,424
Production Period, year	1.83	1.67	1.92	0.83	1.67	1.83
1. Gross Receipts						
Catfish sales[1]	87,324	88,270	96,041	97,225	67,876	102,922
2. Variable Costs						
Feed[2]	43,682	44,600	40,052	24,103	29,931	49,113
Labor & Management	3,465	3,465	6,045	6,045	3,196	3,196
Fingerlings	5,120	6,052	8,479	10,021	4,000	4,530
Harvest and transport[3]	3,910	4,929	5,449	4,398	3,114	4,721
Diesel (aerators, tractors)	33	462	276	276	1,138	185
Aeration Electrical	1,638	2,060	6,727	1,762	1,591	1,262
Chemicals	14	1,040	306	1,845	0	1,370
Interest on Operating Capital	4,050	4,383	4,713	3,391	3,008	4,506
Total Variable Costs	61,913	66,992	72,047	51,841	45,977	68,883
3. Income Above Variable Cost	25,411	22,278	23,994	45,384	21,900	34,039
4. Fixed Cost						
Land charge (not included)	0	0	0	0	0	0
Pond and Machinery depreciation	639	639	1,115	1,115	590	590
Taxes (land)	202	202	352	352	186	186
Interest on Equipment/Mach Purchases	138	138	241	241	128	128
Total Fixed Costs	1,628	1,981	2,841	2,841	1,502	1,502
5. Total Costs	63,541	68,973	74,887	54,682	47,479	70,385
6. Net Returns to Land	23,783	20,297	21,154	42,543	20,398	32,537

[1]Catfish sales receipts based on $1.09/lb

[2]Feed prices taken from industry average during each production cycle: Cycle 1: $380/ton; Cycle 2: $422/ton

[3]Harvest and transport cost based on $0.05/lb of fish

Table 13. Two Cycle Summary of Production data at (Farm 2) a Channel catfish farm in west Alabama, 2010 - 2013.

	Treatment A (MBO)	Treatment B (SBE)	Treatment C (MBE)
Pond size (acre)	9.0	15.7	8.3
Production Period (year)	3.50	2.75	3.50
Head stocked/acre	15,517	13,843	12,846
Average weight at stocking (lbs/1000)	52	60	56
Aeration (HP/acre)	1.11	1.91	2.41
Total lbs harvested (lbs)	176,795	196,942	156,696
Total lbs harvested /acre (lbs/acre)	19,644	12,544	18,879
Weighbacks (lbs)	16,764	4,481	2,010
Net Yield (lbs/acre)	18,845	11,717	18,169
Net Yield per year (lbs/acre/yr)	5,384	4,261	5,191
Average weight at harvest (lbs)	1.62	2.16	1.94
Survival (%)	58	42	76
Total feed fed (lbs)	441,284	325,031	390,298
Total feed fed/acre (lbs/acre)	49,032	20,703	47,024
Average daily feeding rate (lbs feed/acre/day)	57	28	59
Gross FCR	2.50	1.65	2.49
Net FCR	2.60	1.77	2.59

Table 14. Summary enterprise budgets for combined two production cycles and three treatments at (Farm 2) a Channel catfish farm in west Alabama, 2010 - 2013.

