An Economic Comparison of Three Intensive Fish Production Systems

by

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Abstract

A study was conducted to compare the economic costs and returns of three intensive aquaculture production systems located in Auburn and Browns, Alabama. The objective of this project was to examine the potential profitability of intensive aquaculture systems which utilize non-traditional methods of fish production. Three intensive fish production systems were chosen based on their use of modern aquaculture technologies and include an indoor recirculating tilapia system, an integrated tilapia/cucumber greenhouse system, and a catfish floating in-pond raceway system. Enterprise budgets were developed to analyze the economic feasibility, advantages and disadvantages of each system. Economic comparisons were made among systems in three areas; specifically, fixed and variable cost of production and breakeven price. Additionally, total cost and net returns for each system were calculated.

Cost and return budget elements varied by system and were closely linked to the stage of development of each system as it is deployed on each commercial farm. Lower net returns were associated with the systems that were newer and where managerial and operational procedures were being developed and where mechanical ‘kinks’ were still being worked out. Systems that had two or three years of operational and marketing experience were more feasible. Thus, these newer systems may likely take a few years after initiation to become viable commercial enterprises and reach their optimal levels of production and efficiency.

For this study, floating in-pond raceways were designed and built to improve upon traditional pond culture by offering reduced manpower, higher stocking densities, ease of

feeding, grading and complete harvest, precise disease treatment, and collection potential of fish wastes. The calculated investment cost was $128,348 for the 24 raceway units ($5,348 per raceway) including cost for associated piers, electrical system, and machinery and equipment. The actual growth of catfish was tracked and the cost of production was calculated to be $1.58/lb for channel catfish and $1.43/lb for hybrid catfish. However, scenarios using data with improved efficiencies at a commercial scale had estimated cost of production of $0.72/lb for channel catfish, $1.56/lb for grass carp (a high value market item in china), and $0.83/lb for tilapia.

An indoor recirculating tilapia system which has been in commercial production for four years was found to produce market-sized tilapia at $1.59/lb; and could be sold for $2.10/lb live weight, providing a $0.49/lb net return. In the integrated tilapia/cucumber greenhouse system the benefits of incorporating vegetable production with fish production were found to be worthwhile. Tilapia from this integrated, intensive system had a cost of production of $1.55/lb and cucumbers cost $0.25/lb to produce; and the system had a $0.73/lb net return based on $2.10/lb and $1.00/lb tilapia and cucumber selling price, respectively.

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List of Abbreviations

FIPRS	Floating In-Pond Raceway System
IPRS	In-pond Raceway System
ITCGS	Integrated Tilapia/Cucumber Greenhouse System
IRTS	Indoor Recirculating Tilapia System
FCR	Feed Conversion Ratio
RW	Raceway
GH	Greenhouse

Chapter I

Introduction

Aquaculture is one of the fastest growing venues of agriculture (Larsen and Roney 2013). Fish production surpassed beef production in 2013 suggesting a global protein shift in human diet towards fish. Fish production is projected to continue increasing and is expected to continue to surpass other food protein resources (Blumenthal 2013). The global price of fish is steadily increasing due to a rising demand for a healthy protein source and is expected to continue to strengthen in years ahead (Blumenthal 2013; Holliman et al. 2008). Over-harvest and water pollution have restricted harvest and supply of wild-caught fish populations destined for human consumption and, consequently, increased demand towards farm-raised fish (Holliman et al. 2008). As predicted by aquaculture pioneers, with increasing human populations, the world will lean less on capture fisheries and depend more on farm-raised fish (Blumenthal 2013). Authors speculate 2013 may be the year farm-raised fish consumption surpasses wild-caught fish in the United States (U.S.) (Larsen and Roney 2013).

In 2011, an estimated $423 million worth of food-sized catfish were produced making it the largest segment of U.S. aquaculture (USDA 2013). The majority of catfish production is done in the southeast with the main producing states being Mississippi, Alabama, Arkansas, and Texas (USDA 2013). Alabama was ranked second in catfish production behind Mississippi with Alabama growers having produced 38 percent of total live weight harvested across the U.S. in 2012 (USDA 2013). There are currently around

18,175 water acres being used in catfish production in Alabama, down 27 percent from 2005 (USDA 2006; USDA 2013). In 2012, food-sized catfish sales in Alabama totaled more than $110 million with the average price per pound being $0.90 (USDA 2013).

As the second most popular food-fish in the world, there are conflicting views on whether or not tilapia are displacing catfish in the U.S. fish market because of their rapid rise in popularity (Blumenthal 2013). Improved genetics and the tilapia's ability to grow well in a range of intensive systems have allowed the production of these species to advance quickly in the U.S. (Watanabe 2002). In 2010, the U.S. continued to be the largest market for tilapia products with sales reaching over $840 million from imported fish alone (Fitzsimmons et al. 2011). Aggressive pricing by tilapia suppliers has allowed this species to take over in many markets, especially in the northeast (Blumenthal 2013). According to personal communications with industry personnel, Alabama tilapia growers produced around 200 tons of tilapia in 2013 at an average of $2.10/lb (Chappell 2014, personal communication).

Despite being a well-established segment of U.S. aquaculture, the catfish industry has been under duress the past decade with over 50 percent of its farmers leaving the industry (Stewart 2013). Farmers from Alabama and Mississippi have kept the most water area in catfish production despite the 109 percent increase in feed prices and wavering consumer base (Stewart 2013; USDA 2013). The profit margin for catfish farmers has become thin to nonexistent as input prices for production rise and sale prices decrease (Holliman et al. 2008). Surviving the current market and turning a profit for aquaculture producers will require organization to maximize efficiency in production past what traditional pond culture is capable of achieving (Holliman et al. 2008). Farm survival in many instances may require farmers to intensify production to stay profitable by producing more fish per unit volume, lower the cost per unit of product, and extend market access (Holliman et al. 2008).

Moving past current pond culturing methods and selecting the right intensive production system is an important choice the industry must address to meet future demand. Such a system should be chosen based on its ability to produce greater amounts of fish using fewer resources and/or more cost-effective resources. Water, land, nutrient resources and energy are the main aquaculture resources for aquaculture which are becoming more scarce and expensive (Boyd et al. 2008; Schneider et al. 2005). Higher stocking densities tend to lower breakeven prices attracting fish farmers to intensive fish production systems despite their relatively high startup cost (Southworth et al. 2006). Out of the four basic types of fish culture systems, raceways have the potential to emerge as the most profitable (Masser and Lazur 1997). Advantages to raceway systems include reduced manpower, higher stocking densities, improved water quality, ease of feeding, grading and complete harvest, precise disease treatment, collection potential of fish wastes, and less off-flavor (Masser and Lazur 1997).

Ponds are often referred to by farmers as 'black holes' because of the lack of control a producer has over the fish inventory and the growing environment once fish are released into the pond (Blumenthal 2013). Raceways were designed and have been further developed to solve these problematic issues arising from pond culture (Masser and Lazur 1997). Blumenthal's (2013) analysis of the catfish industry suggests problems with mortality, seining, feed conversion ratio (FCR), predators, disease, cannibalism and inventory knowledge. Each could be significantly reduced with the use of raceway systems. Blumenthal's survey found catfish farmers believed they had an average 45 percent loss of their fish crop in each production cycle, which is high when compared to other agriculture or livestock production systems. The majority of mortalities were said to come from disease, cannibalism and bird predation. It was also noted that recent advances in raceway technologies have consistently demonstrated 90 percent survival.

Historically, catfish and tilapia have been cultured in earthen ponds and have even been shown to do well when grown together with other fish species in polyculture (Rakocy and McGinty 1989). The development of the raceway concept originated in the trout industry decades ago and has since taken many forms culturing a number of different fish species (Hinshaw et al. 2004; Regan 2011). Fixed in-pond raceways were developed to help solve problems involved in pond culture (Regan 2011). The fixed in-pond raceway concentrates catfish into open-ended concrete cells while also allowing the co-culturing of secondary species like tilapia and paddlefish outside of the raceway cells to help with water quality (Brown 2010). Floating in-pond raceways were engineered with the same principles behind the fixed in-pond raceways (Regan 2011). Floating in-pond raceways can be built using cheaper materials than concrete and do not involve permanently altering the pond (Masser and Lazur 1997; Regan 2011). Masser and Lazur (1997) designed wooden in-pond raceways with an airlift pump and waste removal system that traditional raceways and cages lacked.

Unlike catfish, tilapia cannot overwinter in ponds in most regions of the U.S. Tilapia are a very resilient species with a low temperature tolerance making them a good species to culture in an indoor setting (Watanabe 2013). Culturing tilapia in temperature-controlled structures like greenhouses or barns enables producers to grow tilapia year round (Watanabe 2013). Indoor fish culture has been integrated with hydroponics to produce a segment of aquaculture with rising popularity called aquaponics (Holliman et al. 2008; Rakocy et al. 2006). The integration of fish and plant production in a recirculating system allows for nutrient-rich waste products from cultured species to be used to produce plants of economic value (Holliman et al. 2008). The intensification of cultured species and niche markets for aquaponic products may be the necessary combination for profitability in an industry currently facing many obstacles (Blumenthal 2013; Rakocy et al. 2006).

With a number of intensive systems available it is essential to use careful financial planning to ensure the success of an aquaculture business. Such planning involves using economic tools and analyses to thoroughly comprehend the potential financial strengths and weaknesses of an enterprise (Engle 2012a). An enterprise budget is a tool available to farm managers to give insight on the potential profitability of an enterprise using a typical set of cost, prices, yields, and feed conversion (Engle 2012a). The information contained in an enterprise budget enables farmers to estimate breakeven prices, production cost, and select between competing production alternatives (Dillon 1993). An enterprise budget consists of two major components, fixed cost and variable cost. The variable cost in this study included all items bought when the farm was producing fish while fixed cost items were present regardless of whether fish were being produced. Depreciation, which is defined as the cash value loss of capital items over time, is included to replace or account for their value as the equipment items wear out in the production process (Engle 2012b).

Enterprise budgets are also helpful for looking at what it will take for a business to survive in the long run (Engle and Stone 1997). In order to be viable in the long run, a farm must first survive the short run (the next year), which requires fish to be sold at a price to cover all the costs needed for fish production, i.e., the variable cost. The breakeven cost to cover the variable cost of production is equal to the variable cost divided by the pounds of fish produced (Engle 2012a; Engle 2012b). Farm survival requires sufficient funds to cover total cost, i.e., the variable and fixed cost. The breakeven price is the fish selling price needed to produce enough income to cover expenses. The breakeven price to cover all production costs is equal to the total cost divided by the pounds produced (Engle 2012a; Engle 2012b). Gross income is the amount of sales revenue, while the net return is the overall income left after deducting all farm expenses from the gross income.

The overall goal of this study was to present current fish farmers and future aquaculturists with an economic examination of different types of intensive production systems utilizing non-traditional pond methods of fish production. Three systems were chosen based on their use of modern aquaculture technologies and potential profitability. They include: 1) an indoor recirculating tilapia system (IRTS), 2) integrated tilapia/cucumber greenhouse system (ITCGS) and 3) a floating in-pond raceway system (FIPRS). The objectives of this study were to:

1. Develop an investment spreadsheet that includes the total construction cost (fixed cost), depreciation, and interest on loans for the three systems.
2. Determine the total operating cost (variable cost) for the three systems.

3. Combine fixed and variable cost to determine the total cost of production for the three systems and calculate breakeven prices, total cost, and net return.
4. Conduct sensitivity analyses for input (feed) and output (fish) prices to determine how varying prices for these items will affect production costs and profitability.

Chapter 2

Materials and Methods

Enterprise budgets were developed for each system using standard farm management procedures, this included the development of a depreciation schedule (using straight-line depreciation), other fixed costs such as interest on investment loans, and repairs and maintenance. The economic lives of items were calculated to most accurately reflect the expected lifetime use of each item. The economic life for capital items associated with the FIPRS were based on discussions with experienced industry personnel familiar with equipment being in the water for long periods of time. The managers for the IRTS and ITCGS estimated the useful life of capital items for their systems based on expectations they had for the duration each item could be used until needing to be replaced. Variable costs were calculated from data for each system. Each system had its own unique aspects; the FIPRS and ITCGS are experimental systems at the Auburn research station while the IRTS has been in existence and operational for four years. We still do not have true knowledge on how long the equipment, machinery, and capital goods will last so these are the best estimates after discussing economic life expectancies with experienced industry personnel.

Comparisons were made between competing enterprises to determine relative profitability (Dillon 1993). Sensitivity analyses were applied to enterprise budgets to show the effect of varying market prices for fish and the feed input price on net returns. This is an important tool to evaluate the overall risk of an enterprise and to identify critical factors in order to predict alternative outcomes (Dillon 1993). The information collected for the enterprise budgets in this study came from two primary sources (FIPRS and Dean Wilson Farm) and one secondary source (Danaher, Ph.D. and Pickens, presentation).

Indoor Recirculating Tilapia System (IRTS)

Construction and production data were collected from a commercial-scale IRTS system located on a 428-acre catfish farm in Browns, Alabama. The recirculating system was housed in a barn (70 ft width x 170 ft length x 16 ft height) which contained 15 raceways (8 ft width x 42 ft length x 4 ft depth). There were five fiberglass grow-out raceways (12,000 gallons each), five wooden raceways (15,000 gallons each), and five cement raceways (6,000 gallons each, Figure 2.1). Five cement raceways were divided into a 5,000 gallon sections for stocker sized-fish (stocker tanks) and a 1,000 gallon section for fingerlings (nursery tanks). Five of the fiberglass grow-out raceways had a built-in solids removal and biological filtration system and five of the wooden grow-out raceways were equipped with polygeyser bead filters. Wooden walkways were constructed to allow easy access to each raceway. Water was supplied to the system from an outdoor pond reservoir (6 acre) and a 6-inch well (120 gallons per minute (gpm) at 78°F steady water temperature). The water for the grow-out raceways was recirculated back to the same tanks after passing through the respective filtration systems. The cement raceways were flow-through systems and wastewater was pumped into an outdoor collection pond.

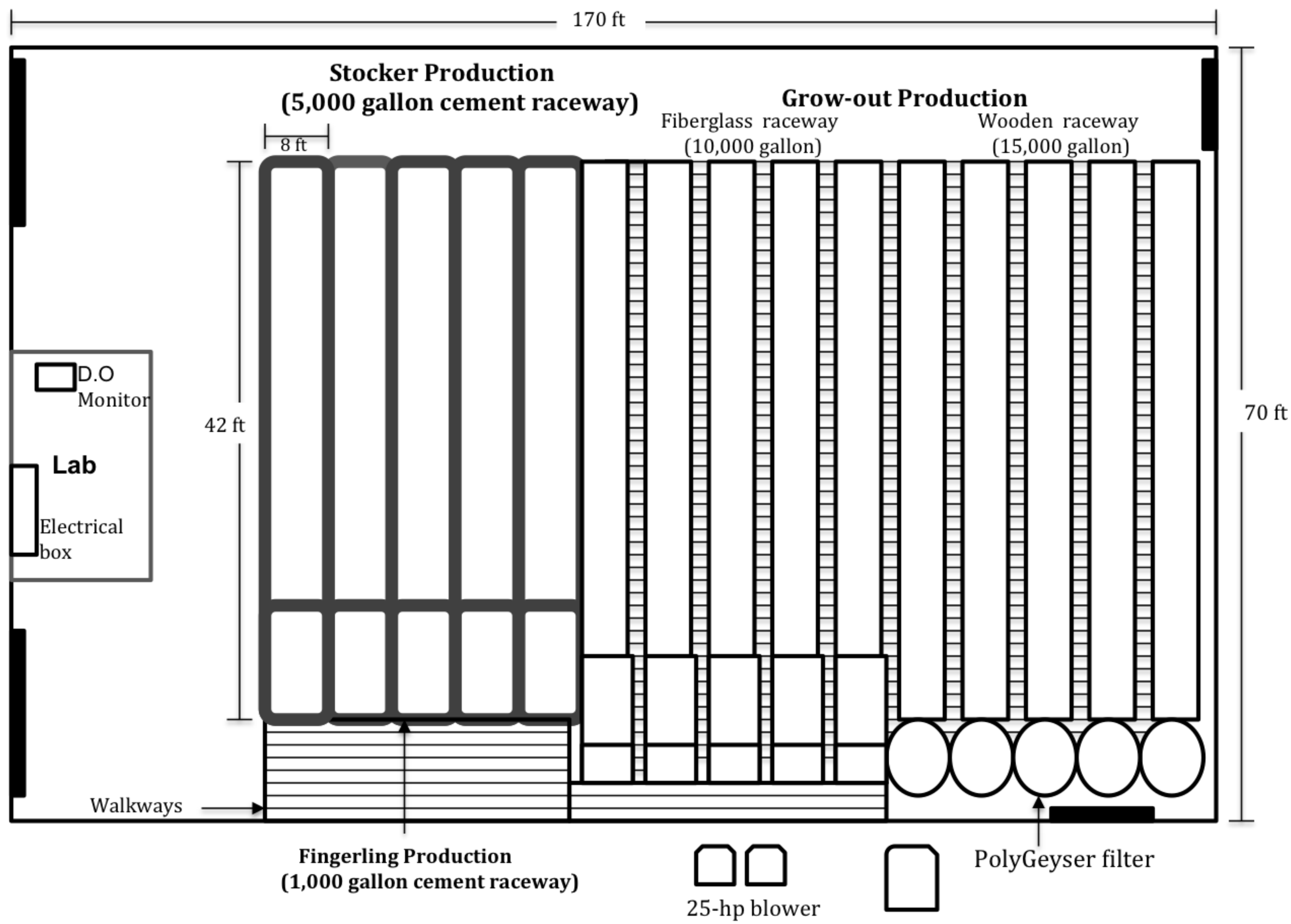
Aeration for the grow-out raceways was supplied by two 25-horsepower (hp) blowers (Roots rotary lobe blower, 25-hp, Dresser Inc.) and diffuser tubes lining the bottom sides of each raceway while aeration for the cement raceways was supplied by two 1.5-hp blowers (regenerative blower, 1.5-hp, Sweetwater®). A wood burner (outdoor wood furnace, 500,000 btu, Central Boiler, Inc.) was used during winter months to heat water, which was pumped through PVC pipes placed in the raceways. The barn was equipped with an electrical system (PowerFlex 400, 240-volt 3-phase, Allen Bradley), monitoring system (pond monitoring system, In-Situ Inc.), and backup generator (natural gas/propane generator, 35-kW 3-phase, Cummins Onan). The monitoring system recorded water temperatures and oxygen levels on two-minute feedback intervals and also included an autodialer, recirculating system monitor, and computer-aided management system. The autodialer was programmed to notify system managers during emergency situations, such as when there was a power outage or a low dissolved oxygen (D.O.) concentration event. The D.O. monitoring system was installed in each raceway and used the computer-aided management program to oversee the measurements for the entire system. The barn was also equipped with a water quality lab to monitor pH and water salinity levels once daily, ammonia once a week, and other water quality parameters as needed.

