AGE DETERMINATION OF HYBRID CATFISH *Ictalurus punctatus* ♀ x *Ictalurus furcatus* ♂ AND CHANNEL CATFISH *Ictalurus punctatus* AND ECONOMIC EVALUATION OF THREE STRATEGIES TO CONTROL BIG FISH ON COMMERCIAL FISH FARMS

by

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Abstract

The number of catfish farms in west Alabama has declined from 250 to 71 over the 2003 to 2020 period. This has been due to a variety of reasons including foreign competition, changing consumer preferences, volatile market prices, increased production costs, and live fish that exceed the maximum desirable size of the processor (i.e., Big Fish). Processing plants desire a live fish within the 0.45 – 1.81 kg range and pay a premium price for this size. Catfish products coming from live fish > 1.81 kg cannot be processed nor sold easily by processing plants to their established markets. This results in farmers receiving a reduced price or no compensation at all for Big Fish. Catfish that routinely escape harvest remain in the pond over multiple production cycles resulting in Big Fish that cause financial and production issues, such as increased feeding that leads to higher costs and deteriorating feed conversion ratios. Additionally, it is likely Big Fish consume smaller catfish in the pond.

A two-year study was conducted to determine the age structure of different size classes of Channel Catfish *Ictalurus punctatus* and hybrid catfish *Ictalurus punctatus* ♀ x *Ictalurus furcatus* found in commercial production ponds and to economically evaluate management strategies to control Big Fish. In 2018, otoliths were collected from 287 catfish (153 Channel Catfish and 134 hybrid catfish ranging from 0.45 – 20.6 kg) from commercial catfish farms in west Alabama to determine their age and growth rates. Results of this study indicate that hybrid catfish had a faster growth rate compared to Channel Catfish at every age class sampled during this study. Channel Catfish and hybrid catfish could grow into Big Fish in 1.5 years and 2.6 years, respectively. Thus, it is recommended that both species should be

harvested after one production cycle when fish are approximately 2 years of age to avoid becoming Big Fish.

In year 2, a survey titled “2019 Big Fish Survey of the Alabama Catfish Industry” was sent to catfish producers in west Alabama. Its objective was to obtain information on catfish management strategies, production characteristics, and their methods of controlling Big Fish. Three management strategies used to control Big Fish based on survey results were analyzed economically. Each strategy had the goal of zeroing out fish in the pond before the next fish crop was stocked. The control strategies included 1) additional re-seinings of the pond after the initial harvest, 2) using rotenone after the pond has been completely harvested of premium sized fish, and 3) draining the pond to renovate its bottom into a smooth surface to improve seining efficiency.

Using survey data and partial budgeting techniques, we were able to establish the costs and benefits of each management strategy. The most cost-effective solution was to hire a custom seine crew for additional re-seining after the initial harvest and this approach will work well with single-batch (hybrid catfish) and multiple-batch (Channel Catfish) systems. The second least expensive approach was the use of rotenone after initial harvest and re-seining, and this approach will work with single-batch (hybrid catfish) systems only but is not viable for the multiple-batch (Channel Catfish) system. Multiple-batch systems have several batches of different age/size classes of fish in the pond simultaneously and use of rotenone would kill fish destined for future harvesting. The most expensive solution is the complete draining and re-working of the pond bottom, this approach will work well with single-batch (hybrid catfish) and multiple-batch (Channel Catfish) systems.

However, based on farmer interviews and survey results, we believe the best long-term solution forward in regards to Big Fish is to re-work pond bottoms as the opportunity arises and cash flow permits, to increase seining efficiency. In the meantime, additional re-seines to remove Big Fish missed from commercial harvests is a good management strategy to reduce and minimize Big Fish on farms. There is no easy solution to the Big Fish problem and a multi-faceted approach will be required to manage this issue.

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Chapter I

Introduction

Current Status of U.S. and Alabama Catfish Industry

Catfish farming is a major economic driver in rural communities across the southern United States. In 2018, catfish accounted for $360 million in live fish sales with Mississippi, Alabama, Arkansas, and Texas accounting for 95% of total sales (NASS 2018, USDA 2019). Catfish production in the U.S. peaked in 2003 with 300 million kg of catfish processed that year and began to decline steadily after 2003 due to foreign competition, increased production costs, changing consumer preferences, and increased feed costs. In 2014, the U.S. catfish industry processed 139 million kg which was a 54% decrease from 2003 (Hanson and Sites 2015).

Alabama is the second largest catfish producer in the U.S. accounting for 33% of all catfish produced and providing over 2,600 jobs that were mostly located in the poorest region of the state (Hanson et al. 2018; USDA 2019). Like other regions, Alabama has been affected by the high volatility common in catfish markets. One response to the volatile markets has been an overall reduction of total production acreage and the consolidation of many small farms into larger producers. For instance, in 2018 there were 71 catfish farms and 6,700 ha of water in Alabama compared to 250 farms and 10,117 ha of water in early 2003. The number of farms in operation declined approximately 70% during that time, but the total water ha in production only declined approximately 30%. This trend will likely continue due to the increasing economies of scale necessary to stay profitable in today's catfish industry (Hanson et al. 2018).

Traditional Farming Practices

In the early years of catfish farming, Channel Catfish *Ictalurus punctatus* were raised in a single-batch production system. Once the catfish reached market-size, farmers drained the pond and harvested all the fish before starting a new production cycle. The single-batch production system resulted in fewer unmarketable fish and more efficient feed conversion ratios (FCRs), but sometimes resulted in lower market prices when the market was flooded with catfish when farmers sold their catfish at roughly the same time (Engle and Pounds 1994). Farmers began implementing a multiple-batch production system so they could have fish ready to sell to the processing plant throughout the year (Engle and Pounds 1994). The switch from a single-batch to a multiple-batch production system allowed farmers to raise multiple crops of fish at the same time and use partial harvesting to avoid annual draining of the ponds. However, the unintended consequences of this has been fish missed during harvest which can grow to sizes unwanted by catfish processing plants, reducing the profitability of the farm (Bott et al. 2015). Hybrid catfish (*Ictalurus punctatus* ♀ x *Ictalurus furcatus* ♂) have been gaining popularity and comprise an estimated 50% of the farmed catfish produced in 2018 in the U.S. (Torrans and Ott 2018). They have faster growth rates, improved FCR, increased disease resistance, increased harvestability and are more tolerant of low dissolved oxygen levels compared to Channel Catfish (Dunham and Masser 2012). Hybrid catfish are typically cultured in a single-batch production system due to their faster growth rates and can quickly become oversized if they are missed during harvest (Dunham and Masser 2012). Hybrid catfish ponds are also rarely drained, but are drained more frequently than Channel Catfish ponds since farmers raise only one crop of fish at a time.

Commercial seines and live cars have been largely unchanged since their adoption in the 1960's. Traditional open ponds are harvested using a seine that is 305 to 427 m long and 2 to 4 m tall. The seine is constructed using 13-mm ropes on the top and bottom. Floats are attached to the top line to keep the net from dropping below the water level and it also has a weighted mudline to keep the net on the bottom of the pond. During harvest, the net is loaded onto a boat and laid around the perimeter of the pond to be seined from the deep end to the shallow end. The most widely used seines are built with 41-mm mesh to allow fish < 0.45 kg to grade through and remain in the pond (Minchew et al. 2007). With the adoption of multiple-batch production systems and the cost of pond renovation, farmers rarely drain and re-work their ponds. This is especially true in west Alabama and east Mississippi, where catfish farms are generally composed of watershed ponds rather than the levee ponds used in the Mississippi Delta and Arkansas. Levee ponds are easier to drain and re-work compared to watershed ponds. Some ponds have not been drained in decades; previous research has concluded that ponds under continuous culture for 15 years will have an average of 40 cm of sediment buildup in the bottom of the pond (Steeby et al. 2003). These older ponds become difficult to harvest with traditional seining equipment due to thick mud, sediment build-up, deep trenches, and uneven pond bottoms (Steeby et al. 2003). Poor pond conditions lead to a decrease in seining efficiency leading to fish evading the seine and escaping harvest. Escaped fish can be a bigger problem in hybrid catfish ponds than Channel Catfish ponds due to their faster growth rate and larger maximum size. Hybrid catfish can become Big Fish in one growing season (Bott et al. 2015; Mischke et al. 2017) and their growth rates increase dramatically in the second season of production if they are not harvested in a timely manner (Dunham and Masser 2012).

Some innovations have occurred including the addition of flexible bar-grading panels, a rolling mud line, and an electric seine. Hybrid catfish have a smaller head and a high dorsal ridge, compared to Channel Catfish, that can hang up in the live car netting or when they are grading through the seine (Dunham and Masser 2012). To counteract this problem, a new live-car was developed that incorporated flexible bar-grading panels instead of the traditional mesh live-car, allowing more efficient grading of hybrid catfish and fewer hang-ups (Kelly and Heikes 2013; Mischke et al. 2017).

Other attempts to redesign the seine have not been as successful. A study conducted by Minchew et al. (2007) developed a traveling mud line by attaching rubber rollers to the bottom of the seine. This allowed the seine to move through the pond quicker by reducing the amount of times the harvest boat has to push the net to dump the mud. This was not adopted by the industry because it increased the cost of the seine by 40% and the spaces in between the rollers could allow fish to escape during harvest. Other strategies to increase seining efficiency that have been investigated included the use of an electric seine to prevent fish from pushing on the net and escaping during harvest (Minchew et al. 2004). In this case, an electrical pulse was emitted intermittently at a range of 6 to 60 Hz throughout harvest of the pond. The electric seine was proven to be more effective at capturing fish compared to the traditional seine. However, safety concerns for the seine crew and concerns from the processing plant that the electric pulse would damage the fillet of the catfish have prevented the electric seine from being adopted by the catfish industry (Minchew et al. 2004).

Big Fish

In 2017 and 2018, catfish processing plants desired a live fish between 0.45 and 1.81 kg so the fish could be easily sold to their established markets and paid a premium price for fish within this size category (Hanson 2018). Fish beyond this range are too large for the mechanized fillet machines at the processing plant and have to be filleted by hand at a higher labor expense. During this study, there was an oversupply of catfish on the market causing processors to be more selective in the sizes of fish they would accept. Another major reason for Big Fish arises from the fact that ponds are not partially harvested as frequently as they should be due to the processor’s changing need for fish, relationships between farmers and the processor, and increasing vertical integration by processors. The latter leads to processors needing less fish from independent producers leaving farmers with fish they cannot sell.

Compounding this problem was a surplus of fish that exceeded the maximum size threshold for the processing plant in pond inventories for which processors were unable to find a viable market. These fish were designated Big Fish (> 1.81 kg) by the processing plants. For this reason, fish in excess of 1.81 kg typically received a reduced price from the processing plant (Wiese et al. 2006). In some instances, farmers received no compensation at all for fish designated as Big Fish by the processing plant (Creel et al. 2019). Big Fish are individually weighed and their collective weight is recorded by the plant to inform the farmer the weight of fish that will receive a reduced payment. The classification of Big Fish and the price paid by processors for these fish can vary from year to year and region to region depending on the supply and demand of catfish. Thus, it can be difficult for farmers to know what size fish processing plants will accept and/or pay a premium price. Big Fish can cause many problems for the farmer and will decrease the profitability of the farm if not properly managed. Currently, there is no information regarding the age Channel Catfish or hybrid catfish become Big Fish.

To date, there has been no research conducted to determine the age of Channel Catfish or hybrid catfish of different sizes cultured in commercial catfish ponds. Buckmeier et al. (2002) used otoliths to estimate the age of Channel Catfish from ponds at the Alabama Agricultural Experiment Station, Auburn University. However, Channel Catfish cultured in commercial catfish ponds likely have faster growth rates than those examined by Buckmeier et al. (2002) due to the optimal growing environment and the availability of a commercial feed ration. Further, intensive management, supplemental feeding, disease management, optimal dissolved oxygen levels, and optimal water quality should allow Channel Catfish to grow at faster rates in commercial catfish ponds than in natural systems.

Likewise, age and growth of hybrid catfish has not been adequately described in commercial catfish ponds. Blue Catfish have a faster growth rate (especially between ages 2 to 3) and can grow to larger sizes compared to Channel Catfish (Homer 2011). Evidence exists that hybrid catfish grow significantly faster than Channel Catfish in commercial settings (Bott et al 2015; Dunham and Masser 2012) but growth rates between these species has never been directly compared before in these systems.

Another contributing factor to the Big Fish problem is farmers often do not have an accurate estimation of pond inventory. Farmers also do not know the size distribution of fish in their ponds (Tucker et al. 1992) and in some instances what species are in their ponds. Multiple-batch systems allow for catfish of different age classes to be present in the pond at the same time, which can decrease the profitability of the farm compared to single-batch systems. Accurate estimations of pond inventory would allow producers to feed fish more efficiently and to better schedule harvest and stocking events leading to a more uniformity at harvest. To reduce the size variation of fish at harvest, Sudhakaran et al. (2012) researched using a trawl to estimate the inventory of catfish ponds. The use of a trawl was efficient in estimating the size distribution of catfish in the pond, but it failed to get an accurate inventory of the pond because the majority of the fish were able to swim to the other side of the pond to escape the trawl. Other methods to estimate the inventory of a pond include multiple seine pulls, the use of sonar, draining the pond, and observing fish during feeding.

An alternative way to prevent size variation within a pond is through graded partial harvest to eliminate the large fish from the pond. In Channel Catfish ponds, graded partial harvests with a University of Arkansas at Pine Bluff (UAPB) in-pond grader were effective in harvesting market sized fish while allowing subprime fish to grade through the seine and remain in the pond. Producers are commonly paid less by the processing plant if a large percentage of their pond harvest is undersized catfish, so the use of the UAPB in-pond grader would allow for less undersized fish to be harvested (Engle et al. 2011). However, this technology has not been widely adopted by the industry.

Due to their faster growth rate, hybrid catfish need to be harvested efficiently. Hybrid catfish that escape harvest can quickly become oversized and cost the farmer money when the processing plant pays a reduced price for fish of a larger suboptimal size. Graded partial harvest for hybrid catfish midway through the production cycle has been shown to reduce the amount of oversized fish at final harvest. However, this technique requires more labor and reduces the overall production in the pond, therefore it is likely not a profitable alternative for commercial producers (Mischke et al. 2017).

Big Fish decreased gross revenue of catfish sales during production years 2017 and 2018 by $12 million and $15 million, respectively (Hanson 2019). This represents a major inefficiency in the commercial catfish industry that severely impact the profitability of many farms. There are several management strategies farmers can use to control Big Fish including regular pond maintenance and more frequent harvests. More research needs to be conducted on the economic viability of different management strategies used by farmers to control Big Fish to determine a long-term management plan to increase the profitability of the farm.

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Chapter II

AGE DETERMINATION OF HYBRID CATFISH *Ictalurus punctatus* ♀ x *Ictalurus furcatus* ♂ AND CHANNEL CATFISH *Ictalurus punctatus* FROM COMMERCIAL FISH FARMS

Abstract

Processing plants prefer live catfish ranging from 0.45 – 1.81 kg because this is the size range they can readily sell to their established markets. Catfish routinely escape harvest and can become Big Fish (> 1.81 kg) in one to two production cycles after initial fingerling stocking. This presents many challenges to farmers and can reduce overall farm profitability if there are a significant percentage of Big Fish present at harvest. This study adds information on otolith age and growth of Channel Catfish and hybrid catfish raised in commercial aquaculture ponds to the literature. Critically, it adds insight into the age these Big Fish occur, the age that fish are typically harvested, and the size fish may become when they avoid harvest.

The study objective was to determine at what age Channel Catfish (*Ictalurus punctatus)* and hybrid catfish (*Ictalurus punctatus* ♀ x *Ictalurus furcatus* ♂) become Big Fish and are subject to a reduced price from the processing plant. In total, 153 Channel Catfish and 134 hybrid catfish were collected from commercial catfish farms in west Alabama during the summer of 2018. Otoliths were removed from each fish to determine the total length and weight at age for the two species.