	Treatment A (MBO)			Treatment B (SBE)			Treatment C (MBE)		
	$	$/acre	$/lb	$	$/acre	$/lb	$	$/acre	$/lb
Pond size (acres)	9.0			15.7			8.3		
Pounds Harvested	176,795			196,942			156,696		
1. Gross Receipts									
Catfish sales	176,594	19,222	1.09	193,266	12,310	1.09	170,799	20,578	1.09
2. Variable Costs									
Feed	88,283	9,808	0.50	64,598	4,086	0.33	79,045	9,523	0.50
Management & Labor	6,930	770	0.04	12,089	770	0.11	6,391	770	0.04
Fingerlings	11,172	1,241	0.06	18,500	1,178	0.09	8,530	1,028	0.05
Harvest and transport	8,840	982	0.05	9,847	627	0.05	7,835	944	0.05
Diesel (aerators, tractors)	495	55	0.00	552	35	0.01	1,322	159	0.01
Aeration Electrical	3,698	411	0.02	8,489	541	0.04	2,854	344	0.02
Chemicals	1,054	117	0.01	2,151	137	0.01	1,370	165	0.01
Int. on Operating Capital	8,433	937	0.05	8,105	516	0.04	7,514	905	0.05
Total Variable Costs	128,905	14,323	0.73	123,888	7,891	0.63	114,860	13,839	0.73
3. Income Above Var.Cost	47,689	5,299	0.27	69,378	4,419	0.35	55,939	6,740	0.36
4. Fixed Cost									
Land charge (not included)	0	0	0	0	0	0	0	0	0
Pond and Machinery Depreciation	1,279	142	0.01	2,231	142	0.01	1,179	142	0.01
Taxes (land)	403	45	0.00	704	45	0.00	372	45	0.00
Int. - Pond Constr. Costs	1,651	183	0.01	2,265	144	0.01	1,197	144	0.01
Total Fixed Costs	3,609	401	0.01	5,681	362	0.03	3,003	362	0.02
5. Total Costs	132,514	14,724	0.75	129,569	8,253	0.66	117,863	14,438	0.75
6. Net Returns to Land	44,080	4,898	0.25	63,697	4,057	0.32	52,935	8,309	0.34

Table 15. Production data for three treatments (A=Multiple-Batch, Owner defined; B=Single-Batch, Extension defined; C=Multiple-Batch, Extension defined) from two production cycles at (Farm 3) a Channel catfish farm in west Alabama, 2010 - 2013.

	Treatment A (MBO)		Treatment B (SBE)		Treatment C (MBE)	
	Cycle 1	Cycle 2	Cycle 1	Cycle 2	Cycle 1	Cycle 2
Pond size (acre)	9.6	9.6	5.9	5.9	7.0	7.0
Production Period (year)	1.67	2.17	2.33	1.92	1.67	2.00
Head stocked/acre	6,320	20,047	7,237	10,404	6,956	6,956
Average weight at stocking (lbs/1000)	45	52	48	51	56	52
Aeration (HP/acre)	2.08	2.08	3.39	3.39	2.86	2.86
Total harvested (lbs)	97,654	85,434	70,986	50,000	66,914	44,728
Total harvested (lbs/acre)	10,172	8,899	12,032	8,475	9,559	6,390
Weighbacks (lbs)	2,054	1,721	782	0	948	178
Net Yield (lbs/acre)	9,887	7,864	11,687	7,941	9,161	6,182
Net Yield per year (lbs/acre/yr)	5,932	3,629	5,009	4,143	5,496	3,091
Average weight at harvest (lbs)	1.6	1.7	2.3	1.6	2.2	2.7
Survival (%)	99	27*	73	52	62	35
Total feed fed (lbs)	236,165	210,607	138,846	118,270	133,734	123,605
Total feed fed/acre (lbs/acre)	24,601	21,938	25,533	20,046	19,105	17,658
Average daily feeding rate (lbs feed/acre/day)	40	28	28	29	35	24
Gross FCR	2.42	2.47	1.96	2.37	2.00	2.76
Net FCR	2.49	2.79	2.01	2.52	2.09	2.86

*pond experienced a nitrite spike which resulted in heavy mortalities

Table 16. Summary enterprise budgets for three treatments and two production cycles at (Farm 3) a Channel catfish farm in west Alabama, 2010 - 2013 (Multiple-batch MB, Single-batch SB, Owner O, Extension E).