Tilapia were sourced from the E. W. Shell Fisheries Center, Auburn, Alabama; Americulture Inc., Animas, New Mexico; and Aquasafra, Brandenton, Florida. The fingerlings were stocked into the five nursery tanks almost biweekly throughout the production year. Fingerlings ranged from 0.018-0.176 ounces each and were moved to the five stocker tanks after 10 weeks in production. After 20 weeks in production the tilapia were stocked into the grow-out tanks and held for an additional 20 weeks or until they reached market size. The fish were offered a 36 percent protein commercial floating feed (Cargill Inc., New Orleans, Louisiana) multiple times a day in amounts appropriate with the percent body weight. Production data used in this study were collected from personal communications with the system manager and farm records. It should be noted the production system, in part, was initially built in 2010 but the production data used in this study only came from the 2012-2013 records after the cement tanks were constructed.

The construction cost for the IRTS were assimilated to estimate an investment cost close to the actual cost of the system. The capital, machinery, and equipment cost were determined and placed into a fixed cost category for further economic analysis. The production data from the 2012-2013 farm records were used to establish production parameters to accurately estimate the required operational expenses. Items associated with producing the tilapia were organized into a variable cost category and used to develop an enterprise budget for the system.

Once the enterprise budget was completed, sensitivity analyses tables were developed to show the effect of varying market prices received per pound of tilapia and feed costs on net returns. A survival sensitivity analysis table was also developed to examine how net returns above variable and total cost would be affected by a range of survival percentages.

Figure 2.1. A schematic of the indoor recirculating tilapia system (IRTS) in West Alabama.



Floating In-Pond Raceway System (FIPRS)

This portion of the study was conducted in two traditional earthen ponds, S-6 (26 acres) and S-1 (23 acres), located in Auburn, Alabama. The raceways were built and assembled at the Agriculture Land and Resources Management Center in Auburn and then transported to the ponds. Each FIPRS contained 12 floating raceways attached to a floating wooden dock (Figure 2.3 and 2.4). Each raceway (6 ft width x 20 ft length x 5 ft depth) was attached to an aluminum water-moving unit (6 ft width x 4 ft length x 3 ft height). A PVC frame fitted with 31 diffuser tubes (100 ft in total) rested inside an aluminum hood and was connected to a blower by seven feet of Rollerflex suction hose. Two raceway units shared a 1.5-hp blower (regenerative blower, 1.5-hp, Sweetwater®) to supply airflow to the water moving units.

The raceways were constructed using a 0.79-inch PVC liner (18 ft width x 20 ft length) attached to an aluminum frame (6 ft width x 20 ft length) fitted with 1-inch x 1-inch PVC coated metal screen. Each wall running length-wise of the raceway was supported by two pieces of treated lumber (2 inch width x 12 inch length x 5 ft height) joined at the top by 20 feet of low-profile aluminum uni-strut. The front and back of the raceways had removable aluminum frames (5.5 ft width x 5 ft length) fitted with 1 inch x 0. 5-inch PVC coated metal screens. Two 8-inch diameter PVC pipes, 20 feet long were attached to the top of the walls and held in place by galvanized pipe clamps.

The raceways in the 26-acre pond (S-6) were placed 45 feet from the pond's edge to achieve at least 8 feet of water depth. Raceways and blowers were attached to a floating wooden dock (8 ft width x 96 ft length) with an additional 45 feet of dock being attached so the raceways would be accessible from the pond bank. A second set of floating raceways were placed in a 23-acre pond (S-1) which had adequate water depth without the need of additional floating docks aside from those required to access the raceways and blowers. A backup generator (power generator, 20-kW, Eaton Corporation) and propane tank were installed for each system in case of a power outage.

Catfishes were stocked (E. W. Shell Fisheries Center, Auburn) into six raceways with fingerlings ranging from 0.59-0.75 inches total length (0.95-1.76 ounces each). Two raceways were stocked with mixed strains of channel catfish, two raceways with mixed strains of blue catfish, and two raceways with hybrid catfish (blue x channel). The fish were offered a 32 percent protein commercial floating feed (Alabama Feed Mill, Uniontown, Alabama) and fed to satiation once daily. Raceways were sampled once every two weeks to monitor growth. Production data collected for the FIPRS was based on fish grown over a five-month period. It should be noted these crops of fish were an initial test batch for this specific FIPRS; consequently, raceways had a lower stocking rate than expected for the future and were not fed aggressively. Minimal mortalities were observed throughout the culture period.

A list of actual construction costs and equipment purchases was developed for the FIPRS units. Economic components (capital cost, equipment and machinery cost, repairs and maintenance, and annual depreciation) were calculated for the investment cost associated with the FIPRS at ponds S-6 and S-1. Costs for structures like wells or ponds were not included in the enterprise budgets throughout this study if previously existing at the site before system construction was initiated. The 59 land acres holding the two ponds where the FIPRS units were owned by Auburn University, thus pond construction and land purchase were excluded from the financial analysis.

Field data assimilated over the culture period served as the production parameters used to estimate the required operational expenses. Three stocking scenarios were developed to project the production data estimated from the five-month study over the entire system utilizing the 24 available cells. The first scenario shows the potential profitability of culturing channel and hybrid catfish. The second scenario illustrates the potential profitability of a hybrid catfish-only system while the final scenario projected the profitability of an all channel catfish system. Enterprise budget simulations were developed for the three scenarios based on the five-month production study. The income above total cost for each enterprise budget was the return to the land, labor, and management resources. Interest on equipment and machinery purchases, operating capital and FIPR construction costs were charged at 8 percent per annum and is included in the financial analysis.

Once the enterprise budget simulations were complete, sensitivity analyses were conducted to compare the impact of fluctuating feed prices and individual stocker selling prices would have on the net returns for each scenario. The scenario we used were as follows: catfish were sold as individuals rather than per pound to increase profit opportunity reflecting the strategy most farmers would employ to keep returns in line with a positive rate of return, given high input cost associated with small scale as opposed to forced marketing on a wholesale schedule to processors. Sensitivity analyses were then applied to net returns above all cost and above variable cost only at varying survival percentages to see if the system in each scenario could become profitable in the long run.

Figure 2.2 A schematic of the floating in-pond raceway system (FIPRS) at Auburn University, Auburn, Alabama. The system is located at S-6, a 26-acre pond.

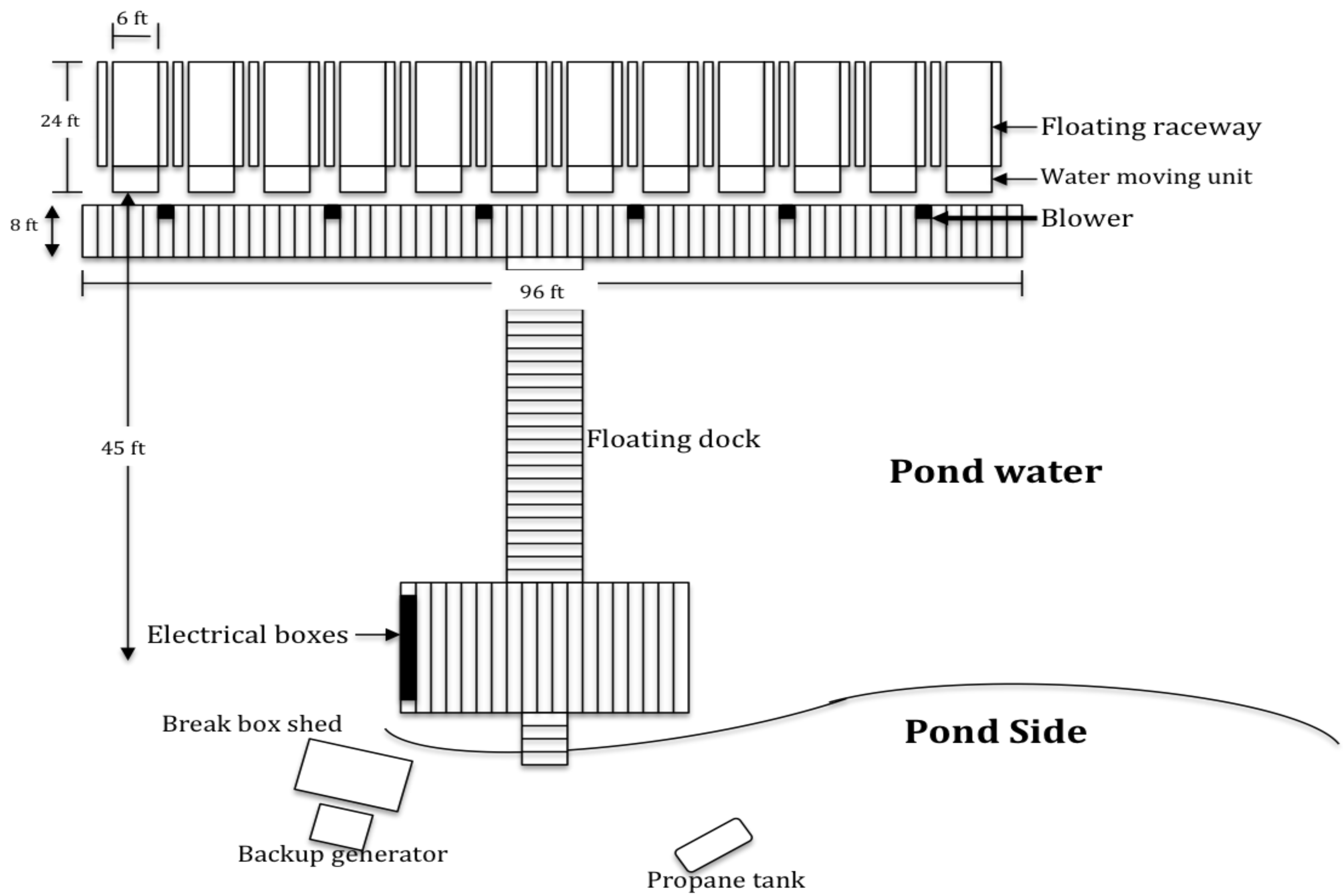
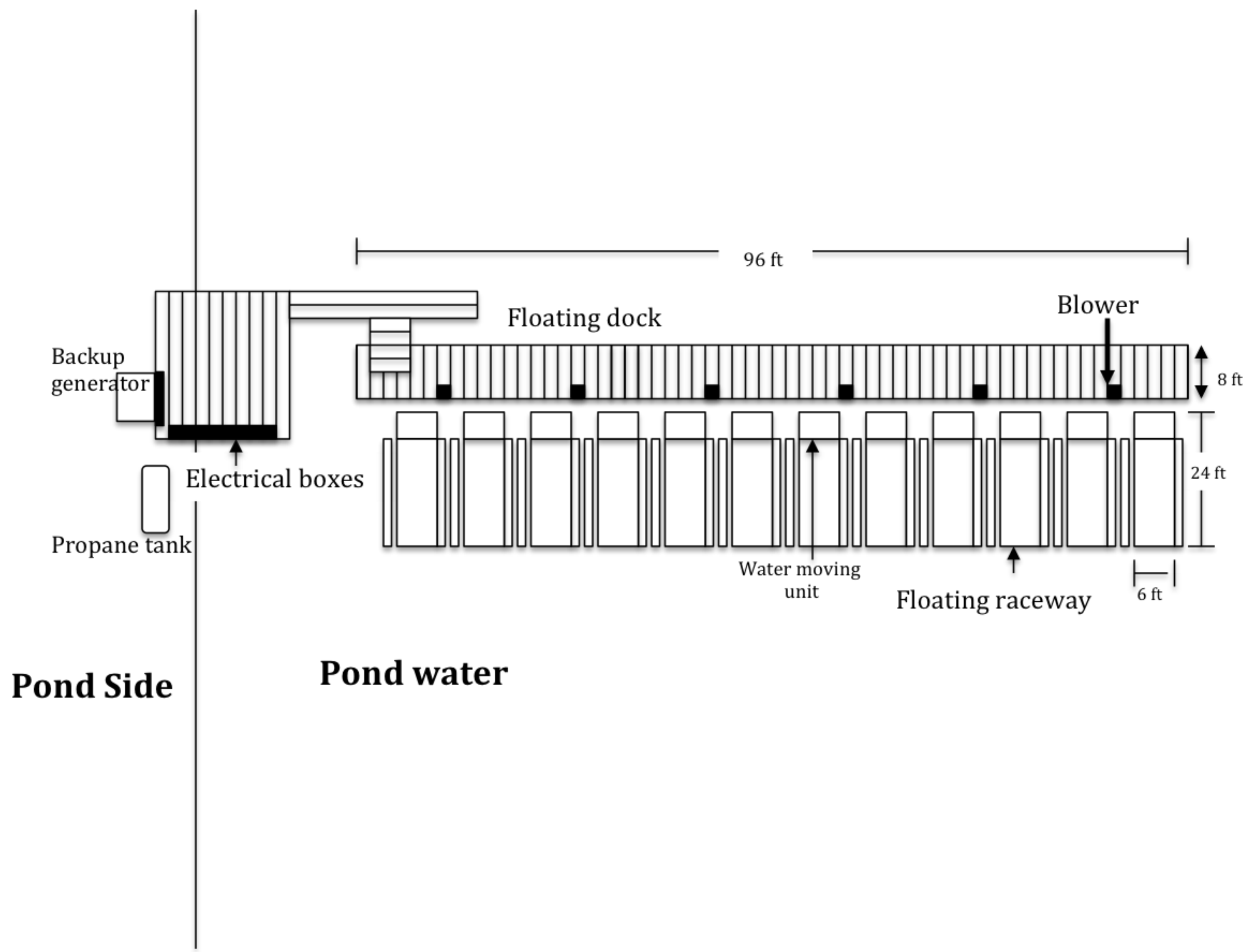


Figure 2.3 A schematic of the floating in-pond raceway system (FIPRS) at Auburn University, Auburn, Alabama. The system is located at S-1, a 23-acre pond.