Results indicate that farmers should harvest Channel Catfish and hybrid catfish before age 2.6 and 1.5, respectively, to avoid being designated as Big Fish by the processing plant. Both species were able to grow to Big Fish in one to two production cycles with hybrid catfish having a faster growth rate compared to Channel Catfish at every age class sampled during the study.

Introduction

Catfish are raised on a commercial scale using several culture systems. Open pond systems are the most commonly used system in Alabama due to their low production cost and ease of use compared to other production systems. Traditional open ponds average 4 ha in size and typically harvest 4,500-5,500 kg/ha of catfish during a typical production season (Brown et al. 2011). In 2016, Alabama farmers produced a total of 54 million kg across 7,061 ha (Hanson et al. 2018). The total kg produced was higher than the kg harvested but it is unknown how many fish escape the seine during harvest. There has been no prior research to determine the age of different size classes of catfish found in commercial catfish ponds or at what age catfish become Big Fish.

In natural systems, fisheries biologists often make management decisions based on the age of fish in a population. This information allows biologists to determine the health of a population, set creel limits, and determine survival and recruitment from year to year (Sakaris et al. 2006). Biologists previously aged fish with non-lethal structures such as scales and fin spines or rays, but these structures have been found to underestimate ages and are generally unreliable (Maceina et al. 2007). In contrast, otoliths have been found to reliably age a wide variety of fish species and are probably the most widely used structure today for most species (Homer et al. 2015). Otoliths are bony structures made of calcium carbonate and are located in the brain cavity of a fish. Otoliths help fish maintain balance while swimming and aid in the detection of sound waves in the water. Each year a fish will deposit an annular ring (growth ring) that can be counted to determine the age of a fish. There are three different pairs of otoliths: the sagitta, asterisci, and the lapilli. Although sagitta otoliths are most commonly used to age fish, lapilli otoliths are used when estimating the age of catfish because they are the biggest pair of otoliths in ostariophyseans (Long and Stewart 2010). For this project, otolith aging techniques commonly used by fisheries biologists in natural systems were employed to determine the age structure of catfish found in commercial aquaculture ponds. The objectives of this study were to (a) determine age and growth of commercially produced Channel Catfish *Ictalurus punctatus* and hybrid catfish *Ictalurus punctatus* ♀ x *Ictalurus furcatus* using otolith-aging techniques and (b) determine the age structure of Big Fish found in Channel Catfish and hybrid catfish ponds.

Materials and Methods

Study Site and Data Collection

Catfish were collected during the summer of 2018 following harvest events from commercial catfish farms in west Alabama and from the SouthFresh processing plant in Eutaw, Alabama. Catfish of various sizes were randomly collected from the conveyor belt following unloading of commercial hauling trucks prior to entering the processing area of the fish plant. Premium catfish were defined as fish between 0.45 and 1.81 kg and Big Fish were defined as fish > 1.81 kg. These thresholds were used by the processing plant to determine the prices paid to farmers. Additionally, a small number of targeted catfish collections were carried out using hook and line techniques at catfish farms to obtain some of the larger fish sampled in this study.

Catfish were collected and transported on ice to the E.W. Shell Fisheries Research Station, Auburn, Alabama. Upon arrival, species, total length, weight, and sex were recorded for each fish. A hacksaw was used to saw through the supraoccipital bone approximately 3 - 5 mm anterior to a line that would connect the two locked pectoral spines (Figure 2.1) to extract lapilli otoliths located in the posterior portion of the skull using the methods of Buckmeier et al. (2002). Attempts were made to collect both lapilli otoliths (Figure 2.2) from each fish to have a replacement otolith if one was damaged during future processing (Long and Stewart 2010). If at least one lapilli otolith was not found, fish were removed from the sample and not included in the analysis.

After sampling was completed, the full processor harvest reports from study ponds for two Channel Catfish ponds and four hybrid catfish ponds were collected. This data was obtained to determine the percent of premium and Big Fish from each species at harvest.

Otolith Processing

Otoliths were dried with a paper towel to remove excess membrane and placed into vials containing ethanol to dry for further processing. After the otoliths were allowed to dry for two to three weeks, one otolith per fish was mounted onto a microscope slide using crystal bond. Each otolith was positioned on the microscope slide with the posterior portion of the otolith facing down and held until the crystal bond hardened. Otoliths were ground until the nucleus was revealed using damp 600-grit sandpaper (Buckmeier et al. 2002). The ground otoliths were examined using a VistaVision Stereo Microscope with side illumination (VWR 89404-492, Radnor, PA) (Figure 2.3). Annuli were counted by two independent readers and disagreements were resolved by a consensus reading. If a consensus was not reached for the otolith, then the fish was removed from the sample (Maceina and Sammons 2006).

Statistical Analysis

Mean length and weight of age-2 to age-4 fish were compared between both species using an Analysis of Variance (ANOVA) (SAS Institute, 2016, Cary, North Carolina). Too few fish older than age-4 were collected to allow analysis. Total lengths and weights were $\log_{10}$ transformed to meet assumptions of normality. A Bonferroni correction for multiple comparisons was applied because multiple inputs were being analyzed at the same time.

Growth rate between species was compared using an Analysis of Covariance (ANCOVA) to test for differences in the slopes of $\log_{10}$ TL and $\log_{10}$ Weight vs age between the species (Sammons et al. 2019). All statistical analyses were conducted using Statistical Analysis System (SAS) Version 9.4.

Results

Channel Catfish sampled ranged from 382 – 725 mm TL and 0.54 - 4.87 kg; whereas, hybrid catfish ranged from 409 – 1,067 mm TL and 0.76 – 20.64 kg (Table 2.1). Hybrid catfish were larger than Channel Catfish at every age class sampled during the study with regards to both TL and average weight (Table 2.1; Figure 2.4). ANOVA analyses revealed total length at age and weight at age were statistically significant between Channel Catfish and hybrid catfish at all age groups tested ($p < 0.0001$) (Figure 2.5).

The average total length differences between Channel Catfish and hybrid catfish at ages 2, 3, 4, 5, and 6 were 71, 137, 167, 239, and 355 mm, respectively (Table 2.1). The average weight differences between Channel Catfish and hybrid catfish at ages 2, 3, 4, 5, and 6 were 0.97, 3.67 5.91, 8.12, and 13.01 kg, respectively (Table 2.1). Data indicated that after one production cycle (17 months) the average weight of Channel Catfish sampled was 1.52 kg in size which is below the 1.81 kg threshold for Big Fish (Table 2.1). Conversely, the average weight of hybrid catfish sampled was 2.49 kg after one production cycle (11 months) which is above the 1.81 kg threshold for Big Fish (Table 2.1). Channel Catfish missed after the first production cycle would grow an average of 1.17 kg during the second production cycle, while hybrid catfish would grow an average of 3.87 kg.

In total, 52,414 kg (72% of harvest) and 20,197 kg (28% of harvest) of Channel Catfish harvested were premium and Big Fish, respectively (Table 2.2). Conversely, 21,121 kg (74% of harvest) and 7,381 kg (26% of harvest) of hybrid catfish harvested were premium and Big Fish, respectively (Table 2.3). Hybrid catfish had a higher average weight compared to Channel Catfish with an average weight of 1.52 kg and 1.64 kg, respectively (Table 2.2; Table 2.3).

Total Length - Weight regressions were calculated for channel and hybrid catfish using the equation $W = aL^{b}$., where W is the weight, L is the length, and ‘a’ is a constant to be empirically determined. The TL-Weight regression equation for Channel Catfish was $W = 0.0000006L^{3.48}$ whereas the regression equation for hybrid catfish was $w = 0.000002L^{3.22}$ (Figure 2.6). The age-total length ($\log_{10}$) regressions for Channel Catfish and hybrid catfish were $y = 0.045x + 2.6158$ and $y = 0.0751x + 2.6015$, respectively (Figure 2.4). The age-weight regressions for Channel Catfish and hybrid catfish were $y = 0.1523x + 2.8642$ and $y = 0.2544x + 2.8646$, respectively (Figure 2.4).

Discussion

Results of this study demonstrate that fish of both species can reach a size in which they would be designated Big Fish rapidly, and fish in this size category are composed of multiple age groups older than age 2. Ideally, Channel Catfish and hybrid catfish are harvested at the end of one production cycle when the catfish are around two years of age. Studies have shown that at the end of one production cycle 16% of Channel Catfish will be missed at harvest (Engle et al. 2011) compared to 10% of hybrid catfish (Dunham and Argue 2011); albeit the number of studies on this topic are few in number. Based on production data from farms sampled during this study, Channel Catfish farms reported a higher percentage of Big Fish harvested compared to hybrid catfish farms. This could be explained by the increased seinability of hybrid catfish (Dunham and Argue 2011) and the usage of single-batch production systems on hybrid farms.

On average, Channel Catfish and hybrid catfish will grow an additional 1.17 and 3.87 kg, respectively, between age two and age three. After two production cycles, the average weights of Channel Catfish and hybrid catfish would be > 1.81 kg in size and would be considered Big Fish by a processing plant. Catfish ponds are typically harvested two times per year with two seine pulls per harvest. The oldest fish sampled during the study was a 7-year old Channel Catfish meaning that this particular fish was missed up to 24 times before being caught. Catfish missed at harvest present many challenges to farmers because these fish no longer have economic value and can even damage the seine during harvest. This will allow market-sized fish to evade harvest through the damaged seine. Further, they may prey on smaller fish, which will ultimately reduce the yield from that pond. For these reasons, it is imperative to harvest both species on time and to minimize the number of fish that escape harvest.

Channel Catfish are opportunistic predators and begin feeding primarily on other fish once they grow to 400 – 500 mm (Swingle 1954; McMahon and Terrell 1982). Fish were found to compromise 88% of the diet of Channel Catfish > 500 mm in Lake Oahe on the

Missouri River (Starotska and Nelson 1974). Similar research conducted by Schmitt et al. (2019) suggests that Blue Catfish in the Chesapeake Bay, Virginia began consuming primarily fish once they reached 500 mm, including cannibalization of smaller Blue Catfish. In natural systems, intraspecific competition can occur when there is a limited food source (Arujo et al. 2011) with some large fish specializing in piscivory to continue growing because their growth cannot be sustained by detritus or vegetarian diets (Greenlee and Lim 2011). Rivers that supported high densities of Blue Catfish were found to have a higher rate of cannibalization compared to rivers with lower densities (Greenlee and Lim 2011).

Catfish farmers believe that catfish missed during harvesting over multiple years may begin consuming the smaller catfish fingerlings. This could lead to a lower percentage of fingerlings reaching market size and a loss of potential income. However, this notion has not always been supported by previous research. A study conducted by Perschbacher (2001) at the University of Arkansas Pine Bluff in 0.04-ha ponds found no instances of cannibalism when 90 – 200 mm Channel Catfish fingerlings were stocked with 260 – 470 mm Channel Catfish. Larger Channel Catfish in the pond exhibited predatory behaviors by attacking and biting the fingerlings in the pond, but they could not eat the fingerlings due to their mouth gape. Conversely, Unprasert et al. (1999) reported numerous instances of cannibalism in tanks and ponds when fingerlings were stocked with Channel Catfish weighing 374 g. Additionally, the larger catfish were observed chasing the smaller catfish into the shallow water of the pond but cannibalization could not be confirmed due to water turbidity.

There has been limited published research conducted on the foraging habits of hybrid catfish in commercial ponds due to their relatively new introduction to the catfish industry. A study conducted by Torrans and Ott (2016) stocked fingerings with market-sized fish that were missed from the first production cycle. There were no reported cases of cannibalism of the hybrid catfish fingerlings, and mortality rates were similar to fingerlings stocked in ponds without missed catfish from the previous production cycle. However, this study only focused on market-sized fish and did not research the cannibalistic behaviors of larger fish, which are frequently found in commercial catfish ponds and are more likely to be piscivorous. Thus, it is likely that Big Fish could begin feeding on the smaller catfish in the ponds once they reach a certain size as seen in natural populations.

During this study, Channel Catfish and hybrid catfish routinely grew to > 400 mm and > 1.81 kg in 2.6 years and 1.5 years, respectively. The largest hybrid catfish collected ranged in size from 914 – 1,067 mm and 15.44 – 20.64 kg and were four to six years old, highlighting their impressive growth rate in commercial catfish ponds (Figure 2.7; Figure 2.8). This size is well above the threshold of when catfish in natural populations are predicted to become piscivores. Catfish in commercial catfish ponds likely cannibalize smaller congeners during the winter, when the catfish are fed a restricted ration and sometimes held off feed throughout the winter (Sealey et al. 1998). More research needs to be conducted on the dietary patterns of oversized Channel Catfish and hybrid catfish found in commercial catfish ponds to determine their feeding preferences and the possible occurrence of cannibalization.

The oldest Channel Catfish sampled during the study were almost exclusively harvested from hybrid only ponds. The farmers indicated that Channel Catfish had not been raised on the farm for 10 years. Both farmers zeroed-out the pond by seining multiple times before stocking the hybrid catfish fingerlings. However, some of the Channel Catfish were able to escape the seine and continued to remain in the pond when the farm was switched to raising exclusively hybrids. In total, four Channel Catfish aged six to seven years old were sampled from these farms. These four fish were female and full of eggs which could indicate a breeding population of Channel Catfish remaining in the pond that the farmers did not know existed. Additionally, a hybrid catfish weighing 14.60 kg was harvested during the study from an exclusively Channel Catfish farm that had never raised hybrid catfish. This fish could have entered the pond by a mistake at the hatchery or from a bird transporting it from a neighboring farm.

Due to increasing production costs, foreign competition, and volatile prices, producers need to intensify production to remain profitable. Alternative production systems have been gaining popularity in recent years, including intensively aerated ponds (Bott et al. 2015; Kumar 2016), in-pond raceway systems (Brown et al. 2011), and split-ponds (Kumar 2016). Each alternative system increases operating costs and risks compared to traditional open pond systems, but can lead to increased yields (Kumar 2016). All three alternative production systems used by catfish farmers are easier to harvest than traditional earthen ponds which would lead to a more uniform harvest with lower escapement. More research needs to be conducted on how alternative production systems influence the percentage of Big Fish harvested from commercial catfish farms.

Conclusions

Big Fish in catfish ponds create problems for farmers who raise both Channel Catfish and hybrid catfish and can negatively impact farm profitability if not properly managed. Channel Catfish were able to grow to > 1.81 kg in 2.6 years while hybrid catfish could exceed 1.81 kg in 1.5 years if they are missed at harvest. Big Fish likely prey on the smaller catfish in the ponds once they grow to a certain size. There are several management tools farmers can use to control Big Fish including regular pond maintenance and more frequent harvests. More research needs to be conducted on the economic viability of different management strategies used by farmers to control Big Fish to determine a long-term management plan to increase the profitability of commercial catfish farms.

Table 2.1. Length and weight information of Channel Catfish and hybrid catfish collected for aging analyses from a processing plant and commercial catfish farms in west Alabama.

Species	Age	N	TL Range (mm)	Mean TL (mm)	Weight Range (kg)	Mean Weight (kg)
Channel	2	51	382 – 690	493	0.54 – 4.13	1.52
	3	72	391 – 725	588	0.65 – 4.87	2.69
	4	21	582 – 722	649	2.17 – 4.25	3.38
	5	4	670 – 710	684	3.22 – 4.05	3.68
	6	3	644 – 671	661	3.05 – 3.95	3.46
	7	2	677 – 713	695	3.69 – 4.33	4.01
Hybrid	2	96	409 -787	564	0.76 – 7.56	2.49
	3	23	502 – 978	725	1.65 – 16.54	6.36
	4	10	632 – 985	816	2.94 – 15.44	9.29
	5	1	-	923	-	11.80
	6	4	930 – 1,067	1,016	11.94 – 20.64	16.47

Table 2.2. Summarized commercial harvest reports for two Channel Catfish farms sampled during the study.