	Treatment A (MBO)		Treatment B (SBE)		Treatment C (MBE)	
	Cycle 1	Cycle 2	Cycle 1	Cycle 2	Cycle 1	Cycle 2
Pond Size, acre	9.6	9.6	5.9	5.9	7.0	7.0
Pounds Harvested	97,654	85,434	70,986	50,000	66,914	44,728
Production Period, year	1.67	2.17	2.33	1.92	1.67	2.00
1. Gross Receipts						
Catfish sales[1]	106,443	93,123	77,375	54,500	72,936	48,754
2. Variable Costs						
Feed[2]	44,871	44,438	26,381	24,955	25,409	26,081
Labor & Management	3,696	3,696	2,272	2,272	2,695	2,695
Fingerlings	4,854	17,321	3,416	5,525	3,895	4,258
Harvest and transport[3]	4,883	4,272	3,549	2,500	3,346	2,236
Diesel (aerators, tractors)	2,853	1,422	0	722	0	333
Aeration Electrical	2,096	2,505	4,759	4,139	2,686	2,365
Chemicals	646	304	466	190	437	432
Interest on Operating Capital	4,473	2,066	2,859	1,074	2,693	862
Total Variable Costs	68,371	76,024	43,701	41,376	41,161	39,262
3. Income Above Variable Cost	38,071	17,099	33,674	13,124	31,775	9,492
4. Fixed Cost						
Land charge (not included)	0	0	0	0	0	0
Pond and Machinery depreciation	682	682	419	419	497	497
Taxes (land)	215	215	132	132	157	157
Interest on Equipment/Mach. Purchases	840	840	516	516	612	612
Total Fixed Costs	2,429	2,429	1,493	1,493	1,771	1,771
5. Total Costs	70,801	78,454	45,193	42,869	42,933	41,033
6. Net Returns to Land	35,642	14,669	32,181	11,631	30,003	7,720

[1]Catfish sales receipts based on $1.09/lb

[2]Feed prices taken from industry average during each production cycle: Cycle 1: $380/ton; Cycle 2: $422/ton, and Cycle 3: $505/ton.

[3]Harvest and transport cost based on $0.05/lb of fish

Table 17. Two Cycle Summary of Production data at (Farm 3) a Channel catfish farm in west Alabama, 2010 - 2013.

	Treatment A (MBO)	Treatment B (SBE)	Treatment C (MBE)
Pond size (acre)	9.6	5.9	7.0
Production Period (year)	3.83	4.25	3.67
Head stocked/acre	26,367	17,641	13,911
Average weight at stocking (lbs/1000)	50	50	55
Aeration (HP/acre)	2.08	3.39	2.86
Total lbs harvested (lbs)	183,088	120,986	111,642
Total lbs harvested /acre (lbs/acre)	19,072	20,506	15,949
Weighbacks (lbs)	4,140	782	1,126
Net Yield (lbs/acre)	17,751	19,629	15,190
Net Yield per year (lbs/acre/yr)	4,631	4,619	4,143
Average weight at harvest (lbs)	1.65	1.92	2.43
Survival (%)	44	61	48
Total feed fed (lbs)	446,772	257,116	257,339
Total feed fed/acre (lbs/acre)	46,539	43,579	36,763
Average daily feeding rate (lbs feed/acre/day)	33	28	27
Gross FCR	2.44	2.13	2.31
Net FCR	2.62	2.22	2.42

Table 18. Summary enterprise budgets for combined two production cycles and three treatments at (Farm 3) a Channel catfish farm in west Alabama, 2010 - 2013.

	Treatment A (MBO)			Treatment B (SBE)			Treatment C (MBE)		
	$	$/acre	$/lb	$	$/acre	$/lb	$	$/acre	$/lb
Pond size (acres)	9.6			5.9			7.0		
Pounds Harvested	183,088			120,986			111,642		
1. Gross Receipts									
Catfish sales	199,566	20,788	1.09	131,875	22,352	1.09	121,690	17,384	1.09
2. Variable Costs									
Feed	89,309	9,303	0.49	51,336	8,701	0.42	51,490	7,356	0.46
Management & Labor	7,392	770	0.04	4,543	770	0.04	5,390	770	0.05
Fingerlings	22,174	2,310	0.12	8,940	1,515	0.07	8,153	1,165	0.07
Harvest and transport	9,154	954	0.05	6,049	1,025	0.05	5,582	797	0.05
Diesel (aerators, tractors)	4,275	445	0.02	722	122	0.01	333	48	0.00
Aeration Electrical	4,601	479	0.03	6,825	1,157	0.06	5,051	722	0.05
Chemicals	950	99	0.01	656	111	0.01	869	124	0.01
Int. on Operating Capital	6,539	681	0.04	3,933	667	0.03	3,555	508	0.03
Total Variable Costs	144,396	15,041	0.79	85,077	14,420	0.70	80,423	11,489	0.72
3. Income Above Var. Cost	55,170	5,747	0.30	46,797	7,932	0.39	41,266	5,895	0.37
4. Fixed Cost									
Land charge (not included)	0	0	0	0	0	0	0	0	0
Pond and Machinery Dep.	1,364	142	0.01	838	213	0.01	994	142	0.01
Taxes (land)	430	45	0.00	264	45	0.00	314	45	0.00
Int. - Pond Constr. Costs	1,385	144	0.01	1,706	262	0.01	1,197	144	0.01
Total Fixed Costs	4,859	506	0.03	2,986	506	0.02	3,543	506	0.03
5. Total Costs	149,254	15,547	0.82	88,063	14,926	0.73	83,966	11,995	0.75
6. Net Returns to Land	50,312	5,241	0.27	43,811	7,426	0.36	37,723	5,389	0.34