Integrated Tilapia/Cucumber Greenhouse System (ITCGS)

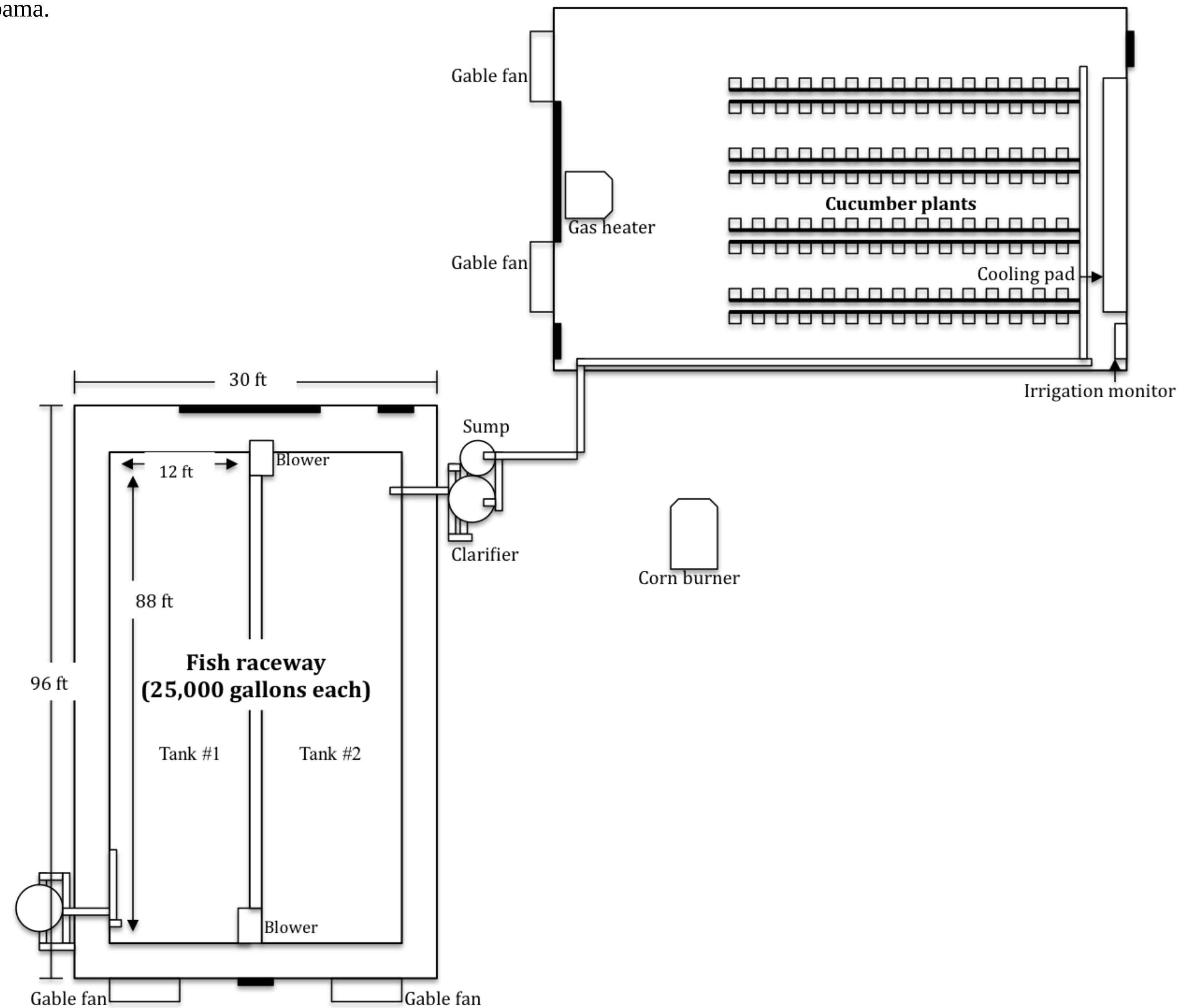
Information on the ITCGS was gathered from secondary sources (Danaher 2012; Danaher 2013; Danaher et al. 2013a; Danaher et al. 2013b; Danaher et al. 2013c; Pickens 2013, personal communication). The ITCGS model is located on the E. W. Shell Fisheries Center facility in Auburn, Alabama. The study site consisted of two greenhouses (30 ft width x 96 ft length x 14 ft height), one containing fish raceways and the other containing plant production structures (Figure 2.2). The greenhouse equipped for fish production contained two raceways supplied by both rain-water reservoir and a well water source. Each 25,000 gallon raceway (12 ft width x 88 ft length x 4 ft depth) was constructed using HDPE membrane liner, wood, and reinforced with steel channel iron beams to strengthen the side-walls.

Continual aeration was supplied by two 1.5-hp blowers (regenerative blower, 1.5-hp, Sweetwater®) and diffuser tubing running the length of the bottom side walls of the raceways. Each raceway was equipped with an airlift device tasked to slowly direct 0-5 gallons per minute of system water to a 500 gallon solids settling tank (clarifier) installed on the outside of the greenhouse. The clarifiers allowed up to 25 percent of the raceway's water volume to pass through daily at a rate of five gpm. Water passing through the clarifier flowed to a polishing sump tank which could be used for watering plant and vegetable crops in the adjacent greenhouse equipped for plants. The fish system raceways required 100-250 gallons of water replacement each day to make up for the water being used for solids removal and to irrigate plants on test in the plant greenhouse. An auto-dialer system was installed to notify system managers of problems specifically pertaining to power outage, low water levels or low D.O. concentrations. A heating unit capable of burning corn, wood pellets and such re-newable fuels was used during winter months to heat water, which was pumped through insulated PVC pipes placed in the raceways for use as heat exchangers to warm the water to ≥ 82°F. The fish greenhouse had two temperature-controlled end wall and gable fans to cool the greenhouse during the summer. Shade cloth was also installed during summer to manage excessive solar heat build-up.

The plant greenhouse was equipped with a cooling pad, two end-wall fans and a gable fan, and ten HAF-fans to manage greenhouse temperature during the summer. A pipe loop from the corn/wood fired heater coupled to a fan equipped radiator as well as gas fired heater (natural gas/propane heater, 150,000 btu, Modine) was employed to maintain temperatures appropriate for the plants on tests during the winter season. An irrigation controller, pump, and pump start relay were installed to irrigate (fertigate) the plants using the water from the polishing/sump tank attached to the fish system. The irrigation system was plumbed into an automated timer pre-programmed by the system manager.

Data describing the construction, equipment, and machinery costs for the plant and fish greenhouses were compiled to determine an investment cost appropriate with this particular system (Pickens 2013). These items were organized into a fixed cost category for further discussion on the economic feasibility of an ITCGS. General production data was provided by the operator and used to establish production parameters to estimate operation expenses associated with growing an annual crop of tilapia and cucumbers. Yearly operation cost estimates and fixed cost were put into an enterprise budget to determine net returns and breakeven prices. The enterprise budgets for all systems included values on a per square foot basis rather than per foot cubed to allow the vegetable production of the ITCGS to be included in further discussion and comparisons. The enterprise budget for this system serves as a discussion point for the potential profitability of incorporating vegetable production into fish production. Sensitivity analysis was not applied to the ITCGS.

Figure 2.4 A schematic of the integrated tilapia/cucumber greenhouse system (ITCGS) at Auburn, University, Auburn, Alabama.



Chapter 3

Results and Discussion

Floating In-Pond Raceway System

Investment Cost- The cost to construct one research-scale FIPR cell (with a portion of floating dock) was $2,917 and the associated gear and equipment cost was $2,431, for a total cost of $5,348 (Table 3.1). The construction cost for a 24-cell FIPRS unit was $69,996 with machinery and equipment cost of $58,352 for a total cost of $128,348. Annual depreciation was $7,131 for the capital items and was $2,762 for equipment items (Table 3.2). Brown (2010) conducted a study on a six-cell, fixed in-pond raceway system (IPRS) with a total investment cost of $113,279. The fixed-IPRS system offered 6694 ft^3 of fish culture area while for an additional $15,069 of investment cost the FIPRS units provided an additional 4250 ft^3 area for fish culture.

It should be noted the initially constructed FIPRS units were designed for research, extension, and demonstration purposes much like the small pond facilities found at the E.W. Shell Aquaculture Center (also built to accommodate aquaculture tour groups) and comprise less volume than would be used in commercial farm settings. The floating dock access way was built 60 percent wider than what would be necessary on a farm to allow larger groups of visitors to view the FIPRS. The electrical system was designed to accommodate both the current raceways and future research project needs; consequently, it is more expensive to assemble than what would normally have been spent on an appropriately sized electrical system for the raceways. Thus, capital and equipment cost could probably be reduced by $5,000 to $10,000 for this size unit.

Table 3.1 Floating in-pond raceway system (FIPRS), 1 cell (6 ft width x 24 ft length x 5 ft depth), construction and equipment cost, Auburn, Alabama, 2013.

Item	Unit	Cost/unit	Number	Total cost	Useful life	Average investment	Annual avg. depreciation /1	Interest on investment /2	Repairs as a percent of new cost	Annual repairs and maintenance
A. Capital cost										
Raceway structure	ea	$1,348	1	$1,348	7	$674	$193	$51	10%	$19
Hood	ea	$1,332	1	$1,332	15	$666	$89	$50	10%	$9
Floating dock	ea	$473	0.5	$237	15	$118	$16	$9	10%	$2
Subtotal				$2,917		$1,458	$297	$109		$30
B. Equipment										
Blower, 1.5 hp	ea	$1,020	0.5	$510	15	$255	$34	$19	10%	$3
Back-up generator 20KW	ea	$4,800	0.08	$400	20	$200	$20	$51	10%	$2
Electrical system	ea	$18,000	0.08	$1,500	25	$750	$60	$56	10%	$6
Propane tank installation	ea	$256	0.08	$21	20	$11	$1	$1	10%	$0
Subtotal				$2,431		$1,216	$115	$91		$12
TOTAL				**$5,348**		**$2,674**	**$412**	**$201**		**$41**

/1 Computed by the straight line method with zero salvage value for depreciable items.

/2 No interest is charged for land and pond construction; they are assumed to already exist; equipment items are charged at an intermediate-term interest rate. Charged at 10% on the total value of land with all other depreciable items charged at 10% on one-half of the investment.

Table 3.2 Floating in-pond raceway system (FIPRS), 24 cells (6 ft width x 24 ft length x 5 ft depth), construction and equipment cost, Auburn, Alabama, 2013.

Item	Unit	Cost/unit	Number	Total cost	Useful life	Average investment	Annual avg. depreciation /1	Interest on investment /2	Repairs as a percent of new cost	Annual repairs and maintenance
A. Capital cost										
Raceway structure	ea	$1,348	24	$32,352	7	$16,176	$4,622	$1,213	10%	$462
Hood	ea	$1,332	24	$31,968	15	$15,984	$2,131	$1,199	10%	$213
Floating dock	ea	$473	12	$5,676	15	$2,838	$378	$213	10%	$38
Subtotal				$69,996		$34,998	$7,131	$2,625		$713
B. Equipment										
Blower, 1.5 hp	ea	$1,020	12	$12,240	15	$6,120	$816	$459	10%	$82
Back-up generator 20KW	ea	$4,800	2	$9,600	20	$4,800	$480	$360	10%	$48
Electrical system	ea	$18,000	2	$36,000	25	$18,000	$1,440	$1,350	10%	$144
Propane tank installation	ea	$256	2	$512	20	$256	$26	$19	10%	$3
Subtotal				$58,352		$29,176	$2,762	$2,188		$276
TOTAL				**$128,348**		**$64,174**	**$9,893**	**$4,813**		**$989**

/1 Computed by the straight line method with zero salvage value for depreciable items.

/2 No interest is charged for land and pond construction; they are assumed to already exist; equipment items are charged at an intermediate-term interest rate. Charged at 10% on the total value of land with all other depreciable items charged at 10% on one-half of the investment.

Production Parameters (Table 3.3) – It has to be noted that the following production data are for the first run in the newly constructed FIPRS unit and a steep learning curve was expected and observed. As more operational experience is gained and the capacity and function of the system is explored, greater production quantities produced at lower cost are expected. Additionally, of the six cells stocked, only three had reportable results. Data from the other cells experienced unexpectedly high losses (explained below) that could be partially explained by not having known the exact number of fish stocked in each cell.

Channel and hybrid catfish fingerlings, ranging from 0.79-0.75 inches total length (0.95-1.76 ounces), were grown for an average of 142 days to produce advanced stockers with an average weight of 0.34 lb. Each raceway was stocked with a mean (x) of 5,358 fingerlings, at a mean density of 12 fish per cubic foot. Channel and hybrid catfish fingerling costs were set for this analysis using industry norms at $0.11 and $0.18 each, respectively, while the selling price for the stockers were $0.40 and $0.50 per individual, respectively. The latter prices were conservative estimations based on the selling prices for similar products. The FIPR cells described in this analysis are small experimental units that, if used as described, would most likely be found on smaller farms producing fish for recreational ponds or direct retail markets rather than for wholesale. Smaller farms personally marketing their product to customers have the ability to set the price as opposed to selling to a processor who sets the price. This will be important to keep in mind when later discussing how the price received per fish should be adjusted achieve a positive rate of return.

The channel catfish demonstrated a higher survival rate, at 99.7 percent, while 84 percent of the hybrid catfish survived to harvest. Lower stocking rates may have played a role in the low number of recorded mortalities and lack of disease outbreaks (in this initial production run for the new FIPRS units). Unaccounted fish losses, which were never harvested or collected as mortalities, proved problematic to explain during this study. For example, one raceway cell was found to be missing approximately 50 percent of the channel catfish initially stocked and was excluded from the study analysis because it was considered an outlier. The actual hybrid catfish survival percentage is most likely closer to 99.7 percent survival of the channel catfish but was left at 84 percent because of the lack of accounting for missing fish. After other causes were ruled out, and due to the location and lack of security at the facility site, theft was the most logical explanation for the missing fish. The need for security is a factor that needs to be understood about the FIPRS system but could be addressed and overcome on commercial farms by employing appropriate security measures. At the same time, the confinement production approach featured in FIPRS which employ covering netting easily eliminates avian predation documented to cause significant economic damage in traditionally managed production ponds.

At the end of the growing season, the calculated FCR from data at harvest was 1.6:1 for channel catfish and 1.7:1 for hybrid catfish. The fish were fed to satiation once daily. It is calculated that the hybrid catfish consumed 0.16 tons more feed than the channel catfish during the course of the study. The higher FCR for hybrid catfish is likely due to the increased number of unaccounted fish compared to the channel catfish raceways. The price for feed was $532 per ton with 0.81 and 0.97 tons of feed offered to channel and hybrid catfish, respectively.

Table 3.3 Production parameters per RW for the floating in-pond raceway system (FIPRS), Auburn, Alabama, 2013.

	Unit	Channel catfish	Hybrid catfish
Pounds stocked	lb/RW	375	455
Fingerling cost for 7" fingerlings (6" to 8" range)	$/ea	0.11	0.18
Fingerling weight, 7" fingerling	lb/1,000	70	85
Survival	%	99.7	84
Selling price for advanced stocker	$/ea	0.40	0.50
Average harvest weight	lb	0.24	0.39
Average days for catfish to reach target size	days	142	142
Feed price, 32% protein	$/ton	532	532
Total amount fed, per RW	tons	0.81	0.97
Feed conversion rate		1.6	1.7
Repair and maintenance cost per RW	$/year	41	41
Daily electrical use per RW	KWhr	19.40	19.40

Enterprise Budgets - Feed, fingerlings, and energy for aeration accounted for 92 percent of the variable cost with fingerling cost being the largest single variable expense in all three scenarios. In a commercial operation, feed cost would normally be the largest operational cost, however, because of non-aggressive feeding during the initial five-month study of the raceways, feed was the second most expensive operation cost.

Scenario 3 was the only enterprise to demonstrate a positive net return to cover total and variable cost. In the case of scenarios 1 and 2, the income above variable cost, an indicator of short-term profitability, was positive. This can be interpreted as the operation can continue producing fish for now as all cash costs are covered by the revenue; however, the farm manager would need to make changes over time to ultimately cover all costs so that the long-term net return would eventually become positive (D'Abramo et al. 2013).

Scenario 1 (12 raceway cells growing channel catfish and 12 raceway cells growing hybrid catfish): The average cost to produce a 0.34 lb channel or hybrid catfish stocker was \$0.46 per individual. This cost consisted of \$0.33 per individual to cover operational or variable cost and \$0.13 per individual to cover fixed cost (Table 3.4). The net return above variable cost when using mixed catfish species was \$13,681 (\$4.75/ft^2) while the net return above total cost was \$-1,841 (\$-0.64/ft^2), (Table 3.4).

Scenario 2 (24 raceway cells growing hybrid catfish): The calculated breakeven price was \$0.42 per individual and \$0.56 per individual to cover variable and total cost, respectively (Table 3.5). The income above variable cost were \$9,157 (\$3.18/ft^2) and \$-6,365 (\$-2.21/ft^2) for the net returns above total cost. Scenario 2 demonstrated the highest feed and hybrid fingerling cost of the three scenarios which, consequently made it the least profitable scenario of the three in the long-term.

Scenario 3 (24 raceway cells growing channel catfish): The cost to produce each stocker-sized channel catfish was \$0.38 per individual. This amount consisted of \$0.26 per individual to cover variable cost plus an additional \$0.12 per individual to cover fixed cost (Table 3.6). The net return above variable and total cost was \$18,205 (\$6.32/ft^2) and \$2,684 (\$0.93/ft^2), respectively.

Table 3.4 Scenario 1: Enterprise budget for the floating in-pond raceway system (FIPRS), 24 cells, producing advanced stockers (12 cells hybrid catfish and 12 cells channel catfish).