Pond	Weight class	N	Total weight (kg)	Mean weight (kg)	% of harvest
Pond A	Premium[1]	18,984	34,766	0.82	81
	Big Fish[2]	1,658	8,162	2.23	19
Pond B	Premium[1]	12,449	17,648	0.64	59
	Big Fish[2]	2,301	12,035	2.37	41
Total	Premium[1]	31,433	52,414	0.73	72
	Big Fish[2]	3,959	20,197	2.30	28

[1] *Premium: catfish weighing between 0.45 – 1.81 kg*
[2] *Big Fish: catfish weighing > 1.81 kg*

Table 2.3. Summarized commercial harvest reports for four hybrid catfish farms sampled during the study

Pond	Weight class	N	Total weight (kg)	Mean weight (kg)	% of harvest
Pond A	Premium[1]	4,115	5,055	1.23	68
	Big Fish[2]	1,038	2,349	2.26	32
Pond B	Premium[1]	3,297	3,932	1.19	72
	Big Fish[2]	666	1,525	2.29	28
Pond C	Premium[1]	5,469	6,213	1.14	68
	Big Fish[2]	1,323	2,909	2.20	32
Pond D	Premium[1]	7,692	5,921	0.77	91
	Big Fish[2]	262	598	2.28	9
Total	Premium[1]	20,573	21,121	1.03	74
	Big Fish[2]	3,289	7,381	2.24	26

[1] Premium: catfish weighing between 0.45 – 1.81 kg

[2] Big Fish: catfish weighing > 1.81 kg

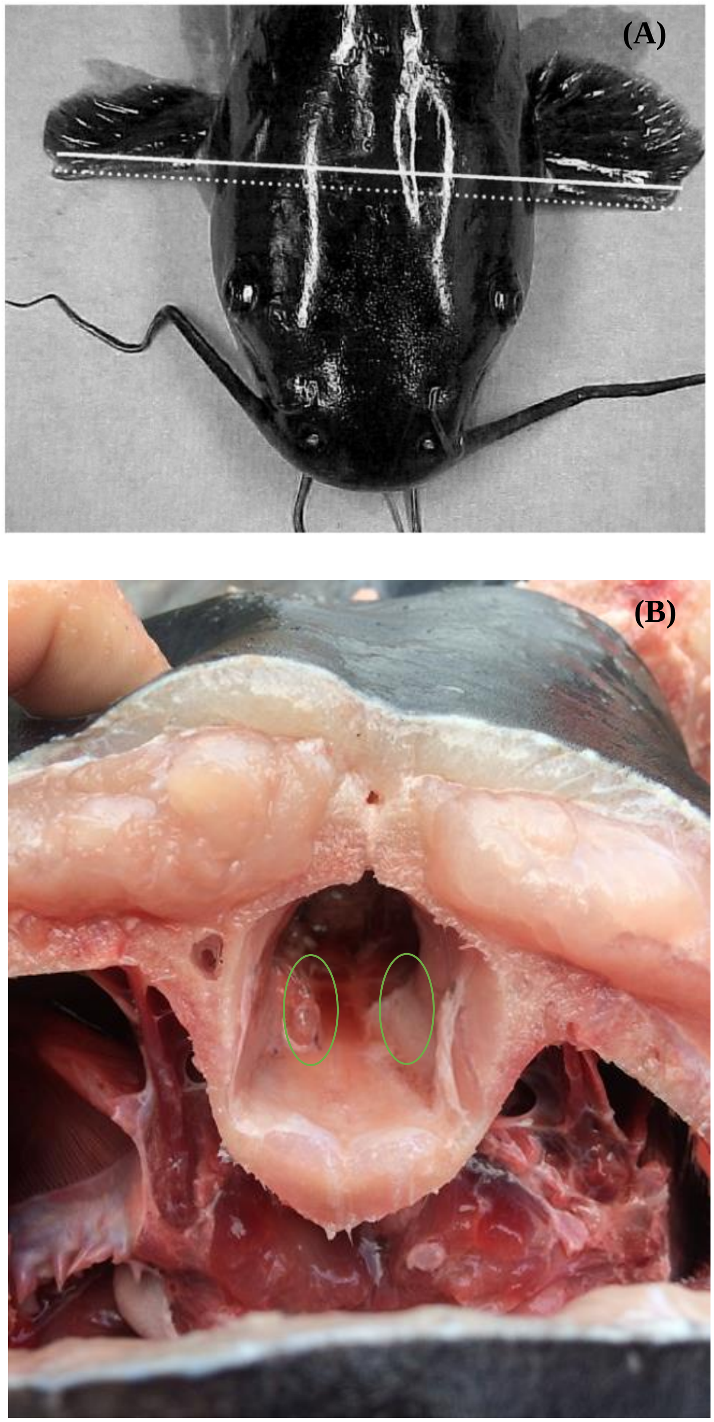

Figure 2.1. Extracting otoliths for aging analysis. **(A)** Proper cutting position on a catfish for otolith extraction (Source: Buckmeier et al. 2002), **(B)** Approximate otolith position in the posterior portion of the skull for a large hybrid catfish.

FIGURE 2.2. Otolith extracted from a 15 kg hybrid catfish.

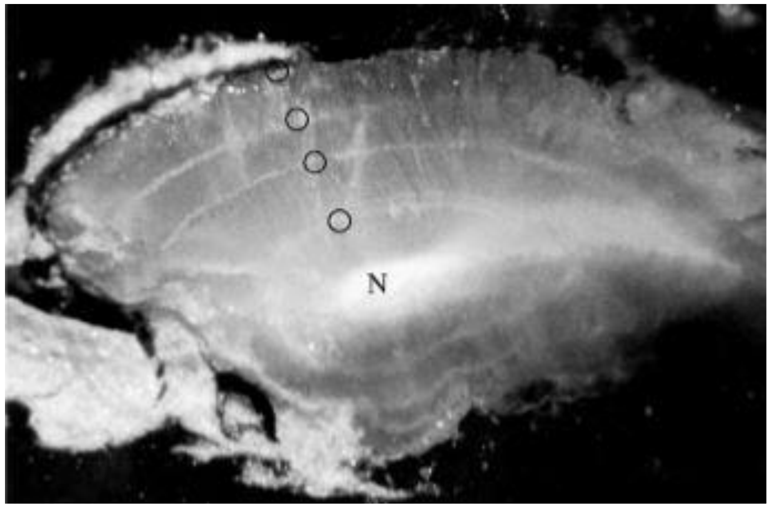

Figure 2.3. Otolith rings viewed from underneath a microscope (Source: Buckmeier et al 2002).

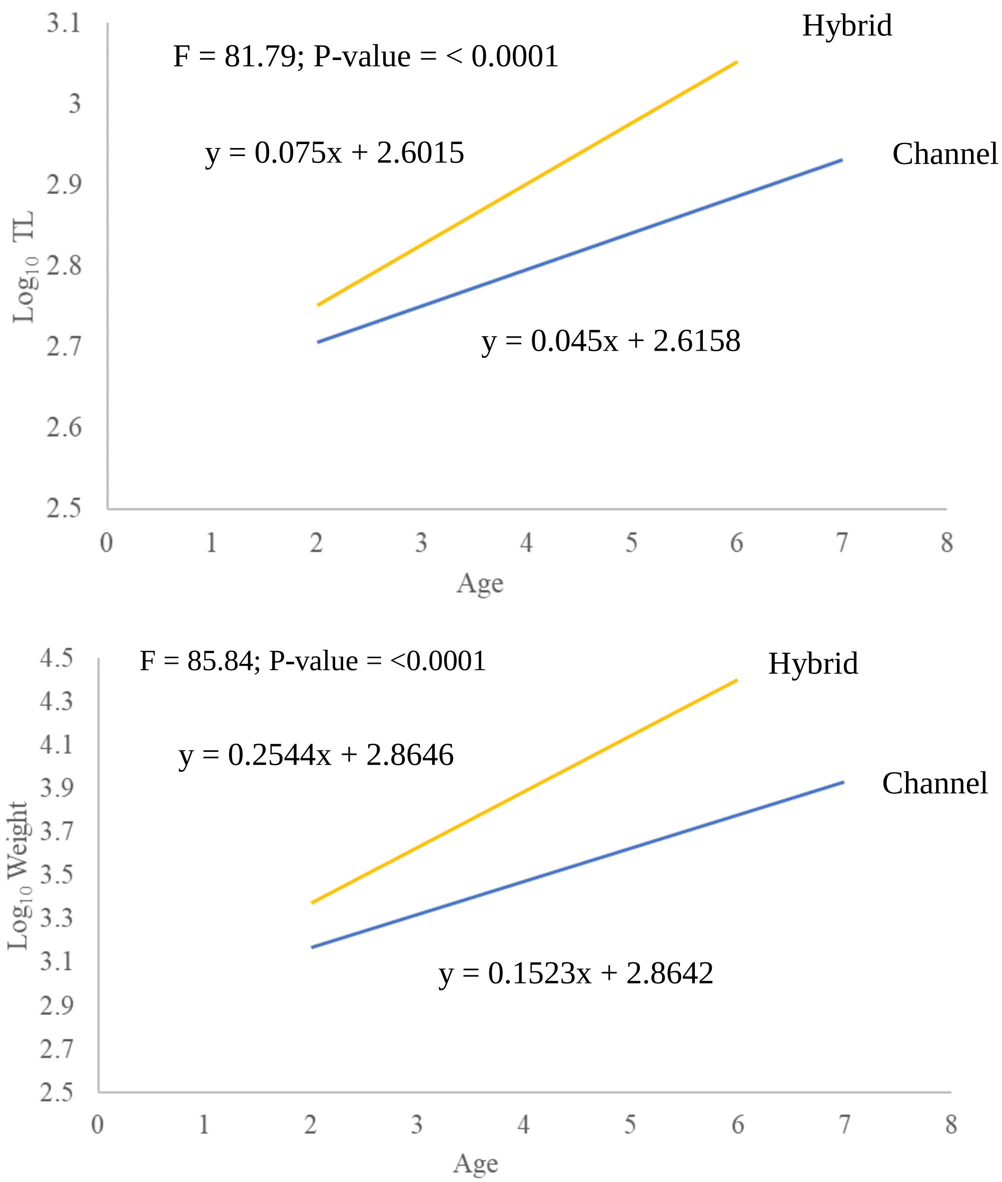

Figure 2.4. Growth of Channel Catfish and hybrid catfish collected from commercial catfish ponds in west Alabama. Differences in the slopes were compared between species using an Analysis of Covariance.

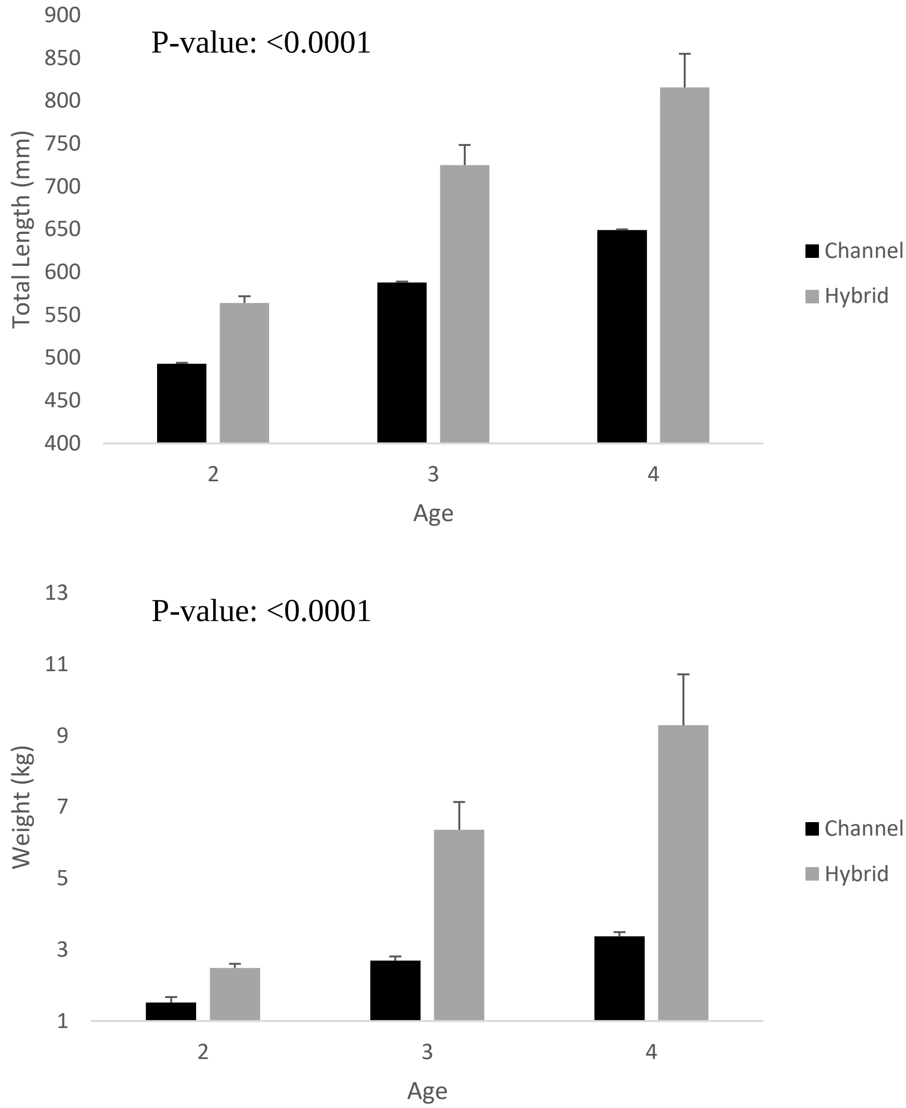

Figure 2.5. Mean total length and weight of age 2 - 4 Channel Catfish and hybrid catfish collected from a processing plant and commercial catfish farms in west Alabama.
**ANCOVA analysis was limited to fish aged 2-4 due to insufficient numbers of fish collected at older ages*

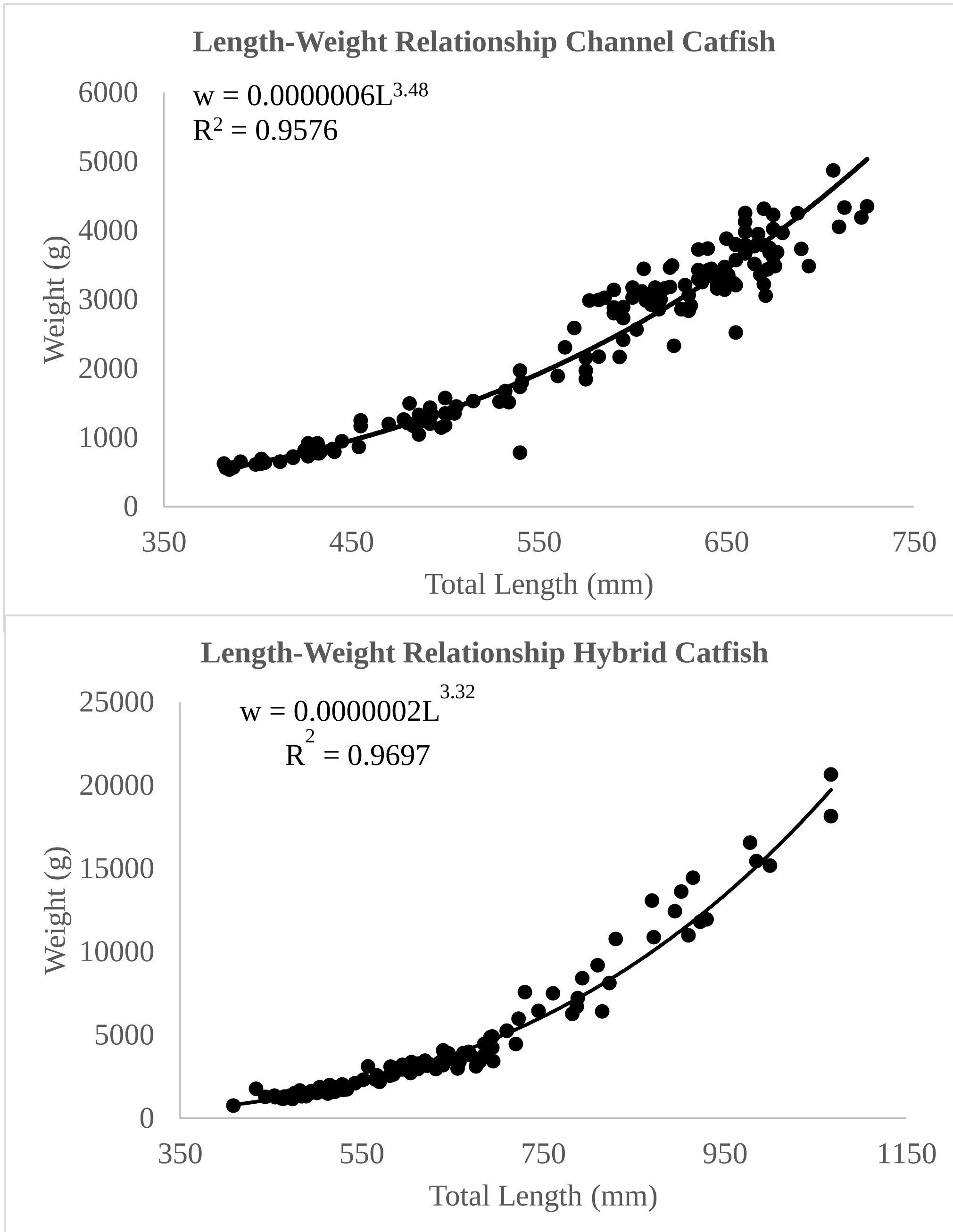

Figure 2.6. Length-weight relationships for Channel Catfish and hybrid catfish collected from commercial catfish ponds in west Alabama.