Table 19. Net returns for Treatment A for all farms and cycles.

	Net Returns			
	Total, $	$/acre	$/lb	$/acre/year
Farm 1				
Cycle 1	38,989	4,935	0.40	5,946
Cycle 2	33,320	4,218	0.33	3,171
Cycle 3	50,480	6,390	0.49	4,805
Average	40,930	5,181	0.41	4,641
Farm 2				
Cycle 1	23,783	2,643	0.30	1,444
Cycle 2	20,297	2,255	0.21	1,350
Average	22,040	2,449	0.26	700
Farm 3				
Cycle 1	35,642	3,713	0.36	2,223
Cycle 2	14,669	1,528	0.17	704
Average	25,156	2,620	0.27	775

Table 20. Net returns for Treatment B for all farms and cycles.

	Net Returns			
	Total, $	$/acre	$/lb	$/acre/year
Farm 1				
Cycle 1	16,806	2,585	0.17	1,820
Cycle 2	46,756	7,193	0.50	5,408
Cycle 3	31,858	4,901	0.46	5,905
Average	31,807	4,893	0.38	4,378
Farm 2				
Cycle 1	21,154	1,347	0.19	702
Cycle 2	42,543	2,710	0.48	3,265
Average	31,849	2,029	0.34	1,984
Farm 3				
Cycle 1	32,181	5,454	0.45	2,341
Cycle 2	11,631	1,971	0.24	1,027
Average	21,906	3,713	0.35	1,684

Table 21. Net returns for Treatment C for all farms and cycles.

	Net Returns			
	Total, $	$/acre	$/lb	$/acre/year
Farm 1				
Cycle 1	28,914	3,314	0.28	2,492
Cycle 2	(18,855)	(2,357)	(0.63)	(1,772)
Cycle 3	(7,249)	(906)	(0.12)	906
Average	(937)	17	(0.16)	542
Farm 2				
Cycle 1	20,398	2,458	0.33	1,472
Cycle 2	32,537	3,920	0.34	2,142
Average	26,468	3,189	0.34	911
Farm 3				
Cycle 1	7,720	1,103	0.17	660
Cycle 2	37,723	5,389	0.34	2,695
Average	22,722	3,246	0.26	884

Table 22. Best Management Practices implemented during the 2010 - 2013 research verification study and BMPs proposed after the study.

BMPs implemented during 2010 - 2013 verification study	BMPs proposed after 2010 - 2013 verification study
Stocking density of 6,750 fish/acre for hybrid and channel catfish	Stocking density of > 6,750 fish/acre for hybrid catfish
Maximum feed rate of 150 lbs/acre/day for hybrid and channel catfish	Increase feed rate to > 150 lbs/acre/day for hybrid catfish
Minimum aeration rate of 5 - 6 Hp/acre for hybrids Minimum aeration rate of 2 Hp/acre for channels	Minimum aeration rate of 3 - 4 Hp/acre for channel catfish

Figure 1. History of aeration (Hp/acre) on the commercial hybrid catfish farm evaluated in this study (1991- 2012).