	Unit	Quantity	Price or cost / unit	Value or cost	Per ft^2 value	Price/cost per stocker	Percent of costs
1. Gross receipts							
Channel catfish sales, 0.24 lb harvest size	indiv	64,103	$ 0.40	25,641		**$ 0.40**	
Hybrid catfish sales, 0.39 lb harvest size	indiv	54,009	$ 0.50	27,004		**$ 0.50**	
Total receipts		**118,112**		**52,646**	**18.28**	**$ 0.45**	
2. Variable cost							
Feed	ton	21	$ 532	11,332	3.93	**$ 0.10**	29%
Channel fingerlings, 5358/raceway*12RW	each	64,296	$0.105	6,751	2.34	**$ 0.06**	17%
Hybrid fingerlings, 5358/raceway*12RW	each	64,296	$0.175	11,252	3.91	**$ 0.10**	29%
Electricity	Kw-hr	83,808	$ 0.08	6,705	2.33	**$ 0.06**	17%
Miscellaneous expenses	per RW	24	$ 30	720	0.25	**$ 0.01**	2%
Interest on operating capital	dol.&%	27,569	8%	2,206	0.77	**$ 0.02**	6%
Total variable costs				**38,965**	**13.53**	**$ 0.33**	100%
3. Income above variable cost				**13,681**	**4.75**	**$ 0.12**	
4. Fixed cost							
Machinery depreciation	dol			2,762	0.96	**$ 0.02**	18%
Capital depreciation	dol			7,131	2.48	**$ 0.06**	46%
Repairs and maintenance	RW	24	$ 21	495	0.17	**$ 0.004**	3%
Interest on construction costs	dol.&%	34,998	8%	2,800	0.97	**$ 0.02**	18%
Interest on equipment/mach. purchases	dol &%	29,176	8%	2,334	0.81	**$ 0.02**	15%
Total fixed cost				**15,521**	**5.39**	**$ 0.13**	100%
5. Total cost				**54,486**	**18.92**	**$ 0.46**	
6. Net return to land, labor, and management				**-1,841**	**-0.64**	**$(0.02)**	
Net returns per square foot, $/ft^2:							
Above specified variable costs					4.75		
Above specified total cost					-0.64		
Breakeven price to cover specified, $/each:							
Variable expenses				**0.330**			
Total expenses				**0.461**			

Table 3.5 Scenario 2: Enterprise budget for the floating in-pond raceway system (FIPRS), 24 cells, producing 0.39lb hybrid stockers.

	Unit	Quantity	Price or cost / unit	Value or cost	Per ft² value	Price/cost per stocker	Percent of costs
1. Gross receipts							
Hybrid catfish sales, 0.39 lb harvest size	indiv	108,017	$ 0.50	54,009		**$ 0.50**	
Total receipts		**108,017**		**54,009**	**18.75**	**$ 0.50**	
2. Variable cost							
Feed	ton	23	$ 532	12,385	4.30	**$ 0.11**	28%
Hybrid fingerlings, 5358/raceway*24RW	each	128,592	$0.175	22,504	7.81	**$ 0.21**	50%
Electricity	Kw-hr	83,808	$ 0.08	6,705	2.33	**$ 0.06**	15%
Miscellaneous expenses	per RW	24	$ 30	720	0.25	**$ 0.01**	2%
Interest on operating capital	dol.&%	31,735	8%	2,539	0.88	**$ 0.02**	6%
Total variable cost				**44,852**	**15.57**	**$ 0.42**	100%
3. Income above variable cost				**9,157**	**3.18**	**$ 0.08**	
4. Fixed cost							
Machinery depreciation	dol			2,762	0.96	**$ 0.03**	18%
Capital depreciation	dol			7,131	2.48	**$ 0.07**	46%
Repairs and maintenance	RW	24	$ 21	495	0.17	**$ 0.005**	3%
Interest on construction costs	dol.&%	34,998	8%	2,800	0.97	**$ 0.03**	18%
Interest on equipment/mach. purchases	dol &%	29,176	8%	2,334	0.81	**$ 0.02**	15%
Total fixed cost				**15,521**	**5.39**	**$ 0.14**	100%
5. Total cost				**60,373**	**20.96**	**$ 0.56**	
6. Net return to land, labor, and management				**-6,365**	**-2.21**	**$(0.06)**	
Net returns per square foot, $/ft²:							
Above specified variable costs					3.18		
Above specified total cost					-2.21		
Breakeven price to cover specified, $/each:							
Variable expenses				**0.415**			
Total expenses				**0.559**			

Table 3.6 Scenario 3: Enterprise budget for the floating in-pond raceway system (FIPRS), 24 cells, producing 0.24lb channel stockers.

	Unit	Quantity	Price or cost / unit	Value or cost	Per ft^2 value	Price/cost per stocker	Percent of costs
1. Gross receipts							
Channel catfish sales, 0.24 lb harvest size	indiv	128,206	$ 0.40	51,282		**$ 0.40**	
Total receipts		**128,206**		**51,282**	**17.81**	**$ 0.40**	
2. Variable costs							
Feed	ton	19	$ 532	10,278	3.57	**$ 0.08**	31%
Channel fingerlings, 5358/raceway*24RW	each	128,592	$0.105	13,502	4.69	**$ 0.11**	41%
Electricity	Kw-hr	83,808	$ 0.08	6,705	2.33	**$ 0.05**	20%
Miscellaneous expenses	per RW	24	$ 30	720	0.25	**$ 0.01**	2%
Interest on operating capital	dol.&%	23,404	8%	1,872	0.65	**$ 0.01**	6%
Total variable cost				**33,077**	**11.49**	**$ 0.26**	100%
3. Income above variable cost				**18,205**	**6.32**	**$ 0.14**	
4. Fixed cost							
Machinery depreciation	dol			2,762	0.96	**$ 0.02**	18%
Capital depreciation	dol			7,131	2.48	**$ 0.06**	46%
Repairs and maintenance	RW	24	$ 21	495	0.17	**$ 0.004**	3%
Interest on construction costs	dol.&%	34,998	8%	2,800	0.97	**$ 0.02**	18%
Interest on equipment/mach. purchases	dol &%	29,176	8%	2,334	0.81	**$ 0.02**	15%
Total fixed cost				**15,521**	**5.39**	**$ 0.12**	100%
5. Total cost				**48,599**	**16.87**	**$ 0.38**	
6. Net return to land, labor, and management				**2,684**	**0.93**	**$ 0.02**	
Net returns per square foot, $/ft^2:							
Above specified variable costs					6.32		
Above specified total cost					0.93		
Breakeven price to cover specified, $/each:							
Variable expenses				**0.258**			
Total expenses				**0.379**			

Sensitivity Analysis – The sensitivity analyses revealed slight adjustments in selling price could lead to long-term profitability against the defined feed price range (Tables 3.7-3.18). For the sensitivity analyses, feed prices ranged from $450 to 650/ton, in $10 increments, while prices received for channel and hybrid catfish stockers ranged from $0.25 to $0.60/individual and $0.30- $0.65/individual, respectively.

In the first scenario, net returns above total cost became positive within the feed price range when the average price received for catfish stockers was $0.50/individual (Table 3.7 and Table 3.8). The mixed catfish raceways held positive net returns above variable cost down to $0.40/individual regardless of feed price (Table 3.9 and Table 3.10). At the lowest feed price ($450/ton) and the highest average selling price ($0.65/individual), the highest amount of income (covering all costs) this system was projected to produce within the given parameters was $24,138 ($8.38/ft^2).

The second scenario was projected to produce income over its variable cost, regardless of feed price, with a selling price as low as $0.45 per individual (Table 3.11 and Table 3.12). The selling price to cover total cost could only decline to as low as $0.60 per individual and still producing positive income (Table 3.13 and Table 3.14). This analysis illustrated that a completely hybrid system (in the initial 'learning curve' of the FIPRS unit at Auburn) would most likely not survive over the long run unless the current selling price per individual fish was raised by $0.10 each (or a higher survival rate was achieved). Given the lowest feed price and highest selling price, this system was projected to make $11,861($4.12/ft^2) of income above total cost.

The sensitivity analysis for scenario three provided the most promising results. Profits were made above the total cost at the current price set for channel catfish stockers

($0.40 each) regardless of the simulated fluctuation in feed prices (Table 3.15 and Table 3.16). The price received per fish could be as low as $0.30 and the enterprise could still survive in the short run at any feed price in the given range (Table 3.17 and Table 3.18). The channel catfish cultured in FIPRS would generate the highest return above total cost of the three scenarios at $30,004 ($10.42/ft^2) given the lowest feed cost and the highest selling price per individual.

The net returns above total cost differ from the net returns above variable cost by adding on the amount to cover fixed cost. Producing positive net returns above total cost is related to long-term profitability while positive income above variable cost is related to short-term profitability (D'Abramo et al. 2013). The three scenarios proved capable of short-term viability, but only the third scenario using channel catfish could sustain long-term profitability.

The survival percentages used in the sensitivity analyses ranged from as low as 65 percent to a high of 100 percent survival. In the case of first and second scenarios, the income above variable cost was positive down to as low as 70 percent survival while net returns above total cost remained positive down to 95 percent survival (Table 3.19 and Table 3.20). At 100 percent survival, the hybrid catfish stocked FIPRS was more profitable than the channel FIPRS. The third scenario using channel catfish remained profitable above variable cost down to 65 percent survival and had potential for long-term profitability to as low as 95 percent survival (Table 3.21). The results of the survival sensitivity analyses demonstrate how efforts to reduce or eliminate mortality rate the most critical element leading to long-term profitability for this system.

Table 3.7 Scenario 1 (FIPRS): Sensitivity analysis- estimated net returns above all expenses for 24 mixed hybrid and channel catfish RW, at varying fish selling price and feed price.

	Avg. price received for catfish stockers $/fish							
Feed price, $/ton	**0.30**	**0.35**	**0.40**	**0.45**	**0.50**	**0.55**	**0.60**	**0.65**
450	-17,201	-11,296	-5,390	516	6,421	12,327	18,232	24,138
460	-17,427	-11,521	-5,616	290	6,195	12,101	18,007	23,912
470	-17,653	-11,747	-5,842	64	5,970	11,875	17,781	23,686
480	-17,879	-11,973	-6,067	-162	5,744	11,649	17,555	23,461
490	-18,104	-12,199	-6,293	-388	5,518	11,424	17,329	23,235
500	-18,330	-12,425	-6,519	-613	5,292	11,198	17,103	23,009
510	-18,556	-12,650	-6,745	-839	5,066	10,972	16,878	22,783
520	-18,782	-12,876	-6,971	-1,065	4,841	10,746	16,652	22,557
530	-19,007	-13,102	-7,196	-1,291	4,615	10,520	16,426	22,332
540	-19,233	-13,328	-7,422	-1,516	4,389	10,295	16,200	22,106
550	-19,459	-13,553	-7,648	-1,742	4,163	10,069	15,975	21,880
560	-19,685	-13,779	-7,874	-1,968	3,938	9,843	15,749	21,654
570	-19,911	-14,005	-8,099	-2,194	3,712	9,617	15,523	21,429
580	-20,136	-14,231	-8,325	-2,420	3,486	9,392	15,297	21,203
590	-20,362	-14,457	-8,551	-2,645	3,260	9,166	15,071	20,977
600	-20,588	-14,682	-8,777	-2,871	3,034	8,940	14,846	20,751
610	-20,814	-14,908	-9,003	-3,097	2,809	8,714	14,620	20,525
620	-21,039	-15,134	-9,228	-3,323	2,583	8,488	14,394	20,300
630	-21,265	-15,360	-9,454	-3,549	2,357	8,263	14,168	20,074
640	-21,491	-15,585	-9,680	-3,774	2,131	8,037	13,942	19,848
650	-21,717	-15,811	-9,906	-4,000	1,906	7,811	13,717	19,622

Table 3.8 Scenario 1 (FIPRS): Sensitivity analysis- estimated net returns above all expenses per ft^2 with 24 mixed channel and hybrid catfish RW, at varying fish selling price and feed price.

	Avg. price received for catfish stockers $/fish							
Feed price, $/ton	**0.30**	**0.35**	**0.40**	**0.45**	**0.50**	**0.55**	**0.60**	**0.65**
450	-5.97	-3.92	-1.87	0.18	2.23	4.28	6.33	8.38
460	-6.05	-4.00	-1.95	0.10	2.15	4.20	6.25	8.30
470	-6.13	-4.08	-2.03	0.02	2.07	4.12	6.17	8.22
480	-6.21	-4.16	-2.11	-0.06	1.99	4.04	6.10	8.15
490	-6.29	-4.24	-2.19	-0.13	1.92	3.97	6.02	8.07
500	-6.36	-4.31	-2.26	-0.21	1.84	3.89	5.94	7.99
510	-6.44	-4.39	-2.34	-0.29	1.76	3.81	5.86	7.91
520	-6.52	-4.47	-2.42	-0.37	1.68	3.73	5.78	7.83
530	-6.60	-4.55	-2.50	-0.45	1.60	3.65	5.70	7.75
540	-6.68	-4.63	-2.58	-0.53	1.52	3.57	5.63	7.68
550	-6.76	-4.71	-2.66	-0.60	1.45	3.50	5.55	7.60
560	-6.84	-4.78	-2.73	-0.68	1.37	3.42	5.47	7.52
570	-6.91	-4.86	-2.81	-0.76	1.29	3.34	5.39	7.44
580	-6.99	-4.94	-2.89	-0.84	1.21	3.26	5.31	7.36
590	-7.07	-5.02	-2.97	-0.92	1.13	3.18	5.23	7.28
600	-7.15	-5.10	-3.05	-1.00	1.05	3.10	5.15	7.21
610	-7.23	-5.18	-3.13	-1.08	0.98	3.03	5.08	7.13
620	-7.31	-5.25	-3.20	-1.15	0.90	2.95	5.00	7.05
630	-7.38	-5.33	-3.28	-1.23	0.82	2.87	4.92	6.97
640	-7.46	-5.41	-3.36	-1.31	0.74	2.79	4.84	6.89
650	-7.54	-5.49	-3.44	-1.39	0.66	2.71	4.76	6.81

Table 3.9 Scenario 1 (FIPRS): Sensitivity analysis- estimated income above variable expenses for 24 mixed hybrid and channel catfish RW, at varying fish selling price and feed price.

	Avg. price received for catfish stockers $/fish							
Feed price, $/ton	**0.30**	**0.35**	**0.40**	**0.45**	**0.50**	**0.55**	**0.60**	**0.65**
450	-1,680	4,226	10,131	16,037	21,943	27,848	33,754	39,659
460	-1,906	4,000	9,906	15,811	21,717	27,622	33,528	39,434
470	-2,131	3,774	9,680	15,585	21,491	27,397	33,302	39,208
480	-2,357	3,549	9,454	15,360	21,265	27,171	33,076	38,982
490	-2,583	3,323	9,228	15,134	21,039	26,945	32,851	38,756
500	-2,809	3,097	9,003	14,908	20,814	26,719	32,625	38,530
510	-3,034	2,871	8,777	14,682	20,588	26,494	32,399	38,305
520	-3,260	2,645	8,551	14,457	20,362	26,268	32,173	38,079
530	-3,486	2,420	8,325	14,231	20,136	26,042	31,948	37,853
540	-3,712	2,194	8,099	14,005	19,911	25,816	31,722	37,627
550	-3,938	1,968	7,874	13,779	19,685	25,590	31,496	37,402
560	-4,163	1,742	7,648	13,553	19,459	25,365	31,270	37,176
570	-4,389	1,516	7,422	13,328	19,233	25,139	31,044	36,950
580	-4,615	1,291	7,196	13,102	19,007	24,913	30,819	36,724
590	-4,841	1,065	6,971	12,876	18,782	24,687	30,593	36,498
600	-5,066	839	6,745	12,650	18,556	24,461	30,367	36,273
610	-5,292	613	6,519	12,425	18,330	24,236	30,141	36,047
620	-5,518	388	6,293	12,199	18,104	24,010	29,916	35,821
630	-5,744	162	6,067	11,973	17,879	23,784	29,690	35,595
640	-5,970	-64	5,842	11,747	17,653	23,558	29,464	35,370
650	-6,195	-290	5,616	11,521	17,427	23,333	29,238	35,144

Table 3.10 Scenario 1 (FIPRS): Sensitivity analysis- estimated income above variable expenses per ft^2 with 24 mixed channel and hybrid catfish RW, at varying fish selling price and feed price.