Figure 2.7. Largest specimens of hybrid catfish collected from commercial catfish ponds in west Alabama. **(A)** Length: 914 mm; Weight: 15.44 kg; Age: 4 years old, **(B)** Length: 1,067 mm; Weight: 18.14 kg; Age: 6 years old **(C)** Length: 1,067 mm; Weight: 20.64 kg; Age: 6 years old

Figure 2.8. Size comparison of an 18.14 kg hybrid catfish (6 years old) to a market-sized hybrid catfish (2 years old) sampled from the same pond.

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Chapter III

ECONOMIC EVALUATION OF THREE STRATEGIES TO CONTROL BIG FISH ON COMMERCIAL CATFISH FARMS

Abstract

Catfish routinely escape harvest and can become Big Fish (> 1.81 kg) in 1 – 2 production cycles. Big Fish present many challenges to farmers and can reduce overall profitability of a farm if there are a significant percentage of them present at harvest. In U.S. production years 2017 and 2018, Big Fish decreased gross revenue from catfish sales by $12 million and $15 million, respectively. A survey, "2019 Big Fish Survey of the Alabama Catfish Industry" was mailed to 73 catfish producers in Alabama to determine their management strategies, production characteristics, and methods utilized to control Big Fish in their ponds. In total, 53 surveys were completed (73% return rate) and analyzed. From the survey and farmer interviews, three Big Fish control strategies were developed for economic evaluation through partial budgeting. Each strategy focused on zeroing out fish in the pond before starting a new production cycle. The three strategies evaluated were 1) hiring a custom seiner for additional seining, 2) using rotenone after additional re-seines, and 3) renovating the pond to improve seining efficiency. Partial budgets were developed for the three control strategies to examine the costs and benefits of each strategy.

Hiring a custom seiner for additional seining was the least expensive management strategy to implement and is the best option for farmers if money is a limiting factor. This approach will work well with single-batch (hybrid catfish) and multiple-batch (Channel

Catfish) systems. The second least expensive management strategy was the use of rotenone. This approach will work with single-batch (hybrid catfish) systems only and is not viable for the multiple-batch (Channel Catfish) system. Draining the pond and re-working the pond bottom was the most expensive, but was also the best long-term solution to controlling Big Fish in catfish ponds because it completely zeros-out the pond and improves seining efficiency. Over the long-term this would allow greater harvest of premium sized fish. Pond renovation provides smooth pond bottoms and increases seining efficiency and needs to be done every 10 to 15 years, making it a good long-term approach. It is recommended that a farm renovate 10% of their ponds annually to maintain long-term harvesting efficiency. This approach will work well with single-batch (hybrid catfish) and multiple-batch (Channel Catfish) systems.

Introduction

Fish that exceed optimal market size for fish processors are commonly termed Big Fish. In Alabama, a Big Fish was considered a fish greater than 1.81 kg in 2017 and 2018 according to the pay structure of the Alabama processing plants. Big Fish have had a negative impact on farm profitability for many years. Both farmers and processors have been unable to find a viable long-term solution to this problem. Processing plants cannot readily sell fillets from large catfish causing them to pay a reduced price and sometimes no compensation at all for Big Fish. Catfish become oversized when they escape harvest and stay in the pond year after year. These fish reduce the overall profitability of a farm by consuming more feed than the market sized fish and can prey on the smaller fish.

In 2017 catfish processing plants in the U.S. processed 128 million kg of premium sized fish and 14 million kg of Big Fish processed. Farmers were paid $2.47 for premium sized fish and $1.57 per kg for Big Fish (Hanson 2018). In 2018 there were 143 million kg of premium sized fish and 16 million kg of Big Fish processed, and farmers were paid $2.19 and $1.23 per kg for each, respectively (Hanson 2019). This resulted in gross revenues to U.S. catfish farmers of $338 million in 2017 and $332 million in 2018. Big Fish only accounted for 9-10% of the amount of fish purchased in these years, but negatively impacted farm profitability for many commercial producers (Hanson 2018; 2019). If all fish purchased had been premium sized it would result in a $12 and $15 million increase to gross revenue for catfish producers in 2017 and 2018, respectively (Hanson 2019). This loss does not take into account the increased production costs associated with oversized fish or the weight of Big Fish that farmers received no money for, making the true cost of Big Fish in reality much higher.

Farmers have implemented various management strategies to reduce the quantity of Big Fish and increase profitability. Management strategies used by farmers range from lethal take of individual Big Fish (using firearms from the feed truck), using gill nets with large mesh sizes to selectively harvest Big Fish, renovating the ponds, and multiple re-seines after harvest (Engle et al. 2011; Dunham and Argue 2011). Some management strategies are likely more effective than others at controlling Big Fish but little research exists to determine the most economically efficient strategies to control Big Fish. Despite concerted and targeted efforts by farmers, fish are usually still missed at harvest, even after multiple re-seines, and could grow to Big Fish by the next production cycle (Bott et al. 2015).

Rotenone is a commonly used piscicide to kill undesirable fish species in ponds, lakes, and rivers. It is extracted from the roots and stems of several plants in the family Fabaceae and kills fish by inhibiting cellular respiration. Rotenone works best when the water temperature is between 7-24^{o} C and is more cost effective when water levels are lowered prior to application (Wynne and Masser 2010). Zeroing-out ponds with rotenone has not been a widely adopted practice by the catfish industry but has been used on a limited basis.

In the early years of catfish farming, farmers predominantly grew catfish in a single-batch production system. The pond was drained and all fish were harvested at the end of the production cycle ensuring all fish were in the premium sized category. Catfish farmers changed to using a multiple-batch production system to have fish ready to sell throughout the year (Engle and Pounds 1994), which means that the majority of ponds on commercial catfish farms in west Alabama have not been drained in decades. Steeby et al. (2003) found non-drained catfish ponds led to pond erosion that decreased seining efficiency. Uneven pond bottoms allow fish to escape harvest and remain in the pond where they can quickly grow to Big Fish. This lack of pond draining in west Alabama is partially due to the nature of the watershed ponds used by farmers in this region. The watershed ponds constructed in west Alabama are often irregular in shape, sometimes quite deep (6-7 m at deep end), and often without any drain structure. Watershed ponds are an efficient way to harvest water off the surrounding watershed to fill ponds. Wells in west Alabama require a depth of 600 feet and thus are expensive to drill and operate.

Enterprise budgets and partial budgets are vital tools to farmers to analyze the profitability of the farm. There are five main parts to an enterprise budget. The first part of an enterprise budget is total revenue for the farm. The second part consists of the expected variable costs the farm would incur throughout the year including feed costs, fingerling costs, electrical costs, chemical costs, etc. The third part of an enterprise budget consists of the fixed costs for the farm including land charge, taxes, depreciation, etc. The fourth part of an enterprise budget consists of the total costs which is the sum of the variable and fixed costs for the farm. The final section of an enterprise budget is the net return section, which is calculated by subtracting the total costs from the total revenue (Engle 2010).

Analyzing possible changes on a farm requires a different budgeting technique, namely a partial budget, which uses information obtained from enterprise budgets to evaluate potential changes daily farm management. Most adjustment decisions affect revenue and expenses. Partial budgeting is a convenient and practical method for analyzing the profit potential of these partial changes in the overall farm management plan (Kay et al. 2004). A partial budget only enters dollars for additional benefits and costs. The benefit and cost sections each have two subsections of additional costs and additional benefits. The two subsections of benefits are 'additional revenue' and 'reduced cost' and when totaled they are the total additional benefits. The two subsections of costs are 'reduced revenue' and 'additional cost' and when totaled are the total additional costs. Total additional costs are subtracted from total additional benefits to calculate the net benefit due to the management change under consideration. In this study, the change relates to adopting Big Fish control strategies. According to partial budget guidelines, a farmer would implement the management strategy if the net benefit due to the change were positive (Kay et al. 2004; Engle 2010; Kumar and Gaunt 2020), though additional risk and capital requirements should be carefully evaluated as well.

The objectives of this study were to (a) characterize west Alabama catfish producer production data for 2017 and 2018, (b) develop enterprise budgets based on producer survey results, (c) evaluate management strategies used on west Alabama catfish farms to control Big Fish, and (d) use partial budgets to economically evaluate management strategies to control Big Fish.

Materials and Methods

Study Area and Data Collection

For this project, a survey titled "2019 Big Fish Survey of the Alabama Catfish Industry" was administered to the catfish producers in west Alabama (Appendix A). The information obtained from the surveys was used to characterize the production parameters of farmers in west Alabama and to determine the methods utilized to control Big Fish in their ponds. This survey sought to investigate the methods and strategies farmers use to reduce occurrence of Big Fish and increase their profits. Catfish farmers were notified of the survey during the annual Alabama Catfish Update Meeting (Demopolis, AL) in December 2018.

The survey consisted of 54 questions broken up into four sections (Appendix A). The questions in section one gathered information on the scope of the Big Fish problem and what management strategies were being implemented to control the issue. Section two of the survey investigated whether a farmer zeroed out their ponds before starting a new production cycle and how they scheduled pond renovation and maintenance. Section three gathered information on stocking and harvesting procedures for production years 2017 and 2018 and asked them to project this information for 2019. The final section asked about general farm information (Appendix A). The developed survey was submitted to the Auburn University Institutional Review Board for their approval to ensure respondent confidentiality and was approved in March 2019.

Farmer names and addresses were provided by the Alabama Fish Farming Center, Greensboro, Alabama. The survey packets contained a cover letter explaining the importance of the study survey and asking for their participation (Appendix A). A pre-addressed return envelope was included to facilitate return of the completed survey. Mail survey techniques used the Dillman (1978) "Total Design Method" to ensure a good return rate. In March 2019, 73 surveys were mailed out to catfish farmers in Alabama. After two weeks, non-respondents were sent a reminder postcard asking them to complete and return the survey. If there was still no response after two additional weeks, non-respondents were sent a second complete survey packet. Lastly, non-respondents were contacted via telephone and asked to fill out the survey either over the phone or in person. Survey data was entered into a Qualtrics database and compiled into total and average values to identify trends.

Enterprise budgets were developed for 2017 and 2018 from production data obtained from the survey and augmented with prior Alabama enterprise budget variable items when absent from survey results. Budgets were developed as a baseline that would be used when developing partial budgets analyzing different Big Fish control methods on west Alabama catfish farms. Specifically, three management strategies for controlling Big Fish investigated were 1) hiring a custom seiner for additional re-seines after the normal harvest 2) using rotenone to zero-out the pond before starting a new production cycle, and 3) renovating the pond to improve seining efficiency.

Separate partial budgets were developed for Channel Catfish and hybrid catfish in each of the three aforementioned management strategies. This allowed for analysis of the additional costs and benefits the farmer would incur when implementing each strategy. Only farms that exclusively raised Channel Catfish or hybrid catfish were used in this analysis because farmers raising both species did not break down their total kg harvested by species. In all, six partial budgets were developed.

Farms were grouped by harvesting option to see if there was a relationship to the percentage of Big Fish. There were four harvesting options for Alabama producers: 1) farms using their own harvest crew exclusively, 2) farms using the processor's harvest crew exclusively, 3) farms hiring custom seine crews exclusively, and 4) farms using a combination of processor harvest crews and hired custom seine crews. It is common practice among farmers in west Alabama to hire a custom seine crew for additional seining after the initial harvest by the processer harvest crew. To compare the percentage of Big Fish and average total kg harvested, farm survey data was sorted by farm size (0-40 ha, 40-81 ha, 81-202 ha) and by average number of seine pulls per pond per year (N= 2, 3, 4, or 5).

The hybrid and Channel Catfish partial budgets for additional re-seines were based on harvest data provided by a processing company and custom seining data obtained from a west Alabama farmer. The processor harvest crew harvested 28,000 kg of hybrid catfish from a 4.5 ha pond at the end of the production cycle. The farmer then hired a custom seine crew for two additional re-seines of that pond. The custom seiners harvested an additional 13,600 kg from the pond and sold at the weighted average price of $2.20/kg for the hybrid catfish and $2.10/kg for Channel Catfish (Hanson 2018).

The difference in weighted selling prices for the two species was due to survey results showing different percentages harvested for each species. Seventy-five percent of Channel Catfish harvested were premium sized and 25% were Big Fish. To obtain the weighted prices, these percentages were multiplied by the average kg produced per farm (796,604 kg), and these products were multiplied by respective premium ($2.33/kg) and the Big Fish ($1.40/kg) prices. This product was then divided by the total kg produced to obtain the Channel Catfish weighted price of $2.10/kg. In a like manner, the hybrid catfish weighted price was calculated. Eighty-seven percent of hybrid catfish harvested were premium sized and 13% were Big Fish; the average kg produced per farm (415,498 kg), and their products multiplied by respective premium ($2.33/kg) and Big Fish ($1.40/kg) prices. This product was then divided by the total kg produced to arrive at the $2.20/kg weighted hybrid catfish price.

The additional revenue in the partial budgets was calculated by multiplying the additional harvest quantity by the weighted fish price to obtain the additional catfish revenues from the re-seines. Re-seining a 4.5-ha pond takes an average of 6 hours for harvest and transport and two separate re-seines occurred, so 12 hours of custom harvest crew work was required. Custom harvesters charge $150/hour (personal communication from custom seine crews in west Alabama). Custom re-seine harvesting costs were calculated by multiplying the hours to re-seine the pond by their cost per hour. Additional benefits and additional costs were summed and costs were subtracted from benefits to obtain the net benefit from this change in management.