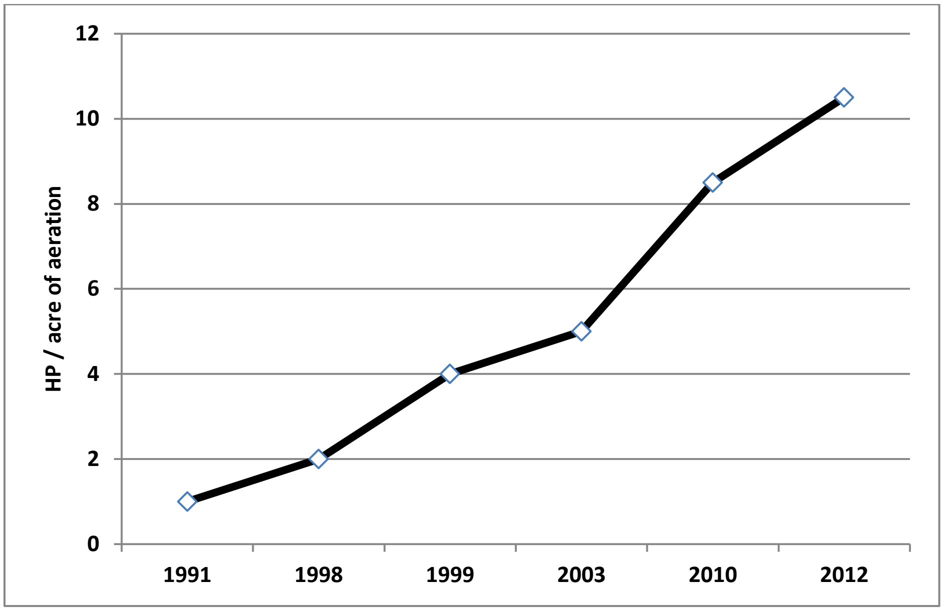


Figure 2. Temperature (°C) observed for Farm 1, Treatments A, B and C in research verification ponds in west Alabama (2010 - 2013).

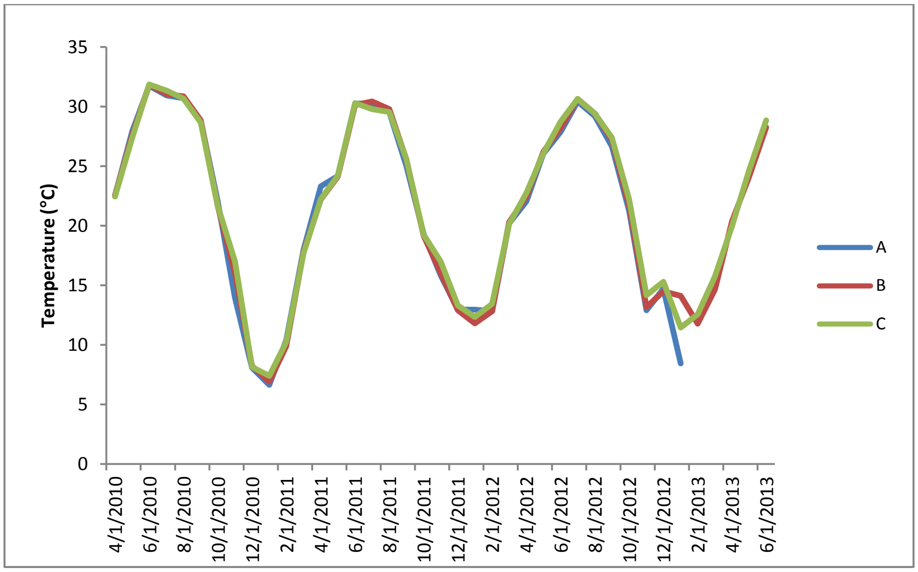


Figure 3. Temperature (°C) observed for Farm 2, Treatments A, B and C in research verification ponds in west Alabama (2010 - 2013).