	Avg. price received for catfish stockers $/fish							
Feed price, $/ton	**0.30**	**0.35**	**0.40**	**0.45**	**0.50**	**0.55**	**0.60**	**0.65**
450	-0.58	1.47	3.52	5.57	7.62	9.67	11.72	13.77
460	-0.66	1.39	3.44	5.49	7.54	9.59	11.64	13.69
470	-0.74	1.31	3.36	5.41	7.46	9.51	11.56	13.61
480	-0.82	1.23	3.28	5.33	7.38	9.43	11.48	13.54
490	-0.90	1.15	3.20	5.25	7.31	9.36	11.41	13.46
500	-0.98	1.08	3.13	5.18	7.23	9.28	11.33	13.38
510	-1.05	1.00	3.05	5.10	7.15	9.20	11.25	13.30
520	-1.13	0.92	2.97	5.02	7.07	9.12	11.17	13.22
530	-1.21	0.84	2.89	4.94	6.99	9.04	11.09	13.14
540	-1.29	0.76	2.81	4.86	6.91	8.96	11.01	13.07
550	-1.37	0.68	2.73	4.78	6.84	8.89	10.94	12.99
560	-1.45	0.60	2.66	4.71	6.76	8.81	10.86	12.91
570	-1.52	0.53	2.58	4.63	6.68	8.73	10.78	12.83
580	-1.60	0.45	2.50	4.55	6.60	8.65	10.70	12.75
590	-1.68	0.37	2.42	4.47	6.52	8.57	10.62	12.67
600	-1.76	0.29	2.34	4.39	6.44	8.49	10.54	12.59
610	-1.84	0.21	2.26	4.31	6.36	8.42	10.47	12.52
620	-1.92	0.13	2.19	4.24	6.29	8.34	10.39	12.44
630	-1.99	0.06	2.11	4.16	6.21	8.26	10.31	12.36
640	-2.07	-0.02	2.03	4.08	6.13	8.18	10.23	12.28
650	-2.15	-0.10	1.95	4.00	6.05	8.10	10.15	12.20

Table 3.11 Scenario 2 (FIPRS): Sensitivity analysis- estimated income above variable expenses for 24 hybrid catfish RW, at varying fish selling price and feed price.

	Price received for hybrid catfish stockers $/fish							
Feed price, $/ton	**0.30**	**0.35**	**0.40**	**0.45**	**0.50**	**0.55**	**0.60**	**0.65**
450	-10,423	-5,022	378	5,779	11,180	16,581	21,982	27,383
460	-10,670	-5,269	132	5,533	10,933	16,334	21,735	27,136
470	-10,917	-5,516	-115	5,286	10,687	16,087	21,488	26,889
480	-11,164	-5,763	-362	5,039	10,440	15,841	21,242	26,642
490	-11,410	-6,010	-609	4,792	10,193	15,594	20,995	26,396
500	-11,657	-6,256	-855	4,545	9,946	15,347	20,748	26,149
510	-11,904	-6,503	-1,102	4,299	9,700	15,100	20,501	25,902
520	-12,151	-6,750	-1,349	4,052	9,453	14,854	20,254	25,655
530	-12,397	-6,997	-1,596	3,805	9,206	14,607	20,008	25,409
540	-12,644	-7,243	-1,842	3,558	8,959	14,360	19,761	25,162
550	-12,891	-7,490	-2,089	3,312	8,712	14,113	19,514	24,915
560	-13,138	-7,737	-2,336	3,065	8,466	13,867	19,267	24,668
570	-13,385	-7,984	-2,583	2,818	8,219	13,620	19,021	24,422
580	-13,631	-8,230	-2,830	2,571	7,972	13,373	18,774	24,175
590	-13,878	-8,477	-3,076	2,325	7,725	13,126	18,527	23,928
600	-14,125	-8,724	-3,323	2,078	7,479	12,879	18,280	23,681
610	-14,372	-8,971	-3,570	1,831	7,232	12,633	18,034	23,434
620	-14,618	-9,218	-3,817	1,584	6,985	12,386	17,787	23,188
630	-14,865	-9,464	-4,063	1,337	6,738	12,139	17,540	22,941
640	-15,112	-9,711	-4,310	1,091	6,492	11,892	17,293	22,694
650	-15,359	-9,958	-4,557	844	6,245	11,646	17,047	22,447

Table 3.12 Scenario 2 (FIPRS): Sensitivity analysis- estimated income above variable expenses per ft^2 with 24 hybrid catfish RW, at varying fish selling price and feed price.

	Price received for hybrid catfish stockers $/fish							
Feed price, $/ton	**0.30**	**0.35**	**0.40**	**0.45**	**0.50**	**0.55**	**0.60**	**0.65**
450	-3.62	-1.74	0.13	2.01	3.88	5.76	7.63	9.51
460	-3.70	-1.83	0.05	1.92	3.80	5.67	7.55	9.42
470	-3.79	-1.92	-0.04	1.84	3.71	5.59	7.46	9.34
480	-3.88	-2.00	-0.13	1.75	3.62	5.50	7.38	9.25
490	-3.96	-2.09	-0.21	1.66	3.54	5.41	7.29	9.17
500	-4.05	-2.17	-0.30	1.58	3.45	5.33	7.20	9.08
510	-4.13	-2.26	-0.38	1.49	3.37	5.24	7.12	8.99
520	-4.22	-2.34	-0.47	1.41	3.28	5.16	7.03	8.91
530	-4.30	-2.43	-0.55	1.32	3.20	5.07	6.95	8.82
540	-4.39	-2.52	-0.64	1.24	3.11	4.99	6.86	8.74
550	-4.48	-2.60	-0.73	1.15	3.03	4.90	6.78	8.65
560	-4.56	-2.69	-0.81	1.06	2.94	4.81	6.69	8.57
570	-4.65	-2.77	-0.90	0.98	2.85	4.73	6.60	8.48
580	-4.73	-2.86	-0.98	0.89	2.77	4.64	6.52	8.39
590	-4.82	-2.94	-1.07	0.81	2.68	4.56	6.43	8.31
600	-4.90	-3.03	-1.15	0.72	2.60	4.47	6.35	8.22
610	-4.99	-3.11	-1.24	0.64	2.51	4.39	6.26	8.14
620	-5.08	-3.20	-1.33	0.55	2.43	4.30	6.18	8.05
630	-5.16	-3.29	-1.41	0.46	2.34	4.21	6.09	7.97
640	-5.25	-3.37	-1.50	0.38	2.25	4.13	6.00	7.88
650	-5.33	-3.46	-1.58	0.29	2.17	4.04	5.92	7.79

Table 3.13 Scenario 2 (FIPRS): Sensitivity analysis- estimated net returns above all expenses for 24 hybrid catfish RW, at varying fish selling price and feed price.

	Price received for hybrid catfish stockers $/fish							
Feed price, $/ton	**0.30**	**0.35**	**0.40**	**0.45**	**0.50**	**0.55**	**0.60**	**0.65**
450	-25,945	-20,544	-15,143	-9,742	-4,341	1,060	6,460	11,861
460	-26,192	-20,791	-15,390	-9,989	-4,588	813	6,214	11,614
470	-26,438	-21,037	-15,637	-10,236	-4,835	566	5,967	11,368
480	-26,685	-21,284	-15,883	-10,483	-5,082	319	5,720	11,121
490	-26,932	-21,531	-16,130	-10,729	-5,328	72	5,473	10,874
500	-27,179	-21,778	-16,377	-10,976	-5,575	-174	5,227	10,627
510	-27,425	-22,025	-16,624	-11,223	-5,822	-421	4,980	10,381
520	-27,672	-22,271	-16,870	-11,470	-6,069	-668	4,733	10,134
530	-27,919	-22,518	-17,117	-11,716	-6,315	-915	4,486	9,887
540	-28,166	-22,765	-17,364	-11,963	-6,562	-1,161	4,239	9,640
550	-28,412	-23,012	-17,611	-12,210	-6,809	-1,408	3,993	9,394
560	-28,659	-23,258	-17,858	-12,457	-7,056	-1,655	3,746	9,147
570	-28,906	-23,505	-18,104	-12,703	-7,303	-1,902	3,499	8,900
580	-29,153	-23,752	-18,351	-12,950	-7,549	-2,148	3,252	8,653
590	-29,400	-23,999	-18,598	-13,197	-7,796	-2,395	3,006	8,407
600	-29,646	-24,245	-18,845	-13,444	-8,043	-2,642	2,759	8,160
610	-29,893	-24,492	-19,091	-13,690	-8,290	-2,889	2,512	7,913
620	-30,140	-24,739	-19,338	-13,937	-8,536	-3,136	2,265	7,666
630	-30,387	-24,986	-19,585	-14,184	-8,783	-3,382	2,019	7,419
640	-30,633	-25,233	-19,832	-14,431	-9,030	-3,629	1,772	7,173
650	-30,880	-25,479	-20,078	-14,678	-9,277	-3,876	1,525	6,926

Table 3.14 Scenario 2 (FIPRS): Sensitivity analysis- estimated net returns above all expenses per ft^2 with 24 hybrid catfish RW, at varying fish selling price and feed price.

	Price received for hybrid catfish stockers $/fish							
Feed price, $/ton	**0.30**	**0.35**	**0.40**	**0.45**	**0.50**	**0.55**	**0.60**	**0.65**
450	-9.01	-7.13	-5.26	-3.38	-1.51	0.37	2.24	4.12
460	-9.09	-7.22	-5.34	-3.47	-1.59	0.28	2.16	4.03
470	-9.18	-7.30	-5.43	-3.55	-1.68	0.20	2.07	3.95
480	-9.27	-7.39	-5.52	-3.64	-1.76	0.11	1.99	3.86
490	-9.35	-7.48	-5.60	-3.73	-1.85	0.03	1.90	3.78
500	-9.44	-7.56	-5.69	-3.81	-1.94	-0.06	1.81	3.69
510	-9.52	-7.65	-5.77	-3.90	-2.02	-0.15	1.73	3.60
520	-9.61	-7.73	-5.86	-3.98	-2.11	-0.23	1.64	3.52
530	-9.69	-7.82	-5.94	-4.07	-2.19	-0.32	1.56	3.43
540	-9.78	-7.90	-6.03	-4.15	-2.28	-0.40	1.47	3.35
550	-9.87	-7.99	-6.11	-4.24	-2.36	-0.49	1.39	3.26
560	-9.95	-8.08	-6.20	-4.33	-2.45	-0.57	1.30	3.18
570	-10.04	-8.16	-6.29	-4.41	-2.54	-0.66	1.21	3.09
580	-10.12	-8.25	-6.37	-4.50	-2.62	-0.75	1.13	3.00
590	-10.21	-8.33	-6.46	-4.58	-2.71	-0.83	1.04	2.92
600	-10.29	-8.42	-6.54	-4.67	-2.79	-0.92	0.96	2.83
610	-10.38	-8.50	-6.63	-4.75	-2.88	-1.00	0.87	2.75
620	-10.47	-8.59	-6.71	-4.84	-2.96	-1.09	0.79	2.66
630	-10.55	-8.68	-6.80	-4.93	-3.05	-1.17	0.70	2.58
640	-10.64	-8.76	-6.89	-5.01	-3.14	-1.26	0.62	2.49
650	-10.72	-8.85	-6.97	-5.10	-3.22	-1.35	0.53	2.40

Table 3.15 Scenario 3 (FIPRS): Sensitivity analysis- estimated net returns above all expenses for 24 channel catfish RW, at varying fish selling price and feed price.

	Price received for channel catfish stockers $/fish							
Feed price, $/ton	**0.25**	**0.30**	**0.35**	**0.40**	**0.45**	**0.50**	**0.55**	**0.60**
450	-14,868	-8,458	-2,047	4,363	10,773	17,184	23,594	30,004
460	-15,073	-8,662	-2,252	4,158	10,568	16,979	23,389	29,799
470	-15,278	-8,867	-2,457	3,953	10,364	16,774	23,184	29,595
480	-15,482	-9,072	-2,662	3,749	10,159	16,569	22,980	29,390
490	-15,687	-9,277	-2,867	3,544	9,954	16,364	22,775	29,185
500	-15,892	-9,482	-3,071	3,339	9,749	16,160	22,570	28,980
510	-16,097	-9,686	-3,276	3,134	9,545	15,955	22,365	28,775
520	-16,302	-9,891	-3,481	2,929	9,340	15,750	22,160	28,571
530	-16,506	-10,096	-3,686	2,725	9,135	15,545	21,956	28,366
540	-16,711	-10,301	-3,890	2,520	8,930	15,340	21,751	28,161
550	-16,916	-10,506	-4,095	2,315	8,725	15,136	21,546	27,956
560	-17,121	-10,710	-4,300	2,110	8,521	14,931	21,341	27,751
570	-17,325	-10,915	-4,505	1,905	8,316	14,726	21,136	27,547
580	-17,530	-11,120	-4,710	1,701	8,111	14,521	20,932	27,342
590	-17,735	-11,325	-4,914	1,496	7,906	14,316	20,727	27,137
600	-17,940	-11,530	-5,119	1,291	7,701	14,112	20,522	26,932
610	-18,145	-11,734	-5,324	1,086	7,497	13,907	20,317	26,728
620	-18,349	-11,939	-5,529	881	7,292	13,702	20,112	26,523
630	-18,554	-12,144	-5,734	677	7,087	13,497	19,908	26,318
640	-18,759	-12,349	-5,938	472	6,882	13,293	19,703	26,113
650	-18,964	-12,554	-6,143	267	6,677	13,088	19,498	25,908

Table 3.16 Scenario 3 (FIPRS): Sensitivity analysis- estimated net returns above all expenses per ft^2 with 24 channel catfish RW, at varying fish selling price and feed price.

	Price received for channel catfish stockers $/fish							
Feed price, $/ton	**0.25**	**0.30**	**0.35**	**0.40**	**0.45**	**0.50**	**0.55**	**0.60**
450	-5.16	-2.94	-0.71	1.51	3.74	5.97	8.19	10.42
460	-5.23	-3.01	-0.78	1.44	3.67	5.90	8.12	10.35
470	-5.30	-3.08	-0.85	1.37	3.60	5.82	8.05	10.28
480	-5.38	-3.15	-0.92	1.30	3.53	5.75	7.98	10.20
490	-5.45	-3.22	-1.00	1.23	3.46	5.68	7.91	10.13
500	-5.52	-3.29	-1.07	1.16	3.39	5.61	7.84	10.06
510	-5.59	-3.36	-1.14	1.09	3.31	5.54	7.77	9.99
520	-5.66	-3.43	-1.21	1.02	3.24	5.47	7.69	9.92
530	-5.73	-3.51	-1.28	0.95	3.17	5.40	7.62	9.85
540	-5.80	-3.58	-1.35	0.87	3.10	5.33	7.55	9.78
550	-5.87	-3.65	-1.42	0.80	3.03	5.26	7.48	9.71
560	-5.94	-3.72	-1.49	0.73	2.96	5.18	7.41	9.64
570	-6.02	-3.79	-1.56	0.66	2.89	5.11	7.34	9.56
580	-6.09	-3.86	-1.64	0.59	2.82	5.04	7.27	9.49
590	-6.16	-3.93	-1.71	0.52	2.75	4.97	7.20	9.42
600	-6.23	-4.00	-1.78	0.45	2.67	4.90	7.13	9.35
610	-6.30	-4.07	-1.85	0.38	2.60	4.83	7.05	9.28
620	-6.37	-4.15	-1.92	0.31	2.53	4.76	6.98	9.21
630	-6.44	-4.22	-1.99	0.23	2.46	4.69	6.91	9.14
640	-6.51	-4.29	-2.06	0.16	2.39	4.62	6.84	9.07
650	-6.58	-4.36	-2.13	0.09	2.32	4.54	6.77	9.00

Table 3.17 Scenario 3 (FIPRS): Sensitivity analysis- income returns above variable expenses for 24 channel catfish RW, at varying fish selling price and feed price.

	Price received for channel catfish stockers $/fish							
Feed price, $/ton	**0.25**	**0.30**	**0.35**	**0.40**	**0.45**	**0.50**	**0.55**	**0.60**
450	654	7,064	13,474	19,884	26,295	32,705	39,115	45,526
460	449	6,859	13,269	19,680	26,090	32,500	38,911	45,321
470	244	6,654	13,065	19,475	25,885	32,295	38,706	45,116
480	39	6,449	12,860	19,270	25,680	32,091	38,501	44,911
490	-166	6,245	12,655	19,065	25,476	31,886	38,296	44,707
500	-370	6,040	12,450	18,860	25,271	31,681	38,091	44,502
510	-575	5,835	12,245	18,656	25,066	31,476	37,887	44,297
520	-780	5,630	12,041	18,451	24,861	31,272	37,682	44,092
530	-985	5,425	11,836	18,246	24,656	31,067	37,477	43,887
540	-1,190	5,221	11,631	18,041	24,452	30,862	37,272	43,683
550	-1,394	5,016	11,426	17,837	24,247	30,657	37,067	43,478
560	-1,599	4,811	11,221	17,632	24,042	30,452	36,863	43,273
570	-1,804	4,606	11,017	17,427	23,837	30,248	36,658	43,068
580	-2,009	4,402	10,812	17,222	23,632	30,043	36,453	42,863
590	-2,214	4,197	10,607	17,017	23,428	29,838	36,248	42,659
600	-2,418	3,992	10,402	16,813	23,223	29,633	36,043	42,454
610	-2,623	3,787	10,197	16,608	23,018	29,428	35,839	42,249
620	-2,828	3,582	9,993	16,403	22,813	29,224	35,634	42,044
630	-3,033	3,378	9,788	16,198	22,608	29,019	35,429	41,839
640	-3,238	3,173	9,583	15,993	22,404	28,814	35,224	41,635
650	-3,442	2,968	9,378	15,789	22,199	28,609	35,020	41,430

Table 3.18 Scenario 3 (FIPRS): Sensitivity analysis- estimated income above variable expenses per ft^2 with 24 channel catfish RW, at varying fish selling price and feed price.