Channel Catfish and hybrid catfish partial budgets were developed for applying rotenone to zero-out a pond before the beginning of the next production cycle. Average production data for these analyses were obtained from the survey and used as the baseline production for each species. In this analysis, two years of post-rotenone production years were used to account for improved profit, which is more premium sized fish and less Big Fish, and the longer duration of this positive management action on the farm. Beneficial additional revenues were only calculated for two production cycles after the rotenone event because little research exists on the seining efficiency of fish that remain in the pond for multiple production cycles. Channel Catfish revenues after rotenone usage were calculated using 100% premium sized fish harvested (and 0% Big Fish) in year one, and 95% premium sized fish harvested (and 5% Big Fish) in year two multiplied by $2.33/kg for premium sized fish and $1.40/kg for Big Fish.

Because of faster hybrid catfish growth rates, the percentage of premium sized and Big Fish harvested quantities differed from the Channel Catfish analysis. Additional revenue from hybrid catfish sales after rotenone usage were calculated using 95% premium sized fish harvested (and 5% Big Fish) in year one post application, and 90% premium sized fish harvested (and 10% Big Fish) in year two post application. These quantities were multiplied by $2.33/kg for premium sized fish and $1.40/kg for Big Fish. Rotenone cost to effectively treat, i.e., kill remaining fish, for a 4.5 ha pond before restocking was $3,893 or $865/ha (personal communication from catfish producer in west Alabama).

Assumptions for the percentages of Channel Catfish and hybrid catfish that would remain after the rotenone treatment (and pond renovation) were based from survey results and previous literature. The first production cycle after implementing one of these two Big Fish control strategies, assumed 100% of Channel Catfish harvested would be premium sized and receive the full processor price. An estimated 16% of Channel Catfish will likely be missed at harvest after the first production cycle (Engle et al. 2011). The missed Channel Catfish will continue to grow, and an estimated 5% will become Big Fish by the year two harvest. Hybrid catfish grow at a much faster rate, and a small percentage of hybrids become Big Fish in one production cycle (5% Big Fish used in this partial budget analysis) (Bott et al. 2015; Mischke et al. 2017). An estimated 10% of hybrid catfish will be missed after the first production cycle harvest (Dunham and Argue 2011). Those fish will become Big Fish by harvest in year two and the farmer price received will be discounted by the processing plant to $1.40/kg.

The third partial budget scenario involves pond draining, renovation and pond bottom smoothing to improve long-term seining efficiency. Farmers were interviewed to determine pond renovation schedules. From those interviews, farmers reported renovating a pond when production declined to less than 4,480 kg/ha for consecutive production years. This production benchmark was used to determine the cost of lost revenue while the pond is out of production for renovations while creating the partial budget for completely renovating the pond. This production benchmark was not used for the other two partial budget analyses.

The pond renovation partial budget analysis used average production data obtained from the survey and separate Channel Catfish and hybrid catfish partial budgets were developed. In this analysis, two years of post-pond renovation are taken into account. Renovation will improve the percentage of premium sized fish harvested and reduce the quantity of Big Fish. Harvest quantities for one and two years after renovation were calculated in a similar manner to the rotenone partial budget revenue calculations. Channel Catfish revenue one year after pond renovation is estimated at 100% premium sized fish (and 0% Big Fish) and 95% premium sized Channel Catfish harvested (and 5% Big Fish) in year two. The average prices used were $2.33/kg for premium sized fish and $1.40/kg for Big Fish. For the faster growing hybrid catfish the percentage of premium sized hybrid catfish harvested one year after pond renovation is 95% (and 5% Big Fish) and after two years 90% premium sized (and 10% Big Fish).

According to the farmer survey, 54% (n = 28) of farmers have renovated at least one of their ponds since they began farming compared to 46% (n = 24) of farmers who have never renovated a pond. The average length between pond renovations was 19 years. Renovating a pond will put the pond out of production for 16 months depending on how long the pond takes to dry out after draining and this is largely dependent on the weather. According to survey results the average length of a production cycle for a Channel Catfish and a hybrid catfish pond is 16 months and 11 months, respectively. Channel Catfish and hybrid catfish farmers would lose an average of 1 and 1.5 production cycles, respectively, while the pond is out of production during renovation. For this reason, farmers would not want to drain and renovate a pond unless there is a high percentage of Big Fish, a low annual production, or a diminished $/ha return for consecutive production years. Pond construction companies in west Alabama charge an average of $3,707/ha to renovate a catfish pond (personal communication with companies who renovate catfish ponds in west Alabama).

Results

Fifty-three surveys were completed and returned for analysis (73% return rate). Results from the survey indicated that in 2017 and 2018 the average farm size in west Alabama was 101 ha and consisted of 23 ponds (Table 3.1; Table 3.3). In 2017, survey respondents reported 4,353 ha of water in Channel Catfish production compared to 998 ha in hybrid catfish production (Table 3.1). In 2018, Channel Catfish production increased to 4,566 ha while hybrid catfish production decreased to 780 ha (Table 3.3). Farmers stocked fingerlings averaging 16 cm at a two-year average stocking rate of 19,295 fish/ha. The average production cycle for catfish was 17 months for Channel Catfish and 11 months for hybrid catfish in 2017 and 16 months and 11 months respectively for 2018 (Table 3.1; Table 3.3). Farmers sold an average of 802,389 kg in 2017 and 785,679 kg in 2018. In 2017, 83% of fish harvested were premium sized fish worth a total of $1.6 million and 17% were Big Fish worth a total of $0.2 million (Table 3.2). In 2018, 80% of fish harvested were premium sized worth a total of $1.4 million and 20% were Big Fish worth a total of $0.2 million (Table 3.4). Total costs were $1.4 million in 2017 (Table 3.2) and $1.4 million in 2018 (Table 3.4). The net returns above all expenses were $445,518 and $116,742 in 2017 and 2018, respectively (Table 3.2; Table 3.4). If all fish sold were premium sized, that is no Big Fish, net returns would increase by $121,358 and $150,321for the average sized farm in west Alabama in 2017 and 2018, respectively. Thus, Big Fish represent a significant loss of receipts and decrease in net returns to commercial farmers in west Alabama.

Based on survey data, the average farm size for farmers that exclusively raised Channel Catfish was 112 ha (N = 18) compared to 36 ha for those who exclusively raised hybrid catfish (N = 9) (Table 3.5). Channel Catfish farmers harvested an average of 796,768 kg of catfish or 7,114 kg/ha with gross receipts of $14,920/ha in 2017 and 2018 (Table 3.5). In contrast, hybrid catfish farmers harvested an average of 415,584 kg of catfish or 11,544 kg/ha with gross receipts of $25,500/ha during the same time period (Table 3.5). The kg produced per ha was greater for hybrid catfish due to their faster growth rate and shorter production cycle compared to Channel Catfish. Gross receipts per hectare were also higher for farmers raising hybrid catfish due to the higher percentage of premium sized fish harvested and the greater production per hectare compared to Channel Catfish ponds.

The main concern reported by catfish farmers that participated in the survey was mortalities due to disease or low dissolved oxygen (27%) (Figure 3.1). This was followed by low prices paid by the processing plants for fish (26%), feed prices (14%), Big Fish (13%), imported aquaculture products (10%), other (lack of labor, not selling fish when ready, and bad seining) (6%), and issues with off-flavor (4%). According to the farmers surveyed, the three factors that most contributed to Big Fish on their farms were seining/capture inefficiency (35%), issues with ponds (irregular pond shape, uneven pond bottom, deep ponds, etc.) (31%), and not enough harvests per pond (13%) (Figure 3.2). The four main methods implemented by farmers to control Big Fish were seining more often (56%), other (use of gill nets, lethal take of Big Fish, trap seines, using bird bangers to scare fish away from the pond edges during seining, and other reported factors) (24%), increasing stocking rates (11%), and re-working the pond bottom for increased seining efficiency (9%) (Figure 3.3).

Farmers who raised hybrid catfish frequently zeroed-out their ponds before starting a new production cycle. This practice was rarely used by Channel Catfish famers. Based on survey results, 66% of hybrid catfish farmers zeroed-out their ponds compared to 14% of Channel Catfish farmers. Multiple seine pulls before restocking fingerlings is the most widely used strategy implemented by farmers to zero-out their ponds before starting a new production cycle (90% of respondents who zeroed-out their ponds; n=19). Nineteen percent of farmers who zeroed-out their ponds completely drained and refilled their ponds before starting a new production cycle (n= 4). Rotenone was not used by surveyed farmers in production years 2017 and 2018.

Based on the survey results, each farm averaged two harvests per pond per year regardless of the harvesting option used (Table 3.6). The processor and custom seiner combination led to the highest percent of premium sized fish harvested (88%), and was 3%, 10%, and 13% greater than for the processor only, custom seiner only, and own harvest crew only options, respectively (Table 3.6). The percent of Big Fish was greatest for the own harvest crew (25%), followed by the custom seiner (22%), processor (15%) and combination of processor and custom seiner (12%) (Table 3.6). Results showed the total kg of harvested fish increased as the number of seine pulls increased (Table 3.7). Additionally, the percent of Big Fish harvested decreased as the number of seine pulls increased, except for one case that had a high variance among its seven observations (Table 3.7).

Partial Budgeting Results

Hiring a custom seiner for additional re-seines

The hybrid catfish farmer increased the farm's revenue by $29,921 for the 4.5 ha pond or $6,649/ha by re-seining the pond two additional times (Table 3.8), while additional seining costs were only $1,800 or $400 per ha. Thus, the net benefit was positive ($6,249) and the additional re-seines should be adopted because it improves the farm's bottom line. Similarly for the Channel Catfish, the net benefit from two additional re-seines was $26,792 or 5,947/ha (Table 3.9) and should be adopted.

Using rotenone to zero-out ponds before starting a new production cycle

The Channel Catfish rotenone partial budget had additional revenues one year after the treatment of $16,576 and $16,245 after the second year harvest, while additional rotenone costs were $3,893 per 4.5 ha pond or $864 per ha (Table 3.10). The net benefit was positive and high, indicating this method should be adopted. For the faster growing hybrid catfish, the net benefit was even higher than for the Channel Catfish results. Hybrid catfish additional revenues one year after the treatment was $26,361 and $25,824 after the second year harvest, while additional rotenone costs were still $3,893 per 4.5 ha pond or $864 per ha (Table 3.11). The net benefit was positive and high, indicating this method should be adopted.

Pond renovation to improve seining efficiency

The average time between pond renovations in west Alabama is 19 years (Table 3.12). A farmer would expect to increase revenues after renovating a pond to increase seining efficiency. The additional revenue for a Channel Catfish pond for two production cycles after pond renovations would be $16,576 and $16,245/ha (Table 3.13). The pond renovation period would result in one production cycle lost, equivalent to $9,408 in revenue lost from the 4,480 kg/ha of fish not produced. Renovation costs are $3,707 per ha. The net benefit for Channel Catfish ponds having two production cycles after the pond is renovated is $19,706/ha (Table 3.13). The additional revenue for a hybrid catfish pond with two production cycles after pond renovations would be $26,361 and $25,824/ha (Table 3.14). There would be 1.5 lost production cycles during the pond renovation period, equivalent to $14,784 in lost revenue. The net benefit from renovating a hybrid catfish pond and allowing for two production cycles after the pond is renovated is $32,829/ha (Table 3.14). More frequent pond renovations should be adopted by both Channel Catfish and hybrid catfish farmers due to the positive net benefit and the improved seining efficiency for the pond.

Discussion

According to survey results from this study, Big Fish was the fourth highest concern of farmers, but is still a biological and financial problem for the farm. This problem can be mitigated through short- and long-term modifications to farm operations and pond infrastructure. Big Fish did have a measurable and pronounced impact on farm profitability. The price of premium sized fish decreased from $2.47/kg to $2.19/kg from 2017 to 2018 while the price of Big Fish decreased from $1.57/kg to $1.23/kg during the same time. The total kg of fish harvested decreased from 2017 to 2018 while the kg of Big Fish harvested increased from 17% of total harvest to 20%. This negatively impacted the revenues and profitability of farmers in west Alabama leading to a loss of $3,255/ha. With the volatility of today's catfish market, farmers need to harvest a higher percentage of premium sized fish to remain profitable. Farmers have no control over the price of catfish, but they can take steps on their farm to control Big Fish in their ponds to increase revenues and profitability.

Zeroing-out a pond before starting a new production cycle was shown to be an effective way to reduce the percentage of Big Fish in the pond. Channel Catfish producers use a multiple-batch production system with different size and age classes of fish present in the pond. For this reason, Channel Catfish ponds are managed as a continuous culture system and rarely zeroed-out their ponds. However, hybrid catfish producers typically use single-batch production systems and routinely zero-out their ponds before starting a new production cycle. This eliminates fish missed at harvest from the first production cycle. Multiple seine pulls before restocking fingerlings was the most commonly used method to zero-out a pond. Hiring a custom seiner for additional re-seines was the least expensive alternative and harvested more fish from ponds that the farmer would not have harvested without hiring a custom seiner. Farmers who seined more often were able to harvest more kg of fish at the end of the production cycle and were able to harvest a lower percentage of Big Fish. However, fish will still be missed using this management strategy. Big Fish will not be completely eliminated through multiple re-seines alone and the pond is never truly zeroed-out using this approach (Bott et al. 2015; Dunham and Argue 2011; Engle et al. 2011). Another management strategy is needed if eliminating all Big Fish in the pond is the goal.

Rotenone is an alternative way to eliminate Big Fish from the catfish pond. However, fish that have been killed using rotenone cannot be sold to the processing plant and must be removed from the pond and properly disposed. For this reason, it is important to ensure no premium sized fish are present in the pond at the time of a rotenone application. This approach should follow regular harvest and re-seining events. Rotenone is expensive and should be used on a rotating basis based on the percentage of Big Fish in that pond. Channel Catfish farmers would likely not choose to apply rotenone to their ponds due to their use of a multiple-batch production system. However, Channel Catfish farms harvested an average of 25% Big Fish during this study indicating a long-term problem of Big Fish for Channel Catfish farms.

Channel Catfish and hybrid catfish can become Big Fish in one to two growing seasons. Based on the results from Chapter 2, the average weight of a 3-year old Channel Catfish is 2.69 kg. While this is above the threshold for Big Fish (1.81 kg), the farmer will likely receive some compensation for a catfish of this size. Additionally, premium sized fish (0.45-1.81 kg) were still harvested after two production cycles that the farmer should not eliminate. The Big Fish in the pond will continue to grow but at a much slower rate compared to hybrid catfish. Due to Channel Catfish's relatively slow growth compared to hybrid catfish, it is recommended to apply rotenone after four to five growing seasons to ensure there is not a high percentage of Big Fish in the pond but only if a single batch production system is being implemented at the farm. The use of rotenone for multiple batch systems is not a viable approach unless a decision has been made to commence a new multiple-batch cycle from scratch.

Hybrid catfish have a faster growth rate compared to Channel Catfish. Based on the results from Chapter 2, the average weight of a 3-year old hybrid catfish is 6.36 kg with some fish exceeding 10 kg (Creel et al. 2019). Processing plants are unlikely to accept fish of this size so these fish have no value to the farmer. For this reason, for farmers using a single batch production system with hybrids, we recommend applying rotenone to ponds every two to three growing seasons to ensure there is not a high percentage of Big Fish in the pond assuming the pond will not be drained.

The only management strategy that can eliminate all the Big Fish from the pond is to completely drain the pond and re-work the pond bottom. This will increase seining efficiency and lead to a greater percentage of premium sized catfish harvested in each production cycle. The cost to renovate the pond, the money lost while the pond is out of production is real and the main reason why farmers in west Alabama rarely renovate their ponds. Another factor in this decision is the lack of accessible water in west Alabama and having to rely on rainfall to fill watershed ponds. However, watershed ponds can become increasingly more difficult to harvest over time, allowing more fish to escape and become Big Fish (Steeby et al. 2003).