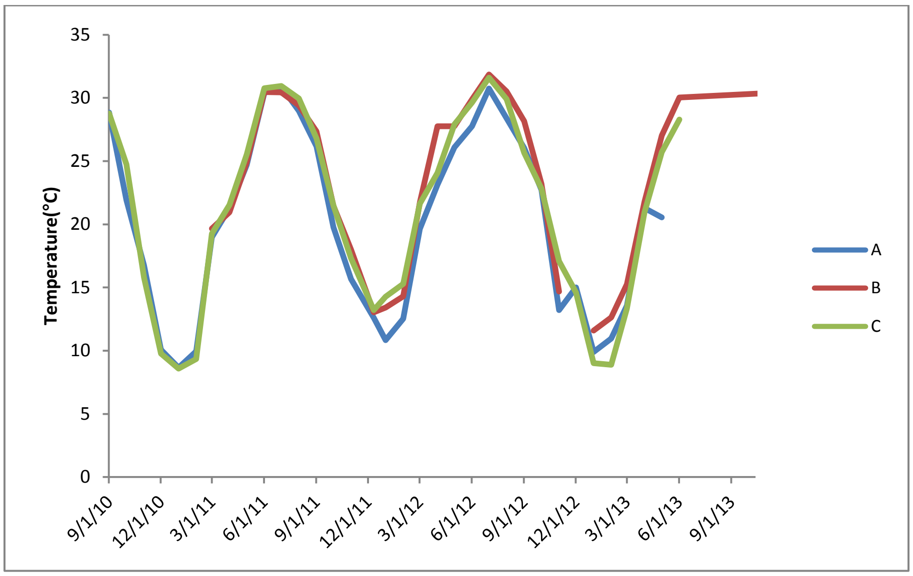
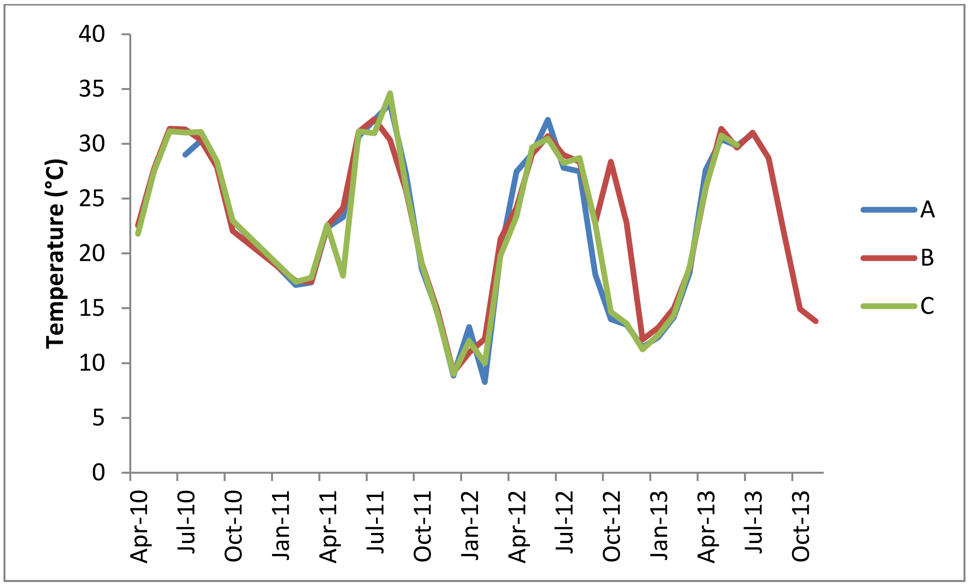


Figure 4. Temperature (°C) observed for Farm 3, Treatments A, B and C in research verification ponds in west Alabama (2010 - 2013).



Appendix 1. Monthly producer feed, tractor hours and chemical use form.

Feed

Oct_2013	2	5	6	Feed Cost, $/ton
1				
2	1385	1570	2035	
3				
4	1160	1290	1605	
5	1350	1525	1810	
6				
7	1325	1595	1830	
8				
9	1365	1590	2070	
10				
11	1390	1480	1880	
12	1290	1340	1655	
13				
14	1405	1665	1900	
15	1095	1325	1635	
16				
17	925	1405	1460	
18				
19	1095	1040	1360	
20				
21				
22	950	970	1310	
23				
24				
25				
26				
27				
28	815	1100	1105	
29				
30				
31	1105	1430	2195	

Tractor Hours

Oct_2013	2	5	6
1			
2			
3			
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11			
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Monthly Chemical Treatments (indicate lbs, ounces, or gallons) and cost per treatment ($)

Date	Pond	Copp. Sulf.	Diuron	Formalin	KMnO4	Salt	Gypsum	
14 oct 2013	5	65 lbs						$108.00
18 oct 2013	6	100 lbs						$166.00
20 oct	2	100 lbs						166.00