	Price received for channel catfish stockers $/fish							
Feed price, $/ton	**0.25**	**0.30**	**0.35**	**0.40**	**0.45**	**0.50**	**0.55**	**0.60**
450	0.23	2.45	4.68	6.90	9.13	11.36	13.58	15.81
460	0.16	2.38	4.61	6.83	9.06	11.28	13.51	15.74
470	0.08	2.31	4.54	6.76	8.99	11.21	13.44	15.67
480	0.01	2.24	4.47	6.69	8.92	11.14	13.37	15.59
490	-0.06	2.17	4.39	6.62	8.85	11.07	13.30	15.52
500	-0.13	2.10	4.32	6.55	8.77	11.00	13.23	15.45
510	-0.20	2.03	4.25	6.48	8.70	10.93	13.16	15.38
520	-0.27	1.95	4.18	6.41	8.63	10.86	13.08	15.31
530	-0.34	1.88	4.11	6.34	8.56	10.79	13.01	15.24
540	-0.41	1.81	4.04	6.26	8.49	10.72	12.94	15.17
550	-0.48	1.74	3.97	6.19	8.42	10.64	12.87	15.10
560	-0.56	1.67	3.90	6.12	8.35	10.57	12.80	15.03
570	-0.63	1.60	3.83	6.05	8.28	10.50	12.73	14.95
580	-0.70	1.53	3.75	5.98	8.21	10.43	12.66	14.88
590	-0.77	1.46	3.68	5.91	8.13	10.36	12.59	14.81
600	-0.84	1.39	3.61	5.84	8.06	10.29	12.52	14.74
610	-0.91	1.31	3.54	5.77	7.99	10.22	12.44	14.67
620	-0.98	1.24	3.47	5.70	7.92	10.15	12.37	14.60
630	-1.05	1.17	3.40	5.62	7.85	10.08	12.30	14.53
640	-1.12	1.10	3.33	5.55	7.78	10.00	12.23	14.46
650	-1.20	1.03	3.26	5.48	7.71	9.93	12.16	14.39

Table 3.19 Scenario 1 (FIPRS): Survival sensitivity analysis- estimated net returns with 24 mixed channel and hybrid catfish RW, at varying survival rates.

Survival, %	Income above variable cost, per ft²	Net return above all cost, per ft²	Income above variable cost, per 24 RW	Net return above all cost, per 24 RW
100	6.56	1.71	18,902	3,380
95	5.56	0.17	16,008	487
90	4.55	-0.84	13,115	-2,406
85	3.55	-1.84	10,222	-5,300
80	2.54	-2.84	7,328	-8,193
75	1.54	-3.85	4,435	-11,086
70	0.54	-4.85	1,542	-13,980
65	-0.47	-5.86	-1,352	-16,873

Table 3.20 Scenario 2 (FIPRS): Survival sensitivity analysis- estimated net returns with 24 hybrid catfish RW, at varying survival rates.

Survival, %	Income above variable cost, per ft²	Net return above all cost, per ft²	Income above variable cost, per 24 RW	Net return above all cost, per 24 RW
100	6.75	1.36	19,444	3,923
95	5.64	0.25	16,229	708
90	4.52	-0.87	13,014	-2,507
85	3.40	-1.99	9,800	-5,722
80	2.29	-3.10	6,585	-8,937
75	1.17	-4.22	3,370	-12,151
70	0.05	-5.34	155	-15,366
65	-1.06	-6.45	-3,060	-18,581

Table 3.21 Scenario 3 (FIPRS): Survival sensitivity analysis- estimated net returns with 24 channel catfish RW, at varying survival rates.

Survival, %	Income above variable cost, per ft²	Net return above all cost, per ft²	Income above variable cost, per 24 RW	Net return above all cost, per 24 RW
100	6.37	0.99	18,359	2,838
95	5.48	0.09	15,788	266
90	4.59	-0.80	13,216	-2,306
85	3.70	-1.69	10,644	-4,878
80	2.80	-2.59	8,072	-7,449
75	1.91	-3.48	5,500	-10,021
70	1.02	-4.37	2,928	-12,593
65	0.12	-5.27	357	-15,165

Indoor Recirculating Tilapia System

Investment Cost - Construction cost for the production barn housing the tilapia production raceway systems and electrical wiring were $146,000 (Table 3.22). The raceways consisted of five fiberglass tanks ($28,000 each), five wooden tanks ($5,000 each) and five epoxy-painted cement block tanks ($4,400 each). Other construction capital items totaled to $118,900. The machinery and equipment needed for the barn cost $89,480. The financial investment required for this system was $544,380 with an annual depreciation of $36,829. The IRTS offered the largest fish culturing area with 20,720 ft^3 but at three times the investment cost of the FIPRS ($128,348, Table 3.2).

It should be noted that this system has undergone changes since its construction in 2010. After several years of operation, the farm manager would now recommend not using the site built wooden tanks and PolyGeyser filters. The wooden tanks were reported to have short lifespan due to a wet environment and lack structural integrity while the PolyGeyser filters were said to be labor intensive to operate and maintain. The more expensive fiberglass tanks last longer and are less problematic but still require significant labor cost to operate. The best construction and system option according to the collaborating farm manager was to build the entire system using formed cement tanks, which are more cost-effective and have demonstrated long lifespans. This would reduce the capital construction cost by $90,400 (assuming a PolyGeyser filter was used for each cement grow-out tank).

The pond and well used in supplying water to the barn existed previously on the farm so pond construction cost were excluded from the capital cost of the barn system. Land purchases were also excluded from the capital cost because the barn was constructed on farm property. A 152-mm well was installed to supply the barn with fresh water and is included in the investment cost ($25,000). Interest on equipment and machinery purchases, operating expenses, and barn construction cost was charged at 8 percent and is included in the financial analysis. Labor cost for the construction of the IRTS are not included in the total capital item cost.

Table 3.22 Indoor recirculating tilapia system (IRTS), 10 production cells (8 ft width x 42 ft length x 4 ft depth), 5 stocker cells (8 ft width x 28 ft length x 4 ft depth), and 5 fingerling cells (8 ft width x 14 ft length x 4 ft depth), construction and equipment cost, West Alabama.

Item	Unit	Cost/unit	Number	Total cost	Useful life	Average investment	Annual avg. depreciation /1	Interest on investment /2	Repairs as a percent of new cost	Annual repairs and maintenance
A. Capital cost										
Well water source	ea	$ 25,000	1	$ 25,000	10	$ 12,500	$ 2,500	$ 938	10%	$ 250
Barn construction	building	$ 120,000	1	$ 120,000	30	$ 60,000	$ 4,000	$ 4,500	10%	$ 400
Electrical wiring for barn	building	$ 26,000	1	$ 26,000	30	$ 13,000	$ 867	$ 975	10%	$ 87
Production tanks										
Wood tanks	ea	$ 5,000	10	$ 50,000	5	$ 25,000	$ 10,000	$ 1,875	10%	$ 1,000
Fiberglass tanks	ea	$ 28,000	5	$ 140,000	30	$ 70,000	$ 4,667	$ 5,250	10%	$ 467
Cement stocker/fingerling tanks	ea	$ 4,400	5	$ 22,000	20	$ 11,000	$ 1,100	$ 825	10%	$ 110
Walkways	ea	$ 4,000	1	$ 4,000	20	$ 2,000	$ 200	$ 150	10%	$ 20
Lab	ea	$ 5,300	1	$ 5,300	4	$ 2,650	$ 1,325	$ 199	10%	$ 133
PolyGeyser filter	ea	$ 11,000	5	$ 55,000	20	$ 27,500	$ 2,750	$ 2,063	10%	$ 275
Bead reclaiming tub	ea	$ 300	2	$ 600	20	$ 300	$ 30	$ 23	10%	$ 3
Air lines	ea	$ 7,000	1	$ 7,000	5	$ 3,500	$ 1,400	$ 263	10%	$ 140
Subtotal				$ 454,900		$227,450	$ 28,838	$ 17,059		$ 2,884
B. Equipment										
Blower, 1.5 hp	ea	$ 1,020	2	$ 2,040	3	$ 1,020	$ 680	$ 77	10%	$ 68
Emergency generator	ea	$ 7,000	1	$ 7,000	20	$ 3,500	$ 350	$ 263	10%	$ 35
Burner	ea	$ 11,840	1	$ 11,840	10	$ 5,920	$ 1,184	$ 444	10%	$ 118
Blower 25 hp	ea	$ 15,000	2	$ 30,000	10	$ 15,000	$ 3,000	$ 1,125	10%	$ 300
Grader net	ea	$ 500	3	$ 1,500	5	$ 750	$ 300	$ 56	10%	$ 30
Sensiphone	ea	$ 100	1	$ 100	10	$ 50	$ 10	$ 4	10%	$ 1
D.O. monitoring system	ea	$ 17,000	1	$ 17,000	15	$ 8,500	$ 1,133	$ 638	10%	$ 113
Fork lift	ea	$ 10,000	1	$ 10,000	10	$ 5,000	$ 1,000	$ 375	10%	$ 100
Feed bin (22 ton)	ea	$ 10,000	1	$ 10,000	30	$ 5,000	$ 333	$ 375	10%	$ 33
Subtotal				$ 89,480		$ 44,740	$ 7,991	$ 3,356		$ 799
TOTAL				**$ 544,380**		**$272,190**	**$ 36,829**	**$ 20,414**		**$ 3,683**

/1 Computed by the straight line method with zero salvage value for depreciable items.

/2 No interest is charged for land and pond construction; they are assumed to already exist; equipment items are charged at an intermediate-term interest rate. Charged at 10% on the total value of land with all other depreciable items charged at 10% on one-half of the investment.

Production Parameters –Nursery (Table 3.23) - Tilapia fingerlings (0.018-0.176 ounces per piece) were purchased for an average of $0.15 per fingerling and were stocked into the nursery tanks (134 ft^3) at a mean density of 52 fish per cubic foot. This amounted to an effective stocking rate of 6881 fingerlings per nursery tank. When tilapia fingerlings reached 0.12 lb they were collected from the primary nursery tanks, weighed and re-stocked into the secondary nursery tanks (668 ft^3) at nine fish density per cubic foot. After having been cultured in the nursery and stocker tanks for 20 weeks, the fish had reached a mean 0.65 pounds and were moved into a grow-out system tank. Market size for the live tilapia was 1.27 lb and market price was nominally $2.10/lb. The production cycle typically required 280 days from 0.018-0.176 ounces fingerling size; but some stock, likely including a higher level of females, demonstrated atypical slow growth were moved to a small holding pond adjacent to the barn and held for springtime sales into recreational markets where they would be sold at $4.00/lb. Stocker-sized (0.12-0.65 lb) fish were occasionally sold at a price of $0.60/stocker. For the purpose of financial accounting in the enterprise budget, it was decided to value the unsold fish inventory present in the raceways on December 31st, 2013. This was done to account for the biomass value on hand and within a production cycle, not yet sold, but having already been fed (feed and other variable input cost are in the budgets). The unsold inventory was valued at $0.28/fingerling and was the input cost invested in the fish to this point.

On average, grow-out tanks were fed a mean 0.72 tons of feed a month with a total of 5.26 tons of feed fed by the time the fish were sold. An FCR of 1.5:1.0 was achieved for a number of tanks but the mean FCR experienced was 1.9:1.0. The mean survival rate from fingerling to market-sized fish approximated 80 percent.

Each raceway used 62-kWh of electrical energy per day. A number of additional inputs were applied while producing fish. These included salt (NaCl), sodium bicarbonate, formalin, pro-biotic bacteria, and chemical reagents for the water quality lab. The salt and sodium bicarbonate was bought at $5.20 (50 lb bag) and $15.68 per bag (40 lb bag), respectively. Muck Reducing Pure-Bacteria (pro-biotic) was purchased $32.95 a gallon and applied weekly to grow-out tanks at a rate of 1 ounce per 1000 gallons. Formalin (37%) was used primarily for general health maintenance on young fingerlings being cultured in the cement raceways and cost $550 per 55 gallon drum.

The FIPRS and ITCGS are small systems capable of being run by a single operator; as a larger system, the IRTS required a full-time and part-time employee in addition to the system manager. Labor charges were included in the operating cost assuming a 40 hour and 20 hour week for the full-time and part-time employee, respectively. Nine dollars an hour was the set rate to cover employment cost.

Table 3.23 Production parameters for the indoor recirculating tilapia system (IRTS), West Alabama, 2013.

Grow-out area for tilapia per wooden tank	ft^3	2,005
Grow-out area for tilapia per fiberglass tank	ft^3	1,337
Stocker tank production area	ft^3	668
Nursery tank production area	ft^3	134
Fingerling weight	lb/1000	11
Stocker-sized tilapia weight	lb	0.65
Market weight	lb	1.27
Days for tilapia to reach target size	days	280
Tilapia stocking rate into nursery tank	fingerlings/tank	6,881
Tilapia stocking rate per nursery cell	lb/cell	76
Average tilapia fingerling cost	$/ea	0.15
Tilapia feed conversion rate		1.9
Tilapia survival	%	80
Total amount fed to tilapia per crop	tons	5.26
Selling price for market-size tilapia	$/lb	2.10
Selling price for stocker-sized tilapia	$/ea	0.60
2014 fingerling inventory value	$/ea	0.28
Selling price for bass forage tilapia	$/lb	4.00
Feed price, 36% protein	$/ton	790
Repair and maintenance cost per tank	$/year	246
Average daily electrical use per tank	KWhr	62
Water quality testing chemicals	$/year	300
Formalin	$/per drum	550
Muck Reducer Pure-Bacteria	$/gal	32.95
Sodium bicarbonate, 40lb bag	$/bag	15.68
Salt, 50lb bag	$/bag	5.20
Labor, 1 full-time and 1 part-time employee	$/hr	9.00

Enterprise Budget- The data collected from farm records covering a two year period from December 1, 2012 to December 31, 2013 were used to develop an enterprise budget which illustrates a year's worth of production and the cost necessary for producing 166,258 pounds of tilapia (Table 3.24). Forty-five percent of the bio-mass produced and described in the enterprise budget were in inventory present in the tanks as of December 31, 2013 and scheduled to be sold the next (2014) year when they reach full market weight. The analysis of enterprise data revealed a breakeven price of $1.19/lb which covers operation cost. An additional $0.40 was required to cover fixed cost. The income received from fish sales above variable cost and net returns above all cost were $139,597 ($27.71/ft^2) and $73,731 ($14.64/ft^2), respectively.

Feed, electricity, labor, and fingerling purchases accounted for 89 percent of all operational cost. Feed represented 46 percent of all variable cost and was the largest single operational expense. Feed cost during this period of analysis ranged from $760/ton to $820 /ton and a mean value of 790/ton was noted. While in prior years significantly more stock was marketed to recreational interests, less than two percent of fish produced in the fish barn in 2013 were moved to the outdoor holding pond to be sold as bass forage fish.

Table 3.24 Indoor recirculating tilapia system (IRTS) enterprise budget, 10 production cells and 5 fingerling/stocker cells, West Alabama, 2013.