Conclusions

Channel Catfish farms reported a higher percentage of Big Fish harvested compared to hybrid catfish farmers. This is due to the usage of a multiple-batch production system without frequently zeroing-out the ponds before starting a new production cycle. Hybrid catfish have a faster growth rate and become Big Fish in 1.5 years compared to 2.6 years for Channel Catfish. The oldest Channel Catfish sampled during this project was 7-years old and weighed 4.33 kg while the oldest hybrid catfish was 6-years old and 20.64 kg. For this reason hybrid catfish are grown using a single-batch production system with farmers zeroing-out their ponds with multiple seine pulls before re-stocking fingerlings to prevent many fish from reaching these large sizes. This practice utilized by hybrid catfish farmers is effective in reducing the amount of Big Fish found in hybrid catfish ponds. However, fish will still escape harvest using this strategy and a more effective method should be used if the farmer wants to eliminate all the Big Fish in the pond.

Based on farmer interviews and survey results, the best long-term solution in regards to Big Fish control is to renovate or re-work pond bottoms as the opportunity arises and cash flows permit, to increase seining efficiency. Due to the common use of Channel Catfish and multiple-batch production systems and the cost of renovations, the average time between pond renovations for farmers that responded to the survey was 19 years. These older ponds will become increasingly harder to seine due to the accumulation of mud, holes and depressions, or the presence of large trenches. There is no easy solution to the Big Fish problem and it will require a multi-faceted approach. Each management strategy needs to be tailored to the specific farm depending on the species cultured, farm size, and individual pond conditions. If ponds cannot be renovated due to cash flow constraints then additional re-seines following harvest of ponds to remove larger fish that were missed would be beneficial in the near term. In multiple-batch systems a seine with a larger mesh size could be used also during re-seines to selectively remove the larger fish remaining in the pond and allow smaller fish that were missed to remain in the pond. Based on the results of the economic analyses of this study, each of these three methods appear to have positive net benefits.

Table 3.1. 2017 Alabama catfish production totals, averages and ranges based on west Alabama catfish producer survey results.

Variable	N	2017 Total (Adjusted Total)	2017 Mean (range)
Number of water hectares	53	5,369 (6,894)[a]	101 (15 - 621)
Number of ponds in production	53	1,193	23 (4 - 130)
Average ha/pond	53	-	4 (2 – 6)
Number of people working on your farm	52	175	3 (1 - 17)
Harvests per year	52	113	2 (1 - 4)
Kg of fish sold	46	36,909,887 (47,392,295)[b]	802,389 (113,379 – 5,668,934)
Kg of Big Fish sold (> 1.81 kg)	46	5,918,877 (7,599,838)[b]	134,520 (431 – 1,247,166)
Fish ready for sale but unable to find a buyer (kg)	5	1,433,107 (1,840,109)[b]	4,535 (4,535 – 566,893)
Total amount of feed fed (kg)	42	67,573,238 (86,764,038)[b]	1,608,887 (72,562 – 11,791,383)
Did you clean out or zero out your ponds before restocking?	52	- -	17% Yes 83% No
Target stocking rate (#/ha)	53	-	19,246 (9,884 – 33,359)

Table 3.1. Continued

Variable	N	2017 Total (adjusted total)	2017 Mean (range)
Fingerling size	51	-	16 (10 – 20)
Channel Catfish hectares	41	4,353	106 (6 – 526)
Hybrid catfish hectares	26	998	38 (4 – 235)
Single-batch hectares	28	1,386	50 (11 – 535)
Multiple-batch hectares	39	4,452	116 (6 – 574)
Batches per pond	39	-	2 (1 – 3)
Typical length of a production cycle-Channel Catfish (months)	40	-	17 (12 - 19)
Typical length of a production cycle-hybrid catfish (months)	28	-	11 (6 - 15)
FCR (kg of feed fed/kg of fish sold)	37	-	2.24 (1.51 – 4.13)
Total FCR (kg of feed feed/kg of fish sold + estimate of fish ready to sell but unable to find a buyer)	37	-	2.22 (1.51 – 4.13)

[a] *Total water hectares in Alabama 2017 (2019 Fish Farming News)*

[b] *Totals using the expansion factor to scale up to the Alabama Catfish Industry*

Expansion Factor used: 1.284 (6,894 water hectares / 5,369 water hectares from the survey)

Each line item was obtained from the reported observations from the survey

Table 3.2. 2017 Enterprise budget for the Alabama catfish industry for a 101 ha farm based on production averages from the survey results.

	Unit	Quantity	Price or Cost / unit	Value or Cost	Per ha Value	Cost Per kg	Percent of ALL Costs	Percent of Variable Costs
1. Gross Receipts								
Catfish sales, PRIME	kg	667,983	2.469	1,649,251	16,329	$ **2.469**		
Catfish sales, BIG FISH	kg	134,543	1.567	210,828	2,087	$ **1.567**		
		802,526		**1,860,079**	18,417	**2.318**		
2. Variable Costs								
Feed, food fish	ton	1,773	354	627,642	6,214	$ **0.008**	44%	50%
Labor								
Management	year	1	40,000	40,000	396	$ **0.050**	3%	3%
Hired labor, at various wages	year	7	varies	128,000	1,267	$ **0.159**	9%	10%
Fingerlings	each	1,500,000	0.075	112,312	1,112	$ **0.140**	8%	9%
Transport of harvested fish /1	kg	802,526	0.033	26,483	262	$ **0.033**	2%	2%
Fuel & lubricants								
Diesel	l	84,536	0.70	59,175	586	$ **0.074**	4%	5%
Gasoline	l	46,909	0.64	30,022	297	$ **0.037**	2%	2%
Electricity								0%
Aeration	10-hp hr	12,596	0.932	11,736	116	$ **0.015**	1%	1%
Meter charges	meter-month	60	35	2,100	21	$ **0.003**		0%
Water pumping	hectare	101	136	13,736	136	$ **0.017**	1%	1%
Repairs and Maintenance	month	12	2,240	26,882	266	$ **0.033**	2%	2%
Bird chasing	year	1	2,000	2,000	20	$ **0.002**	0%	0%
Chemicals								
Salt	ton	101	131	13,231	131	$ **0.016**	1%	1%
Diuron, off-flavor control	trt/ha	606	22	13,433	133	$ **0.017**	1%	1%
Copper sulfate, trematode treat.	trt/ha	101	22	2,222	22	$ **0.003**	0%	0%
Miscellaneous expenses	per ha	101	62	6,262	62	$ **0.008**	0%	0%
Interest on Operating Capital	dol	1,448,825	0.10	144,883	1,434	$ **0.181**	10%	11%
Total Variable Costs				**1,260,119**	12,476	$ **1.570**	89%	100%
3. Income Above Variable Cost				**599,960**	**5,940**	$ **0.748**		
4. Fixed Cost								
Land charge (not included)	dol	192,000	0.10	19,200	190	$ **0.024**	1%	0%
Machinery depreciation	dol			46,185	457	$ **0.058**	3%	37%
Pond depreciation	dol			23,114	229	$ **0.029**	2%	18%
Taxes (land)	ha	83	101	8,433	83	$ **0.011**	0.6%	7%
Interest on Pond Construction Costs	dol.&%	275,517	0.10	27,552	273	$ **0.034**	2%	22%
Interest on Equipment/Mach. Purchases	dol &%	205,973	0.10	20,597	204	$ **0.026**	1%	16%
Total Fixed Costs				**145,081**	1,436	$ **0.181**	10%	100%
5. Overhead								
Telephone	month	12	208	2,500	25	$ **0.003**	0%	27%
Accounting/legal	year	1	2,400	2,400	24	$ **0.003**	0%	26%
Supplies and Administrative	year	1	600	600	6	$ **0.001**	0%	6%
Office supplies	year	1	600	600	6	$ **0.001**	0%	6%
Insurance, general liability	ha	101	15.00	1,515	15	$ **0.002**	0%	17%
Insurance on equipment, machinery	dol/$	436,640	0.004	1,747	17	$ **0.002**	0%	19%
Total Overhead Costs				**9,362**	93	$ **0.012**	1%	100%
6. Total Costs				**1,414,561**	14,006	$ **1.763**	100%	
7. Net Returns Above All Specified Expenses				**445,518**	**4,411**	$ **0.555**		

Table 3.3. 2018 Alabama catfish production totals, averages and ranges based on west Alabama catfish producer survey results.

Variable	N	2017 Total (Adjusted Total)	2017 Mean (range)
Number of water hectares	53	5,370 (6,938)[a]	101 (15 - 607)
Number of ponds in production	53	1,193	23 (4 - 125)
Average hectares/pond	53	-	4 (2 – 6)
Number of people working on your farm	46	175	3 (1 - 17)
Harvests per year	52	113	2 (1 - 4)
Kg of fish sold	46	36,141,246 (46,694,490)[b]	785,679 (136,054 – 5,442,177)
Kg of Big Fish sold (> 1.81 kg)	46	7,240,602 (9,354,858)[b]	157,404 (431 – 1,541,950)
Fish ready for sale but unable to find a buyer (kg)	5	1,378,685 (1,781,261)[b]	275,737 (18,141 – 566,893)
Total amount of feed fed (kg)	42	65,914,281 (85,161,251)[b]	1,569,388 (72,562 – 11,791,383)
Did you clean out or zero out your ponds before restocking?	52	- -	17% Yes 83% No
Target stocking rate (#/ha)	53	-	19,344 (9,884 – 29,652)
Fingerling size (cm)	51	-	16 (10 - 20)

Table 3.3. Continued

Variable	N	2018 Total (adjusted total)	2018 Mean (range)
Channel Catfish hectares	42	4,566	109 (1 – 607)
Hybrid catfish hectares	29	780	29 (2 – 65)
Single-batch hectares	28	1,318	47 (2 – 520)
Multiple-batch hectares	38	4,512	119 (8 – 607)
Batches per pond	39	-	2 (1 – 3)
Typical length of a production cycle- Channel Catfish (months)	44	-	16 (10 - 18)
Typical length of a production cycle- hybrid catfish (months)	27	-	11 (6 - 14)
FCR (kg of feed fed/kg of fish sold)	37	-	2.2 (1.5 – 3.6)
Total FCR (kg of feed feed/kg of fish sold + estimate of fish ready to sell but unable to find a buyer)	37	-	2.2 (1.5 – 3.6)

[a] *Total water hectares in Alabama 2018 (2019 Fish Farming News)*

[b] *Totals using the expansion factor to scale up to the Alabama Catfish Industry*

Expansion Factor used: 1.292 (6,942 water hectares / 5,370 water hectares from the survey)

Each line item was obtained from the reported observations from the survey

Table 3.4. 2018 Enterprise Budget for the Alabama Catfish Industry for a 101 ha farm based on production averages from the survey results.

	Unit	Quantity	Price or Cost / unit	Value or Cost	Per ha Value	Cost Per kg	Percent of ALL Costs	Percent of Variable Costs
1. Gross Receipts								
Catfish sales, PRIME	kg	628,275	2.185	1,372,781	13,592 $	**2.185**		
Catfish sales, BIG FISH	kg	157,404	1.230	193,607	1,917 $	**1.230**		
		785,679		**1,566,388**	15,509	**1.994**		
2. Variable Costs								
Feed, food fish	ton	1,730	377	652,210	6,458 $	**0.008**	45%	50%
Labor								
Management	year	1	40,000	40,000	396 $	**0.051**	3%	3%
Hired labor, at various wages	year	7	varies	128,000	1,267 $	**0.163**	9%	10%
Fingerlings	each	1,500,000	0.075	112,312	1,112 $	**0.143**	8%	9%
Transport of harvested fish /1	kg	785,679	0.033	25,927	257 $	**0.033**	2%	2%
Fuel & lubricants								
Diesel	l	84,536	0.72	60,866	603 $	**0.077**	4%	5%
Gasoline	l	46,909	0.84	39,404	390 $	**0.050**	3%	3%
Electricity								0%
Aeration	10-hp hr	12,596	0.932	11,736	116 $	**0.015**	1%	1%
Meter charges	meter-month	60	35	2,100	21 $	**0.003**		0%
Water pumping	hectare	101	136	13,736	136 $	**0.017**	1%	1%
Repairs and Maintenance	month	12	2,240	26,882	266 $	**0.034**	2%	2%
Bird chasing	year	1	2,000	2,000	20 $	**0.003**	0%	0%
Chemicals								
Salt	ton	101	131	13,231	131 $	**0.017**	1%	1%
Diuron, off-flavor control	trt/ha	606	22	13,433	133 $	**0.017**	1%	1%
Copper sulfate, trematode treat.	trt/ha	101	22	2,222	22 $	**0.003**	0%	0%
Miscellaneous expenses	per ha	101	62	6,262	62 $	**0.008**	0%	0%
Interest on Operating Capital	dol	1,448,825	0.10	144,883	1,434 $	**0.184**	10%	11%
Total Variable Costs				**1,295,203**	12,824 $	**1.649**	89%	100%
3. Income Above Variable Cost				**271,185**	**2,685 $**	0.345		
4. Fixed Cost								
Land charge (not included)	dol	192,000	0.10	19,200	190 $	**0.024**	1%	0%
Machinery depreciation	dol			46,185	457 $	**0.059**	3%	37%
Pond depreciation	dol			23,114	229 $	**0.029**	2%	18%
Taxes (land)	ha	83	101	8,433	83 $	**0.011**	1%	7%
Interest on Pond Construction Costs	dol.&%	275,517	0.10	27,552	273 $	**0.035**	2%	22%
Interest on Equipment/Mach. Purchases	dol &%	205,973	0.10	20,597	204 $	**0.026**	1%	16%
Total Fixed Costs				**145,081**	1,436 $	**0.185**	10%	100%
5. Overhead								
Telephone	month	12	208	2,500	25 $	**0.003**	0%	27%
Accounting/legal	year	1	2,400	2,400	24 $	**0.003**	0%	26%
Supplies and Administrative	year	1	600	600	6 $	**0.001**	0%	6%
Office supplies	year	1	600	600	6 $	**0.001**	0%	6%
Insurance, general liability	ha	101	15.00	1,515	15 $	**0.002**	0%	17%
Insurance on equipment, machinery	dol/$	436,640	0.004	1,747	17 $	**0.002**	0%	19%
Total Overhead Costs				**9,362**	93 $	**0.012**	1%	100%
6. Total Costs				**1,449,645**	14,353 $	**1.845**	100%	
7. Net Returns Above All Specified Expenses				**116,742**	**1,156 $**	0.149		

Table 3.5. Average production of Channel Catfish and hybrid catfish farms in west Alabama before rotenone based on survey data.

Species	N	Category	Value
Channel Catfish	18	Farm Size (ha)	112
	18	Pond Size (ha)	4.5
	18	Kg produced/ha	7,114
	18	Gross receipts ($/ha)	14,920
Hybrid Catfish	9	Farm Size (ha)	36
	9	Pond Size (ha)	4.5
	9	Kg produced/ha	11,544
	9	Gross receipts ($/ha)	25,500

**Only farms that exclusively raise Channel Catfish or hybrid catfish were used in this analysis. Farmers raising both species do not break down their total kg harvested by species.*

Table 3.6. Harvesting options and % Big Fish harvested from the survey results.

Harvester option	Farm size (ha)	Total kg produced	% Premium	% Big Fish	Harvests per year
Own harvest crew	304	2,611,331	75	25	2
Processor	121	877,517	85	15	2
Custom seiner	110	757,953	78	22	2
Processor & custom seiner	42	417,987	88	12	2

Table 3.7. Total number of seine pulls per pond per year and the effect on the amount of Big Fish harvested.

Farm size (ha)	N	Seine pulls	Avg total kg harvested	% Big Fish
0-40	4	2	176,674	13
	7	3	243,303	30
	4	4	257,692	11
40-81	4	3	576,626	18
	3	4	641,380	15
81-202	2	2	850,486	12
	4	5	1,185,010	10

Table 3.8. Partial budget from a hybrid catfish farm after two additional re-seines following commercial harvest.