	Unit	Quantity	Price or cost / unit	Value or cost	Per ft² value	Cost per lb	Percent of costs
1. Gross receipts							
Fish sales	lb	91,307	$ 2.10	191,745	38.06	**$ 2.10**	
Stocker sales	lb	917	$ 0.92	847	0.17	**$ 0.92**	
Inventory value, not sold as of 12/31/2013							
Food size	lb	51,071	$ 2.10	107,248	21.29	**$ 2.10**	
Stockers	lb	19,839	$ 0.92	18,314	3.64	**$ 0.92**	
Fingerlings	lb	37	$ 195	7,279	1.44	**$ 195**	
Black pit	lb	3,087	$ 4	12,347	2.45	**$ 4**	
Total receipts		**166,258**		**337,779**	**67.05**	**$ 2.03**	
2. Variable cost							
Feed, food fish	ton	116	$ 790	91,478	18.16	**$ 0.55**	46%
Fingerlings, 6800/fingerling raceway	ea	182,745	$ 0.15	27,412	5.44	**$ 0.16**	14%
Labor	year	3,250	$ 9.00	29,250	5.81	**$ 0.18**	15%
Chemicals	year	2	$ 300	600	0.12	**$0.004**	0.3%
Electricity	kW	357,500	$ 0.08	28,600	5.68	**$ 0.17**	14%
Formalin	ea	2	$ 550	1,100	0.22	**$ 0.01**	0.6%
Muck Reducer Pure-Bacteria	gal	65	$ 33	2,145	0.43	**$ 0.01**	1%
Sodium bicarb	bag	149	$ 16	2,340	0.46	**$ 0.01**	1%
Salt	bag	543	$ 5	2,821	0.56	**$ 0.02**	1%
Heat	tons	61	$ 20	1,218	0.24	**$ 0.01**	0.6%
Interest on operating cost	dol.&%	140,223	8%	11,218	2.23	**$ 0.07**	6%
Total variable cost				**198,182**	**39.34**	**$ 1.19**	100%
3. Income above variable cost				**139,597**	**27.71**	**$ 0.84**	
4. Fixed cost							
Machinery depreciation	dol			7,991	1.59	**$ 0.05**	12%
Capital depreciation	dol			28,838	5.72	**$ 0.17**	44%
Repairs and maintenance	$/month	12	$ 307	3,683	0.73	**$ 0.02**	6%
Interest on construction cost	dol.&%	227,450	8%	18,196	3.61	**$ 0.11**	28%
Interest on equipment/mach. purchases	dol &%	89,480	8%	7,158	1.42	**$ 0.04**	11%
Total fixed cost				**65,866**	**13.08**	**$ 0.40**	100%
5. Total cost				**264,048**	**52.42**	**$ 1.59**	
6. Net return to land, labor, and management				**73,731**	**14.64**	**$ 0.44**	
Net returns per square foot, $/ft²:							
Above specified variable costs					27.71		
Above specified total cost					14.64		
Breakeven price to cover specified, $/each:							
Variable expenses				**1.192**			
Total expenses				**1.588**			

Sensitivity Analysis (Tables 3.25-3.28)– Prices received for tilapia varied from $1.25/lb to $1.60/lb for the analyses focusing on income above variable cost; and ranged from $1.75/lb to $2.10/lb for analyses focusing on net returns above all cost. The two ranges were used to identify the conditions wherein feed cost relative to tilapia sales prices would result in a mix of negative and positive outcomes. Feed prices ranged from $690 to $890/ton. Net returns above all cost were positive across any of the varied feed prices when sales price received for tilapia was $1.95/lb (Table 3.25 and Table 3.26) and for income above variable cost when sales price received was $1.50/lb (Table 3.27 and Table 3.28). This analysis illustrates the stability of growing tilapia with this system against the volatility of market prices.

The survival percentages ranged from 30 to 100 percent survival across grow-out systems (Table 3.29). With no mortalities or at least very high survival, the system had the potential to return $158,175 ($31.40/ft^2) and $224,042 ($44.47/ft^2) of income above total cost and above variable cost, respectively. The IRTS has the ability to be profitable in the short-run even if only 50 percent of its fish produced in 2013 were sold. In order be profitable at current market prices for live tilapia, long-term mean survival rates above 70 percent are required.

Table 3.25 Indoor recirculating tilapia system (IRTS): Sensitivity analysis- estimated net returns above all expenses at varying fish selling price and feed price.

	Price received for market sized tilapia $/lb							
Feed price, $/ton	**1.75**	**1.80**	**1.85**	**1.90**	**1.95**	**2.00**	**2.05**	**2.10**
690	-2,613	4,506	11,625	18,744	25,863	32,982	40,101	47,219
700	-3,840	3,279	10,398	17,516	24,635	31,754	38,873	45,992
710	-5,068	2,051	9,170	16,289	23,408	30,527	37,646	44,765
720	-6,295	824	7,943	15,062	22,180	29,299	36,418	43,537
730	-7,522	-404	6,715	13,834	20,953	28,072	35,191	42,310
740	-8,750	-1,631	5,488	12,607	19,726	26,845	33,963	41,082
750	-9,977	-2,858	4,260	11,379	18,498	25,617	32,736	39,855
760	-11,205	-4,086	3,033	10,152	17,271	24,390	31,509	38,627
770	-12,432	-5,313	1,806	8,924	16,043	23,162	30,281	37,400
780	-13,660	-6,541	578	7,697	14,816	21,935	29,054	36,173
790	-14,887	-7,768	-649	6,470	13,588	20,707	27,826	34,945
800	-16,114	-8,996	-1,877	5,242	12,361	19,480	26,599	33,718
810	-17,342	-10,223	-3,104	4,015	11,134	18,253	25,371	32,490
820	-18,569	-11,450	-4,332	2,787	9,906	17,025	24,144	31,263
830	-19,797	-12,678	-5,559	1,560	8,679	15,798	22,917	30,035
840	-21,024	-13,905	-6,786	332	7,451	14,570	21,689	28,808
850	-22,252	-15,133	-8,014	-895	6,224	13,343	20,462	27,581
860	-23,479	-16,360	-9,241	-2,122	4,997	12,115	19,234	26,353
870	-24,706	-17,588	-10,469	-3,350	3,769	10,888	18,007	25,126
880	-25,934	-18,815	-11,696	-4,577	2,542	9,661	16,779	23,898
890	-27,161	-20,042	-12,924	-5,805	1,314	8,433	15,552	22,671

Table 3.26 Indoor recirculating tilapia system (IRTS): Sensitivity analysis- estimated net returns above all expenses per ft^2, at varying fish selling price and feed price.

	Price received for market sized tilapia $/lb							
Feed price, $/ton	**1.75**	**1.80**	**1.85**	**1.90**	**1.95**	**2.00**	**2.05**	**2.10**
690	-0.52	0.89	2.31	3.72	5.13	6.55	7.96	9.37
700	-0.76	0.65	2.06	3.48	4.89	6.30	7.72	9.13
710	-1.01	0.41	1.82	3.23	4.65	6.06	7.47	8.89
720	-1.25	0.16	1.58	2.99	4.40	5.82	7.23	8.64
730	-1.49	-0.08	1.33	2.75	4.16	5.57	6.99	8.40
740	-1.74	-0.32	1.09	2.50	3.92	5.33	6.74	8.16
750	-1.98	-0.57	0.85	2.26	3.67	5.09	6.50	7.91
760	-2.22	-0.81	0.60	2.02	3.43	4.84	6.25	7.67
770	-2.47	-1.05	0.36	1.77	3.18	4.60	6.01	7.42
780	-2.71	-1.30	0.11	1.53	2.94	4.35	5.77	7.18
790	-2.96	-1.54	-0.13	1.28	2.70	4.11	5.52	6.94
800	-3.20	-1.79	-0.37	1.04	2.45	3.87	5.28	6.69
810	-3.44	-2.03	-0.62	0.80	2.21	3.62	5.04	6.45
820	-3.69	-2.27	-0.86	0.55	1.97	3.38	4.79	6.21
830	-3.93	-2.52	-1.10	0.31	1.72	3.14	4.55	5.96
840	-4.17	-2.76	-1.35	0.07	1.48	2.89	4.31	5.72
850	-4.42	-3.00	-1.59	-0.18	1.24	2.65	4.06	5.48
860	-4.66	-3.25	-1.83	-0.42	0.99	2.41	3.82	5.23
870	-4.90	-3.49	-2.08	-0.66	0.75	2.16	3.57	4.99
880	-5.15	-3.73	-2.32	-0.91	0.50	1.92	3.33	4.74
890	-5.39	-3.98	-2.57	-1.15	0.26	1.67	3.09	4.50

Table 3.27 Indoor recirculating tilapia system (IRTS): Sensitivity analysis- estimated income above variable expenses at varying fish selling price and feed price.

	Price received for market sized tilapia $/lb							
Feed price, $/ton	**1.25**	**1.30**	**1.35**	**1.40**	**1.45**	**1.50**	**1.55**	**1.60**
690	-7,935	-816	6,302	13,421	20,540	27,659	34,778	41,897
700	-9,163	-2,044	5,075	12,194	19,313	26,432	33,551	40,669
710	-10,390	-3,271	3,848	10,966	18,085	25,204	32,323	39,442
720	-11,618	-4,499	2,620	9,739	16,858	23,977	31,096	38,215
730	-12,845	-5,726	1,393	8,512	15,631	22,749	29,868	36,987
740	-14,072	-6,954	165	7,284	14,403	21,522	28,641	35,760
750	-15,300	-8,181	-1,062	6,057	13,176	20,295	27,413	34,532
760	-16,527	-9,408	-2,290	4,829	11,948	19,067	26,186	33,305
770	-17,755	-10,636	-3,517	3,602	10,721	17,840	24,959	32,077
780	-18,982	-11,863	-4,744	2,375	9,493	16,612	23,731	30,850
790	-20,210	-13,091	-5,972	1,147	8,266	15,385	22,504	29,623
800	-21,437	-14,318	-7,199	-80	7,039	14,157	21,276	28,395
810	-22,664	-15,546	-8,427	-1,308	5,811	12,930	20,049	27,168
820	-23,892	-16,773	-9,654	-2,535	4,584	11,703	18,821	25,940
830	-25,119	-18,000	-10,882	-3,763	3,356	10,475	17,594	24,713
840	-26,347	-19,228	-12,109	-4,990	2,129	9,248	16,367	23,485
850	-27,574	-20,455	-13,336	-6,217	901	8,020	15,139	22,258
860	-28,802	-21,683	-14,564	-7,445	-326	6,793	13,912	21,031
870	-30,029	-22,910	-15,791	-8,672	-1,553	5,565	12,684	19,803
880	-31,256	-24,138	-17,019	-9,900	-2,781	4,338	11,457	18,576
890	-32,484	-25,365	-18,246	-11,127	-4,008	3,111	10,229	17,348

Table 3.28 Indoor recirculating tilapia system (IRTS): Sensitivity analysis- estimated income above variable expenses per ft^2, at varying fish selling price and feed price.

	Price received for market sized tilapia $/lb							
Feed price, $/ton	**1.25**	**1.30**	**1.35**	**1.40**	**1.45**	**1.50**	**1.55**	**1.60**
690	-1.58	-0.16	1.25	2.66	4.08	5.49	6.90	8.32
700	-1.82	-0.41	1.01	2.42	3.83	5.25	6.66	8.07
710	-2.06	-0.65	0.76	2.18	3.59	5.00	6.42	7.83
720	-2.31	-0.89	0.52	1.93	3.35	4.76	6.17	7.59
730	-2.55	-1.14	0.28	1.69	3.10	4.52	5.93	7.34
740	-2.79	-1.38	0.03	1.45	2.86	4.27	5.69	7.10
750	-3.04	-1.62	-0.21	1.20	2.62	4.03	5.44	6.86
760	-3.28	-1.87	-0.45	0.96	2.37	3.79	5.20	6.61
770	-3.52	-2.11	-0.70	0.72	2.13	3.54	4.95	6.37
780	-3.77	-2.35	-0.94	0.47	1.88	3.30	4.71	6.12
790	-4.01	-2.60	-1.19	0.23	1.64	3.05	4.47	5.88
800	-4.26	-2.84	-1.43	-0.02	1.40	2.81	4.22	5.64
810	-4.50	-3.09	-1.67	-0.26	1.15	2.57	3.98	5.39
820	-4.74	-3.33	-1.92	-0.50	0.91	2.32	3.74	5.15
830	-4.99	-3.57	-2.16	-0.75	0.67	2.08	3.49	4.91
840	-5.23	-3.82	-2.40	-0.99	0.42	1.84	3.25	4.66
850	-5.47	-4.06	-2.65	-1.23	0.18	1.59	3.01	4.42
860	-5.72	-4.30	-2.89	-1.48	-0.06	1.35	2.76	4.17
870	-5.96	-4.55	-3.13	-1.72	-0.31	1.10	2.52	3.93
880	-6.20	-4.79	-3.38	-1.97	-0.55	0.86	2.27	3.69
890	-6.45	-5.04	-3.62	-2.21	-0.80	0.62	2.03	3.44

Table 3.29 Indoor recirculating tilapia system (IRTS): Survival sensitivity analysis- estimated net returns at varying survival rates.

Survival, %	Income above variable cost, per ft^2	Net return above all cost, per ft^2	Income above variable cost, per 24 RW	Net return above all cost, per 24 RW
100	44.47	31.40	224,042	158,175
90	36.09	23.02	181,819	115,953
80	27.71	14.64	139,597	73,731
70	19.33	6.25	97,357	31,508
60	10.95	-2.13	55,152	-10,714
50	2.57	-10.51	12,930	-52,936
40	-5.81	-18.89	-29,292	-95,159
30	-14.20	-27.21	-71,515	-137,381

Integrated Tilapia/Cucumber Greenhouse System

Investment Cost - Information used to develop Tables 3.30 through 3.32 came from secondary sources (Danaher 2012; Danaher 2013; Danaher et al. 2013a; Danaher et al. 2013b; Danaher et al. 2013c; Pickens 2013, personal communication). The investment required for the plant and fish greenhouses were $17,905 and $34,358, respectively, with annual depreciation at $939 and $3,072, respectively (Table 3.30). Additional structures were required for the fish production system increasing the investment about $16,500 more than the plant greenhouse whose only additional structure was a trellising system. The fish greenhouse was equipped with two large wood framed production tanks (12 ft wide x 88 ft length x 4 ft depth; 25,000 gallons), two clarifiers (500-gallon, 4 ft diameter x 6 ft height), an air system (310 feet of 2-inch PVC pipe connected the two blowers to antimicrobial diffuser tubing along the bottom sides of the raceways), and plumbing for the tanks (400 feet of 2-inch PVC pipe delivered water from the well, a 3-inch PVC pipe airlift delivered tank water to the clarifiers through 20 feet of 2-inch PVC pipe, and 40 feet of 2-inch PVC pipe used for draining the tanks).

The machinery and equipment items needed for fish production cost $16,336 and $10,041 for plant production. An evaporative cooling pad and liquefied petroleum (LP) gas fired heater was installed in the plant greenhouse while the fish greenhouse required 2 units, 1.5 HP regenerative blowers, a corn/wood pellet burner (for primary heating of the greenhouse), and a back-up generator. The overall investment required for the combined tilapia-cucumber system was estimated at $78,640 with an annual depreciation of $10,345.

Table 3.30 Integrated tilapia/cucumber greenhouse system (ITCGS), 2 cells (12 ft width x 88 ft length x 4 ft depth), construction and equipment cost, Auburn, Alabama.

Item	Unit	Cost/unit	Number	Total cost	Useful life	Average investment	Annual avg. depreciation /1	Interest on investment /2	Repairs as a percent of new cost	Annual repairs and maintenance
A. Capital cost										
Fish production										
Greenhouse structure	ea	$17,314	1	$ 17,314	20	$ 8,657	$ 866	$ 649	10%	$ 87
Shade cloth 80%	ea	$ 1,014	1	$ 1,014	5	$ 507	$ 203	$ 38	10%	$ 20
Wooden production tank	ea	$ 4,353	2	$ 8,706	8	$ 4,353	$ 1,088	$ 326	10%	$ 109
Air system	ea	$ 1,964	1	$ 1,964	8	$ 982	$ 246	$ 74	10%	$ 25
Clarifier and airlift system	ea	$ 1,800	1	$ 1,800	8	$ 900	$ 225	$ 67	10%	$ 22
Plumbing	ea	$ 3,560	1	$ 3,560	8	$ 1,780	$ 445	$ 134	10%	$ 45
Subtotal				$ 34,358		$ 17,179	$ 3,072	$ 1,288		$ 307
Plant production										
Greenhouse structure	ea	$17,314	1	$ 17,314	20	$ 8,657	$ 866	$ 649	10%	$ 87
Trellis system	ea	$ 590	1	$ 590	8	$ 295	$ 74	$ 22	10%	$ 7
Subtotal				$ 17,905		$ 8,952	$ 939	$ 671		$ 94
B. Equipment										
Fish machinery and equipment										
Fish production supplies	ea	$ 3,273	1	$ 3,273	2	$ 1,637	$ 1,637	$ 123	10%	$ 164
Generator	ea	$ 3,000	1	$ 3,000	6	$ 1,500	$ 500	$ 113	10%	$ 50
Corn boiler and accessories	ea	$ 7,000	1	$ 7,000	6	$ 3,500	$ 1,167	$ 263	10%	$ 117
1.5 hp blowers	ea	$ 1,021	3	$ 3,063	8	$ 1,532	$ 383	$ 115	10%	$ 38
Subtotal				$ 16,336		$ 8,168	$ 3,686	$ 613		$ 369
Plant machinery and equipment										
Plant production supplies	ea	$ 4,795	1	$ 4,795	3	$ 2,398	$ 1,598	$ 180	10%	$ 160
Heater	ea	$ 2,671	1	$ 2,671	5	$ 1,336	$ 534	$ 100	10%	$ 53
Cooling pad	ea	$ 2,575	1	$ 2,575	5	$ 1,288	$ 515	$ 97	10%	$ 52
Subtotal				$ 10,041		$ 5,021	$ 2,648	$ 377		$ 265
TOTAL				**$ 78,640**		**$ 39,320**	**$ 10,345**	**$ 2,949**		**$ 1,035**

Source: Jeremy Pickens, personal communications

/1 Computed by the straight line method with zero salvage value for depreciable items.

/2 No interest is charged for land and pond construction; they are assumed to already exist; equipment items are charged at an intermediate-term interest rate. Charged at 10% on the total value of land with all other depreciable items charged at 10% on one-half of the investment.