Category	Cost or Revenue ($/ha)
Benefits	
(A) Additional revenue	
Additional revenue from harvesting additional kg of fish ((13,600 kg from 2 re-seines x $2.20/kg)	6,649
/ 4.5 ha pond)	
(B) Reduced cost	0
Total additional benefit (A + B)	6,649
Costs	
(C) Reduced revenue	0
(D) Additional costs	
Additional cost to re-seine pond twice (($150/hr x 6 hrs x 2 re-seines)	400
/ 4.5 ha pond)	
Total additional cost (C + D)	400
Net Benefit ([A + B] – [C + D])	6,249

Table 3.9. Partial budget from a Channel Catfish farm after two additional re-seines following commercial harvest.

Category	Cost or Revenue ($/ha)
Benefits	
(A) Additional revenue Additional revenue from harvesting additional kg of fish ((13,600 kg from 2 re-seines x $2.10/kg) / 4.5 ha pond	6,347
(B) Reduced cost	0
Total additional benefit (A + B)	6,347
Costs	
(C) Reduced revenue	0
(D) Additional costs Additional cost to re-seine pond twice (($150/hr x 6 hrs x 2 re-seines) / 4.5 ha pond)	400
Total additional cost (C + D)	400
Net Benefit ([A + B] – [C + D])	5,947

Table 3.10. Partial budget for a Channel Catfish pond after zeroing-out a 4.5 ha pond with rotenone.

Category	Cost or Revenue ($/ha)
Benefits	
(A) Additional revenue	
Additional revenue from harvesting additional kg of fish Year 1: (7,114 kg/ha x 100% premium fish x $2.33/kg)	16,576
Year 2: (7,114 kg/ha x 95% premium fish x $2.33/kg) + (7,114 kg/ha x 5% Big Fish x $1.40/kg)	16,245
(B) Reduced cost	0
Total additional benefit (A + B)	32,821
Costs	
(C) Reduced revenue	0
(D) Additional costs Additional cost to rotenone pond ($3,893 / 4.5 ha)	865
Total additional cost (C + D)	865
Net Benefit ([A + B] – [C + D])	31,956

*Farmers that use rotenone typically apply it after commercial harvest and additional re-seines. These costs would be incurred by the farmer regardless of the use of rotenone and do not represent an additional cost in this partial-budget.

Table 3.11. Partial budget for a hybrid catfish pond after zeroing-out a 4.5 ha pond with rotenone.

Category	Cost or Revenue ($/ha)
Benefits	
(A) Additional revenue Additional revenue from harvesting additional kg of fish Year 1: (11,544 kg/ha x 95% premium fish x $2.33/kg) + (11,544 kg/ha x 5% Big Fish x $1.40/kg)	26,361
Year 2: (11,544 kg/ha x 90% premium fish x $2.33/kg) + (11,544 kg/ha x 10% Big Fish x $1.40/kg)	25,824
(B) Reduced cost	0
Total additional benefit (A + B)	52,185
Costs	
(C) Reduced revenue	0
(D) Additional costs Additional cost to rotenone pond Rotenone: ($3,893 / 4.5 ha)	865
Total additional cost (C + D)	865
Net Benefit ([A + B] – [C + D])	51,320

*Farmers typically apply rotenone after commercial harvest and additional re-seines. These costs would be incurred by the farmer regardless of the use of rotenone and do not represent an additional cost in this partial-budget.

Table 3.12. Pond information and renovation schedules for commercial catfish farms in west Alabama based on survey data.

Variable	Mean (Range)
Hectares/pond (2017 – 2018 average)	4.5 (2 – 6)
Batches per pond (2017 – 2018 average)	2 (1 – 3)
Pond depth (m)	2 (1 - 3)
Harvests per year (2017 – 2018 average)	2 (1 – 4)
Average hp/hectare	11 (4 – 25)
Have you renovated any of your ponds	54% Yes 46% No
Average length between renovations (years)	19 (10 – 30)
Typical length of a production cycle- Channel Catfish (months) (2017 – 2018 average)	16 (10 – 19)
Typical length of a production cycle- hybrid catfish (months) (2017 – 2018 average)	11 (6 – 15)
When you renovate your ponds how long is that pond out of production (months)	16 (7 - 36)

Table 3.13. Partial budget for a Channel Catfish pond after pond renovation.

Category	Cost or Revenue ($/ha)
Benefits	
(A) Additional revenue	
Additional revenue from harvesting additional kg of fish Year 1: (7,114 kg/ha x 100% premium fish x $2.33/kg)	16,576
Year 2: (7,114 kg/ha x 95% premium fish x $2.33/kg) + (7,114 kg/ha x 5% Big Fish x $1.40/kg)	16,245
(B) Reduced cost	0
Total additional benefit (A + B)	32,821
Costs	
(C) Reduced revenue	
Reduced revenue from lost production time during renovation ((4,480 kg/ha x $2.10/kg) x 1 production cycle)	9,408
(D) Additional costs	
Additional cost to renovate pond ($16,682 / 4.5 ha)	3,707
Total additional cost (C + D)	13,115
Net Benefit ([A + B] – [C + D])	19,706

Table 3.14. Partial budget for a hybrid catfish pond after pond renovation.

Category	Cost or Revenue ($/ha)
Benefits	
(A) Additional revenue Additional revenue from harvesting additional kg of fish Year 1: (11,544 kg/ha x 95% premium fish x $2.33/kg) + (11,544 kg/ha x 5% Big Fish x $1.40/kg)	26,361
Year 2: (11,544 kg/ha x 90% premium fish x $2.33/kg) + (11,544 kg/ha x 10% Big Fish x $1.40/kg)	25,824
(B) Reduced cost	0
Total additional benefit (A + B)	52,185
Costs	
(C) Reduced revenue Reduced revenue from lost production time during renovation ((4,480 kg/ha x $2.20/kg) x 1.5 production cycles)	14,784
(D) Additional costs Additional cost to renovate pond ($16,682 / 4.5 ha)	3,707
Total additional cost (C + D)	18,491
Net Benefit ([A + B] – [C + D])	32,829

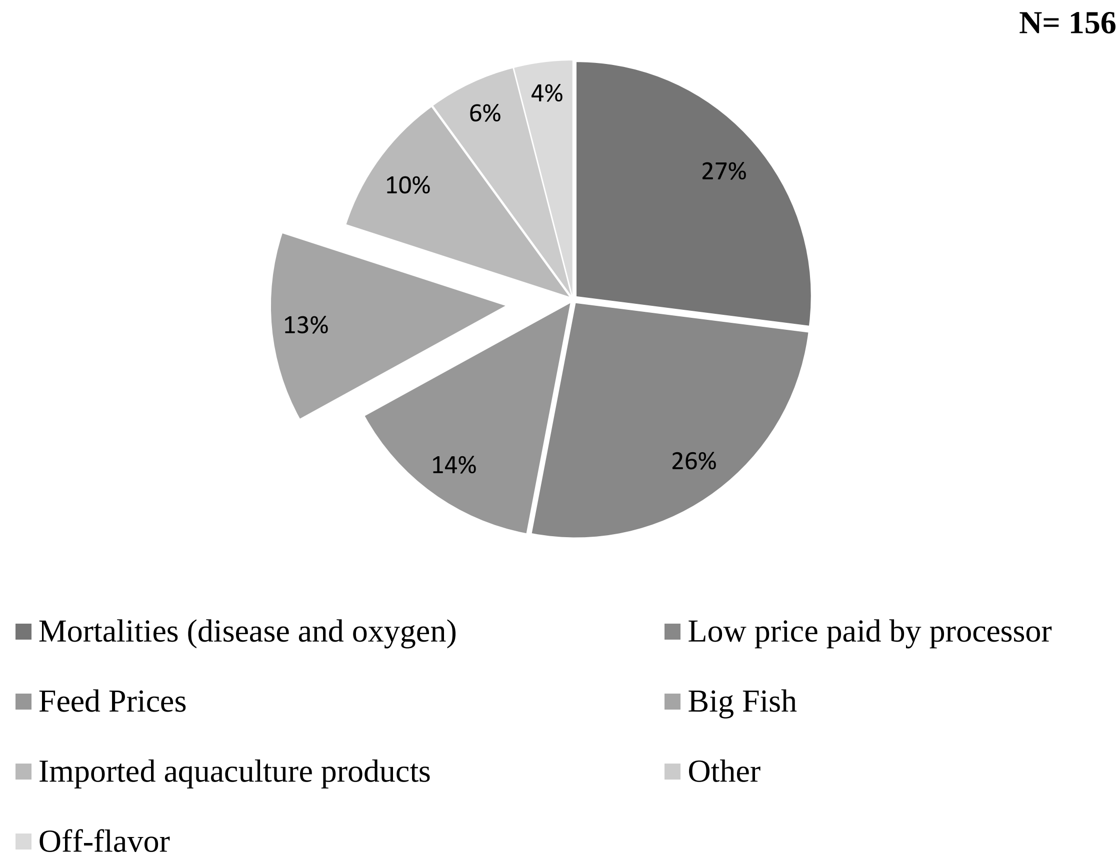

Figure 3.1. Survey results for biggest concern on the farm.

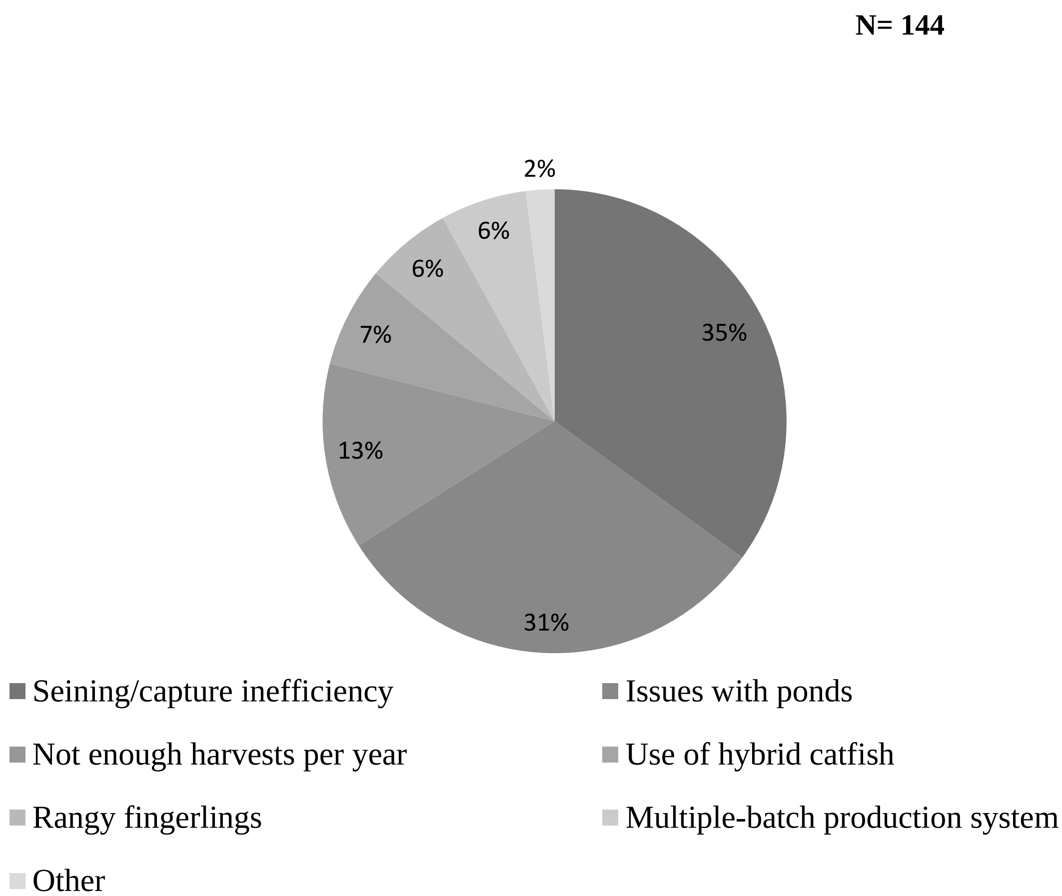

Figure 3.2. Survey results for what contributes most to Big Fish.

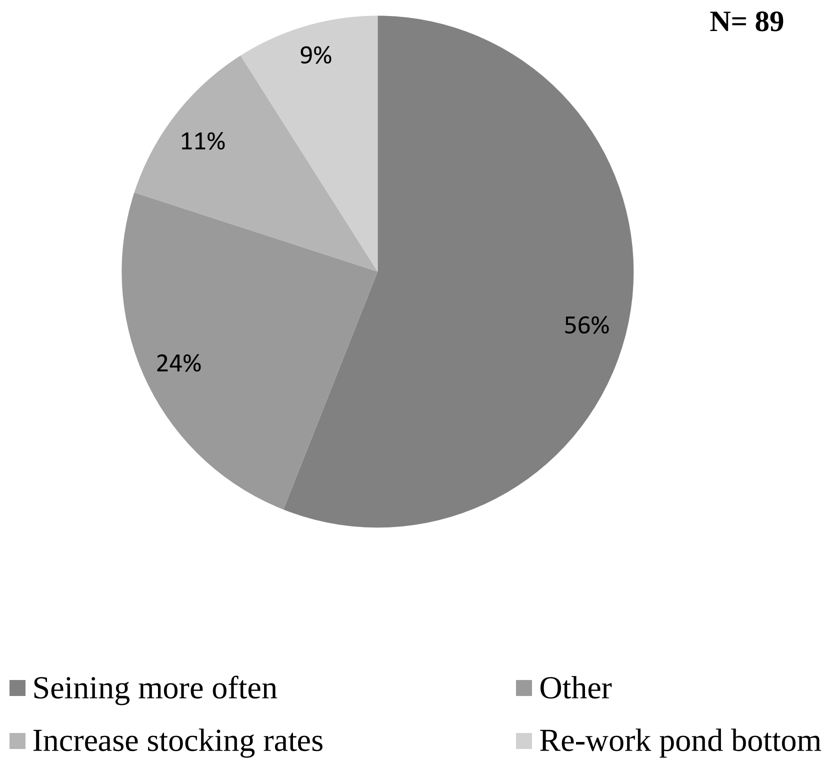

Figure 3.3. Survey results for methods used by farmers to control Big Fish.

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Chapter IV

SUMMARY AND CONCLUSIONS

Live catfish that exceed processor's desired weight have been termed Big Fish by the commercial catfish industry. Big Fish (> 1.81 kg) have had a negative impact on farm profitability for many years. Both farmers and processors have been unable to find a viable long-term solution to this problem. Most processing plants cannot readily sell fillets from these large catfish causing them to pay a reduced price and sometimes no compensation.

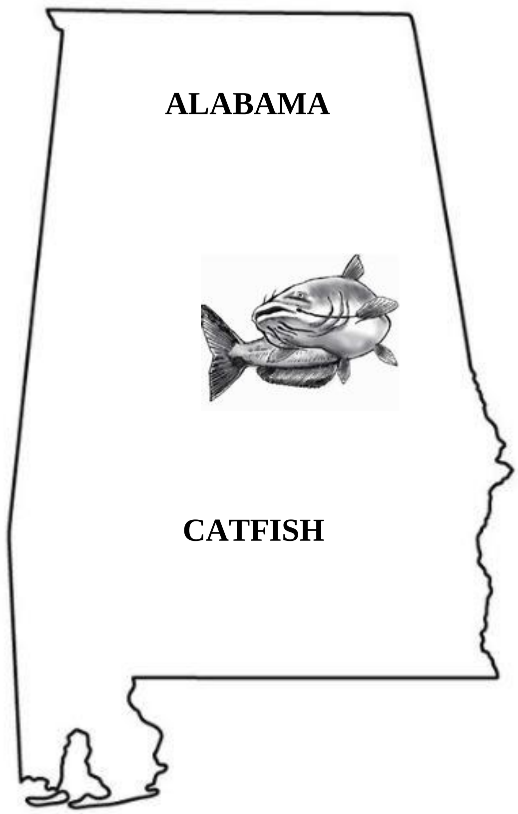
Many factors can lead to Big Fish including uneven pond bottoms that prevent efficient seining, rangy fingerlings (wide size distribution) at stocking, and commercial seining practices. In the summer of 2018, otoliths were collected from 287 catfish (153 Channel Catfish and 134 hybrid ranging from 0.45 – 20.6 kg) from commercial catfish farms in west Alabama to determine the age and growth of catfish of different size classes. Based on our findings, Channel Catfish and hybrid catfish are typically two years old when they are harvested at the end of the first production cycle. Catfish missed at harvest for multiple years will lead to wide size variation of fish present in the pond. These Big Fish negatively impact the farm by increasing FCRs, increasing feed costs, and may lead to the predation of smaller catfish in the pond. Processors, during this research period, preferred catfish within the 0.45 – 1.81 kg size range. From the total weight to age equations estimated in this research, Channel Catfish should be harvested when they are between 1.4 and 2.6 years old, while hybrid catfish should be harvested when they are between 0.8 and 1.5 years old to avoid growing into the Big Fish category (>1.81 kg).

The Big Fish problem has a significant economic impact on farm profitability every few years and appears to be directly tied to the supply and demand for fish. If there is an undersupply of catfish on the market, processing plants will pay a higher price for Big Fish compared to years when there is an oversupply of catfish. Big Fish represent a key inefficiency for commercial catfish farms regardless of the price paid by processing plants in a given year. A survey titled “2019 Big Fish survey of the Alabama catfish industry” was mailed to catfish producers in west Alabama to determine the scope of the Big Fish problem at the farm level and their different management strategies used to control Big Fish.

The additional costs and benefits of three management strategies commonly used by farmers to control Big Fish were established using survey data. Each strategy focused on how to remove Big Fish before the next crop was stocked and initiated. The most cost-effective solution was to seine more often by hiring a custom seine crew for additional re-seines after the initial harvest, followed by using rotenone after additional re-seines, and lastly, completely draining and re-working the pond bottom. Each management strategy needs to be tailored to the specific farm depending on the species cultured, farm size, and pond conditions. Based on farmer interviews and survey results, we believe the best long-term solution forward in regards to Big Fish is to re-work the pond bottoms, as the opportunity arises and cash flow permits, to increase seining efficiency long-term leading to improved commercial seining practices. In the meantime, additional re-seines to remove Big Fish missed from commercial harvests is a good management strategy to minimize Big Fish on farms. There is no easy solution to the Big Fish problem and a multi-faceted approach will be required to manage this issue. I hope to continue working on Big Fish and determine a long-term solution that benefits both the processing plants and the farmers.

Appendix A

2019 Big Fish Survey
of the Alabama Catfish Industry



A Study By:
Daniel Creel, M.S. Student
The School of Fisheries, Aquaculture, and Aquatic Sciences
Auburn University

I hope everyone is off to a good start in 2019. We know that Big Fish in ponds has been a problem for many years and can lead to reduced profits because these fish receive a discounted price at the processing plant. Each manager has their own solutions to reduce the occurrence of Big Fish from draining or zeroing out their ponds before starting a new production cycle to multiple seinings after harvest. With this in mind, enclosed is a survey designed to collect information on the different solutions farm managers have implemented to prevent fish from becoming oversized. We will use the information from your farm and combine it with information from other farmers in Alabama to determine what practices effectively reduce the Big Fish problem and increase profitability. Please take a few minutes to fill out the survey and return it to us in the pre-paid envelope enclosed. Your participation is very important to this project and with this information we will be able to develop enterprise budgets to determine the most economical practices to address the Big Fish problem. Individual data collected from this survey will be kept confidential. Any data presented will be averages and trends that in no way reflect any individual farm. Please answer each question as best you can. If a specific question makes you uncomfortable do not feel obligated to answer it. If you have any questions, feel free to call or email me at the address below.

Thank you for your help on this project,

Sincerely,

Daniel Creel	Terry Hanson	Luke Roy
Masters Student	Professor and Ext Spc	Assoc Prof and Ext Spc
Auburn University	Auburn University	AL Fish Farming Center
Jdc0037@auburn.edu	trh0008@auburn.edu	royluke@auburn.edu
334-422-5177	334-844-9207	334-624-4016

Instructions:

Please place the completed survey in the return envelope provided and mail it back to us as soon as possible. If you have any questions about the survey, please contact me, and I will do my best to answer your questions.

Thank You,

Daniel Creel

The following questions pertain to Big Fish on your farm

		2017	2018
1.	Number of water acres actively farmed		
2.	Number of ponds in production		
3.	Number of people working on your farm		
4.	Total pounds of fish sold for the entire year		
5.	Total pounds of fish ready for sale but you were unable to find a buyer		
6.	Total amount of feed fed on the whole farm for the entire year (pounds)		
7.	Target stocking rate (head per acre)		
8.	Size fingerlings typically used for stocking (inches)		

9. In 2017 and 2018, how many pounds of Big Fish did you harvest? Please write your best estimate

2017	2018
4-6 lbs ________	4-6 lbs_________
>6 lbs _________	>6 lbs _________

10. Biggest fish to come from your farm?

Channel	Hybrid
__________ pounds	_____________ pounds

11. How old do you think the fish above was (please write your best guess)?

Channel	Hybrid
_________ years	_________ years

12. **What do you think contributes most to Big Fish (> 4 pounds) on your farm?**
Select the 3 biggest factors.

[ ] seining/capture inefficiency

[ ] use of hybrid catfish

[ ] irregular pond shape

[ ] uneven pond bottom

[ ] not enough harvests per pond per year

[ ] rangy fingerlings (wide size variation)

[ ] multiple batch production system

[ ] other (please explain) ______________

13. **What methods have you taken on your farm to control or reduce Big Fish (> 4 pounds)?**
Select your 3 most used methods.

[ ] increase stocking rates

[ ] reduce stocking rates

[ ] reduce feeding rates

[ ] use a firearm to kill Big Fish

[ ] use rotenone to kill remaining fish after harvest

[ ] multiple seinings after harvest

[ ] re-work pond bottom to improve seining efficiency

[ ] follow regular schedule of draining ponds

[ ] using a gill net to target Big Fish

[ ] other (please explain) ________________

14. **How many acres of hybrid production did you have in 2017 and 2018?**

2017	2018
___________ acres	___________ acres

15. If you raise hybrids (or have raised them in the past), do you feel like they are more likely to result in a Big Fish problem compared to Channel Catfish?

Check one

[ ] Yes

[ ] No

16. In 2019, do you plan to _________?

Check one

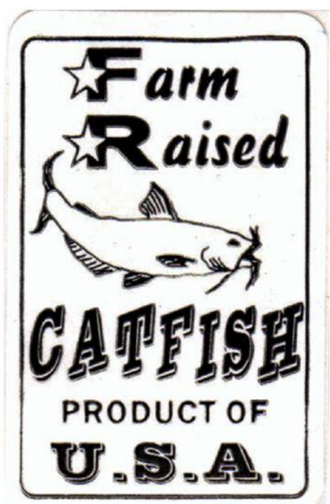
[ ] switch to raising hybrids
[ ] continue raising hybrids
[ ] switch to raising channels
[ ] continue raising channels
[ ] other

17. What is the longest amount of time it has taken you to get a pond on flavor?

[ ] 1-3 weeks
[ ] 1 month
[ ] 2-3 months
[ ] longer _____ months

18. Please provide info on your pond types

Pond Type	Total Acres	Avg Water Depth	Max Water Depth	Min Water Depth
Embankment (levee)				
Watershed				
Hybrid Watershed-Embankment				



19. What do you consider to be the biggest concern on your farm that could affect profitability?
Please select your top 3 concerns

[ ] low price paid by processor

[ ] disease mortality

[ ] Big Fish

[ ] feed prices

[ ] not able to get the number of fingerlings needed when you need them

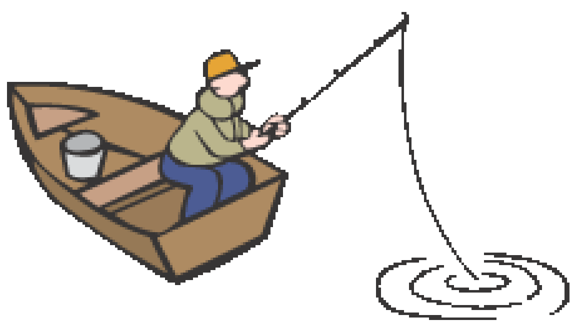
[ ] blue-green algae/ off flavor

[ ] low oxygen mortality

[ ] toxic algae mortality

[ ] imported aquaculture products

[ ] other ___________



The next set of questions deal with zeroing out ponds and pond renovation.

20. Did you clean out or zero out your ponds before starting a new production cycle in 2017 or 2018?

2017		2018	
[ ]	Yes	[ ]	Yes
[ ]	No	[ ]	No (if "no" to both skip to question 22)

21. What methods have you used in the past to clean out or zero out your ponds?

[ ] multiple seine pulls before restocking fingerlings

[ ] applying rotenone to kill missed fish

[ ] draining and refilling the ponds before restocking

[ ] other _______________

[ ] not applicable

22. How often do you renovate your ponds (completely drain the pond and rework the bottom)?

[ ] 10% of your ponds each year

[ ] every 10 years

[ ] every 20 years

[ ] other ___________

[ ] as needed, which is an average of _____ years between each pond renovation

23. What is the last year you renovated any of your ponds (completely drained the pond and renovated the bottom)?

_______________ year (ex. 2010)

24. Number of acres renovated that year (in question 23)?

______________ acres

25. When you have renovated your ponds, what was the topography of your pond bottom?

[ ] flat

[ ] holes and depressions

[ ] deep troughs running the length of pond (catfish super highway)

[ ] thick mud

[ ] other ___________

26. When you renovate your ponds, how long is that pond out of production?

[ ] 1 year

[ ] 2 years

[ ] 3 years

[ ] __________ months

27. **When you renovate your ponds, who does the work?**

[ ] you

[ ] contractor

28. **When you renovate your ponds, how do you refill them?**

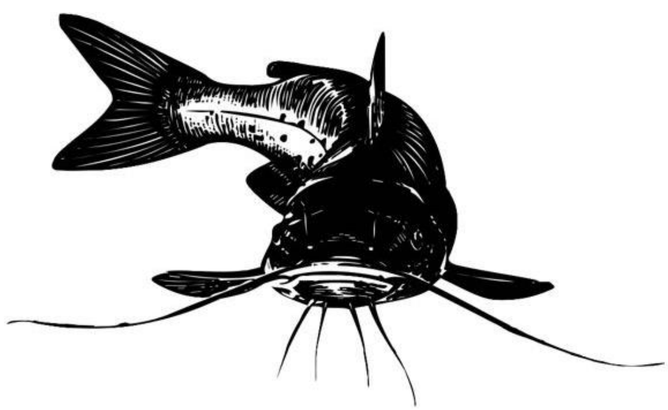
[ ] well water

[ ] watershed runoff

[ ] stream/river

[ ] pumping from another pond

[ ] other ______________



The next set of questions will ask for 2017 and 2018 data and projected data for 2019

29. In 2017 and 2018, how many acres of channel and/or hybrid catfish were stocked? (Put 0 if you did not stock one species)

2017	2018
Channels ________ acres	Channels _______ acres
Hybrids _________ acres	Hybrids ________ acres

30. If you raise hybrid catfish, what year did you start raising hybrids?

__________ year (ex. 2010)

31. What acreage did you manage in single-batch or multiple-batch production systems in 2017 and 2018?

2017	2018
Single-batch _________ acres	Single-batch ________ acres
Multiple-batch ________acres	Multiple-batch ______ acres

32. **If you use a multiple-batch system, how many batches do you attempt to maintain in the pond at any one time? How many do you expect to maintain in 2019?**

2017	2018	2019
[ ] 2	[ ] 2	[ ] 2
[ ] 3	[ ] 3	[ ] 3
[ ] 4	[ ] 4	[ ] 4
[ ] other ____	[ ] other ____	[ ] other__

33. **What is the average length of a typical production cycle?**

2017	2018
Channel _______ months	Channel ______ months
Hybrid ________ months	Hybrid _______ months

34. **On average, how many times per year is each pond <u>stocked</u>?**

Check one box per year

2017		2018	
[ ]	1	[ ]	1
[ ]	2	[ ]	2
[ ]	3	[ ]	3
[ ]	other _____ #	[ ]	other _____ #

35. **On average, how many times per year is each pond <u>harvested?</u>**

Check one box per year

2017		2018	
[ ]	1	[ ]	1
[ ]	2	[ ]	2
[ ]	3	[ ]	3
[ ]	4	[ ]	4
[ ]	other ____ #	[ ]	other ____ #

36. On average, how many seine pulls do you obtain per harvest event?

Check one box per year

2017		2018	
[ ]	1	[ ]	1
[ ]	2	[ ]	2
[ ]	3	[ ]	3
[ ]	4	[ ]	4
[ ]	other _____ #	[ ]	other ____ #

37. In 2017 or 2018, did you postpone harvest of market ready fish in hopes the price of fish would increase?

2017		2018	
[ ]	Yes	[ ]	Yes
[ ]	No	[ ]	No

38. If yes to question 37, what is the longest time you postponed harvest waiting for the price of fish to increase?

[ ] 1-3 weeks

[ ] 1 month

[ ] 2-3 months

[ ] longer _______ months

39. **In 2019, will your stocking density change, and to what number per acre?**

Channels	Hybrids
[ ] increase, to what ___	[ ] increase, to what ___
[ ] decrease, to what ___	[ ] decrease, to what ___
[ ] no change	[ ] no change

40. **In 2019, will you stock 100% of your ponds?**

[ ] Yes [ ] No

41. **If no to question 40, what percentage of all your ponds will you stock?**

________ percent

The next set of questions will ask for general information about you and your farm.

42. **What is your age?**

[ ] 18-24

[ ] 25-34

[ ] 35-44

[ ] 45-54

[ ] 55-64

[ ] 65 and up

43. What is your gender?

[ ] Male

[ ] Female

44. What is your role on the farm?

[ ] owner/operator

[ ] owner not actively managing

[ ] manager

[ ] other ______

45. How many years of experience do you have raising catfish?

___________ years

46. In what county is your farm located?

____

47. Did you use size-graded channel or hybrid fingerlings in 2017 and/or 2018, or will you use them in 2019?

2017	2018	2019
[ ] channel	[ ] channel	[ ] channel
[ ] hybrid	[ ] hybrid	[ ] hybrid
[ ] both	[ ] both	[ ] both
[ ] did not use	[ ] did not use	[ ] did not use
[ ] could not get them	[ ] could not get them	[ ] could not get them

48. Pond water source (check all that apply):

[ ] well

[ ] surface water runoff

[ ] stream/river

[ ] other, please explain __________

49. How many ponds are difficult to harvest?

____

50. What is the difficulty in harvesting these ponds?

[ ] irregular pond shape

[ ] uneven pond bottom

[ ] thick mud on the bottom

[ ] not enough mud on the bottom

[ ] other, please explain ___________

51. In the past two years, did you feed less or more due to Big Fish problem?

2017		2018	
[ ]	____ % less	[ ]	____ % less
[ ]	No change	[ ]	No change
[ ]	____ % more	[ ]	_____ % more

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

________________________ hp per water acre

53. Who harvests your ponds?

[ ] own harvest crew

[ ] processor harvest crew

[ ] custom harvest crew

[ ] other _____________

54. Please write any comments you may have for us here.

Thank you very much for completing this survey. Please put the completed survey in the enclosed, pre- stamped envelope and return to us. Thank you for your time.

Sincerely,

Daniel Creel