Production Parameters (Table 3.31) - Information for the production parameters used to project one year of tilapia and cucumber production utilizing the greenhouse system in Auburn, Alabama came from secondary sources (Danaher 2012; Danaher 2013; Danaher et al. 2013a; Danaher et al. 2013b; Danaher et al. 2013c; Pickens 2013, personal communication) and provides an accurate means to analyze and compare to the two prior described intensive systems detailed in this study. The analysis of this system required assimilation of data as well as some cost to be assumed and estimated. The cost for 0.24 lb tilapia stockers was fixed at $0.35/stocker and the price per cucumber seed was $0.52. The production cycle per crop of fish and cucumbers was 120 and 100 days, respectively. The harvest weight for tilapia was 1.00 lb and the stocking rate was 4,200 fingerlings per raceway (one fish per cubic foot). Twenty pounds of cucumbers were harvested from each cucumber plant per crop. Both tilapia tanks received 2.25 tons of commercial floating feed at priced at $790/ton per crop with an assumed FCR of 1.5: 1.0. The plants received alternating amounts of fish water and fertilizer over the course of the year. Tilapia and cucumbers were assumed to be sold at $2.10/lb and $1.00/lb, respectively.

The electrical power use of the plant greenhouse was determined to be 30-kWh per day while the fish greenhouse needed utilized 100-kWh per day. The actual repairs and maintenance for the fish greenhouse was $676 for the year and $359 for the plant greenhouse. While in production, the tilapia production system need required 10 bags (50 lb) of hydrated lime priced at $10 per bag to maintain an appropriate pH (7.5-8.5) and $400 of additional water quality related chemicals for the year (chemical replacements for frequently used water quality analysis tests, i.e., pH, alkalinity, ammonia, or nitrites). Four hundred dollars was estimated and allotted for chemicals that might be needed for pest control in the plant greenhouse. The heating energy used in greenhouses were estimated at $155 and $343 of corn and LP gas for heat during the winter months, respectively.

Table 3.31 Production parameters for the integrated tilapia/cucumber greenhouse system (ITCGS), Auburn, Alabama.

Fish Production		
Grow-out area for tilapia per tank	ft^3	3,342
Stocker tilapia weight	lb	0.24
Market weight	lb	1.00
Days for tilapia to reach target size	days	120
Tilapia stocking rate	fingerlings	4,200
Tilapia stocker cost	$/ea	0.35
Tilapia feed conversion rate		1.5
Tilapia survival	%	95
Total amount of feed fed to tilapia	tons	2.25
Selling price for market size tilapia	$/lb	2.10
Feed price, 36% protein	$/ton	790
Repair and maintenance cost for fish GH	$/year	676
Average daily electrical use for fish GH	KWhr	100
Chemicals for water quality	$/year	400
Heating fuel, corn	$/month	155
Hydrated lime, 50lb bag	$/bag	10
Plant Production		
Production area for cucumbers	ft^2	40,320
Pounds of cucumbers harvested	$lb/ft^2/crop$	5.53
Number of plants	$plants/ft^2$	0.28
Crop cycle duration	days	100
Cucumber seed price	$/seed	0.52
Selling price for cucumbers	$/lb	1.00
Repair and maintenance cost for plant GH	$/year	359
Average daily electrical use for plant GH	KWhr	30
Chemicals for plant production	$/year	400
LP gas	$/month	343
Fertilizer	$/year	250

Enterprise Budget - The enterprise budget developed for the ITCGS using the defined production parameters to project one year of integrated production revealed three crops of fish and cucumbers could produce 23,940 lb of tilapia and 47,779 lb of cucumbers (Table 3.32). The gross receipts for tilapia production were $50,274 and $47,779 for cucumbers. The breakeven price for tilapia was $1.16 per lb to cover variable expense and an additional $0.39 per lb to cover fixed cost. The breakeven price to produce cucumbers was $0.25 per lb. This amount consisted of $0.14 per lb to cover operational cost and $0.11 per lb for fixed costs. The system-wide net return above variable expenses was $63,641 ($\$12.75/ft^2$) and $49,116 ($\$9.84/ft^2$) above total cost.

Feed and fingerlings accounted for 64 percent of the overall operational cost for the ITCGS. The major operational expense for the cucumber enterprise was the cost to heat the greenhouse. Land and well construction costs were not included for this enterprise budget. The well supplying water to the fish greenhouse previously existed and Auburn University owns the land at the ITCGS location. In actual adoption of this technology in Alabama, we assumed the operator/manager would also own the land. Labor cost were also excluded from the enterprise budget and thus, the enterprise budget represents a return to the land, labor, and management resources.

Table 3.32 Integrated tilapia/cucumber greenhouse system (ITCGS) enterprise budget, 2 cells, producing 1.0 lb tilapia, Auburn, Alabama.

	Unit	Quantity	Price or cost / unit	Value or cost	Per ft² value	Cost per lb	Percent of costs
1. Gross receipts							
Fish sales	lb	23,940	2.10	50,274		$ 2.10	
Cucumber sales	lb	47,779	1.00	47,779		$ 1.00	
Total receipts		**71,719**		**98,053**	**19.64**	**$ 1.37**	
2. Variable cost							
Fish							
Fingerlings, 4200/tank, 2 tanks total	each	25,200	0.35	8,820	1.77	$ 0.12	26%
Feed, food fish	ton	16	790	12,917	2.59	$ 0.18	38%
Electricity for fish GH	Kw-hr	36,500	0.08	2,920	0.58	$ 0.04	8%
Chemicals	year	1	400	400	0.08	$ 0.01	1%
Hydrated lime	bags	10	10	100	0.02	$ 0.00	0.3%
Heat fish	tons	6	155	930	0.19	$ 0.01	3%
Interest on operating captial for fish		19,565	0.08	1,565	0.31	$ 0.02	5%
Cucumbers							
Seedlings	seed	2,402	0.52	1,251	0.25	$ 0.02	4%
Electricity for cucumber GH	Kw-hr	10,950	0.08	876	0.18	$ 0.01	3%
Chemicals	year	1	400	400	0.08	$ 0.01	1%
Fertilizer	bags	1	250	250	0.05	$ 0.00	0.7%
LP	tons	2,400	1.50	3,600	0.72	$ 0.05	10%
Interest on operating captial for cucumbers	dol.&%	4,783	8%	383	0.08	$ 0.01	1%
TOTAL				**34,412**	**6.89**	**$ 0.48**	100%
3. Income above variable cost				**63,641**	**12.75**	**$ 0.89**	
4. Fixed cost							
Fish production							
Machinery depreciation	dol			3,686	0.74	$ 0.05	25%
Capital depreciation	dol			3,072	0.62	$ 0.04	21%
Repairs and maintenance	month	12	56	676	0.14	$ 0.01	5%
Interest on equipment and construction	dol.&%	17,179	0.08	1,374	0.28	$ 0.02	9%
Interest on equiptment/mach. purchases	dol.&%	8,168	0.08	653	0.13	$ 0.01	4%
Cucumber production							
Machinery depreciation	dol			2,648	0.53	$ 0.04	18%
Capital depreciation	dol			939	0.19	$ 0.01	6%
Repairs and maintenance	month	12	30	359	0.07	$ 0.01	2%
Interest on equipment and construction	dol.&%	8,952	8%	716	0.14	$ 0.01	5%
Interest on equiptment/mach. purchases	dol.&%	5,021	8%	402	0.08	$ 0.01	3%
Total fixed cost				**14,525**	**2.91**	**$ 0.20**	100%
5. Total cost				**48,937**	**9.80**	**$ 0.68**	
6. Net return to land, labor, and management				**49,116**	**9.84**	**$ 0.68**	
Net returns per square foot, $/ft²:							
Above specified variable cost					12.75		
Above specified total cost					9.84		
Breakeven price to cover specified, $/lb:							
Variable expenses fish				**1.155**			
Total expenses fish				**1.550**			
Variable expenses cucumber				**0.141**			
Total expenses cucumber				**0.247**			

There are advantages and disadvantages associated with every production and cropping system and profitability in both the short- and long-term is critical. Farmers and aquaculturists should carefully note what comprises a successful intensive and integrated system. Maximizing production per unit area, while maintaining profitability over a range of volatile input and output market prices, and covering capital investments in a reasonable amount of time are important when choosing any intensive production system.

Table 3.33 summarizes the important facets of the enterprise budgets developed for comparing the three intensive fish production systems analyzed in this study. In terms of fish culture area, the IRTS utilized the largest area with 20,720 ft^3. The IRTS demonstrated greater profitability than the FIPRS (the FIPRS data was from a 'shake-down' production cycle meant to gain student operational experience and solve other mechanical problems in its initial run). Compared to the other systems, the IRTS required the highest investment cost at more than $540,000. While decisions on operating inputs can change annually, capital investment decisions are made less often and typically involve more money; and changing, altering, or reversing a capital investment decision can be difficult and costly (Kay and Edwards 1994). The sensitivity analyses applied to the IRTS suggests that it is a 'hardy' enterprise meaning that it holds up well against the volatility of market prices for both inputs and revenue. Profitability was achieved for both the short- and long-term regardless of drastic fluctuations of fish selling prices, feed cost, and fish survival. The FIPRS system was more susceptible to changes in market prices due to since catfish stockers are a relatively low-value in terms of wholesale market value compared to the live sales of tilapia. All three scenarios growing catfish in the FIPRS could potentially be profitable by selling the fish in the appropriate markets that allow the producer to dictate the selling price while avoiding wholesale markets.

Systems featuring greater levels of control (over animals) like the ones examined in this study, will become more important and common in the future as global human populations increase and land and water for farming decrease in abundance. Intensive fish production systems continue to move increasingly close to maximizing fish production on a system volume basis as well as for that of the land. The ITCGS offered the least expensive way to produce fish per unit area (ft^2) of production area when vegetable production was included in the enterprise to partially offset fish production cost (Table 3.34). In the IRTS, fish production cost was more than 50 percent higher to produce fish on a per cubic foot basis than in the small FIPRS and ITCGS fish-plant greenhouse system analyzed here. When we consider output of fish and associated sales to retail and recreational buyers willing to pay $1.25-1.75 per pound of catfish for example, the value of the approach looks more appealing. Keeping the control of setting the selling price for products in the hands of the operator protects smaller-scaled farm's survival from being dictated by outer forces, i.e., commercial processors.

The FIPRS units in this study were designed for replicated research much like the half-acre research plots in Auburn. While practical for research purposes, these units were not designed for commercial production. Further, larger scale FIPRS units developed within the commercial sector in West Alabama contain water volumes ranging from 3000-5000 cubic feet. These units are of a scale more appropriate to commercial marketing processors. The cost per unit volume decreases as unit size increases; for example, the cost per unit volume (ft^3) of a FIPR cell is $11.72 while the larger FIPR cells (10 ft wide x 40 ft long x 5 ft depth) currently being installed in West Alabama offers three times more production area at half the cost per cubic foot. Producers should keep in mind that manageability of the system is more important than lowering the cost per unit volume, at a certain point units can become to large to be managed effectively.

Incorporating vegetable production within an integrated system approach alongside fish production is another business route that could be taken by aquaculturists and farmers. The ITCGS utilizes the nutrient-rich wastewater from the fish tanks to serve as a partial fertilizer for plant/vegetable production. Fertilizer cost within a greenhouse vegetable or ornamental plant enterprise are the most expensive element of the plant production budget while the cost of feed is the most costly item for the fish production budget. Although the cucumbers in this study were not grown solely using the fish wastewater, the fish effluent does dramatically reduce fertilizer cost which in effect reduce the breakeven price for vegetable production; in addition, this combination has market appeal to some consumers. The ITCGS required the least capital, equipment, and machinery investment with almost half the fish production area as the FIPRS yet yielded $46,771 more in gross receipts above the FIPRS. Again, the small-scale FIPRS 2013 production trail was a learning period and performance is expected to improve in the years ahead. When we consider the FIPRS as a retail system for recreational clients and not a wholesale or production model the approach is far more attractive. The combination of fish production with marketing and with a suite of high-value vegetable products can be very profitable. While the ITCGS is a small system it was projected to earn 95 percent more than the net return above all cost for the FIPRS and 67 percent of what the IRTS returned to the investment.

Table 3.33 Summary comparison of three intensive fish production systems (FIPRS, IRTS, & ITCGS).

	Floating in-pond RW system- producing 0.24lb channel catfish stockers	*Indoor recirculating tilapia system*- producing 1.27lb tilapia	*Integrated tilapia/cucumber GH system*- producing 1lb tilapia
Fish production area (ft^3)	10,944	20,720	6,684
System components	24 RW	5 nursery RW, 5 stocker RW, 10 grow-out RW	2 fish RW, 1 plant GH
Investment	$128,348	$544,380	$78,640
Annual depreciation	$9,893	$36,829	$10,345
Gross reciepts	$51,282	$337,779	$98,053
Income above variable cost	$18,205	$139,597	$63,641
Net returns above total cost	$2,684	$73,731	$49,116
Breakeven price above total cost	$0.38	$1.59	$1.55

RW= Raceway; GH= Greenhouse

Table 3.34 Summary table of variable and fixed cost for three intensive fish production systems (FIPRS, IRTS, & ITCGS).

	Variable cost		**Fixed cost**	
	$/system	$/ft^2	$/system	$/ft^2
Floating in-pond RW system- producing 0.24lb channel catfish stockers	$ 33,077	$ 11.49	$15,521	$ 5.39
Indoor recirculating system- producing 1.27lb tilapia	$198,182	$39.34	$ 65,866	$13.08
Integrated tilapia/cucumber GH system- producing 1lb tilapia	$ 34,412	$ 6.89	$14,525	$ 2.91

RW= Raceway; GH= Greenhouse

Chapter 4

Summary and Conclusion

Intensifying fish production enterprises to earn an improved rate of return has been an objective the more progressive sectors of the aquaculture industry has made toward positive advances in recent years. Improved technologies can provide opportunity to advance our ability to grow larger amounts of fish with increasing efficiency while using less water and space. Intensive aquaculture is a promising solution to feeding a growing global human population expected to approach 10 billion by 2040.

Integrated systems like the ITCGS are yet another option with tremendous potential for profitability. The greenhouses offer relatively low investment cost and are an efficient way to enhance production per ft^2. Utilizing fish waste collected from modern systems to produce high value crops sets the ITCGS apart from the other production systems. Because the ITCGS is an experimental unit, its true potential for commercial production could not be utilized. It is estimated three additional plant greenhouses could be run utilizing the wastewater coming from one tilapia greenhouse (Pickens 2013, personal communication). Production on this scale would result in around 70 percent more profit at double the investment cost (Table 4.1)

The IRTS is the only system discussed in this study which has proven capable of operating on a commercial scale at the time of this analysis.   One should expect a steep learning curve when putting an intensive system into commercial production as operators and mangers need time to adjust to this new technology and become familiar with its working parts and learn to quickly and efficiently resolve arising issues. The IRTS is a good example of a production system which continues to evolve through both scientific inquiry and trial and error. Figure 4.1 illustrates the learning curve for the tilapia barn (IRTS). The start-up years after its initial construction did not result in large amounts of fish sales. In 2013, however, after only four years in production, 70 percent more fish were harvested and sold than in the previous three years combined. And, it is not only improving the efficiency and output of the system's production, but it also takes time to develop market outlets to sell the produced goods.

Economic planning is an important preliminary step before deciding on an intensive fish production system. Enterprise budget analysis is a useful too, for not only projecting potential profitability but also for comparing annual production data to pre-decided production goals. Production goals should be ambitious but realistic and measurable. Table 4.2 is an example of the projected goals and profitably versus actual production data for the IRTS. The farm manager set ambitious yet achievable goals and though there is room for improvement, the system produced fairly close to what was originally planned. Sensitivity analysis is another important economic tool for testing an operations ability to produce a profit over a range of varying market prices. The sensitivity analyses done for this study showed the IRTS more capable of staying profitable over a wide range of market prices and survival percentages than the FIPRS.

Unique systems like the ones discussed in this study have all been designed to improve upon previous system iterations by means of combined efficiency and output. The FIPRS, for example, has similar benefits as the fixed-IPRS but can be built using cheaper materials and give farm managers the freedom to relocate the raceways to other ponds. The small units described here are most appropriate to smaller stakeholders for producing and marketing more toward retail and recreational customers. Because this study was the first trail using the newly constructed FIPRS we do not know the outcome of the unaccounted fish. The variable survival observed in the FIPRS study could be due to theft, escapes, death, or stocking-rate calculation error. Measures should be taken when testing this system in the future to protect the raceways from animal predation and human interference as well as routine inspections for each cell to ensure fish are not escaping from damaged areas.

The initial production trial did not represent our best effort at producing fish and will likely parallel the anticipated learning curve we saw in the commercial IRTS system. Having learned more about the FIPRS through trial and error done in this study, future research should be done to learn about the potential of these units on a commercial scale. It is of interest to examine how different the outcome could have been using commercial production parameters from Brown's (2010) study on the IPRS rather than the results from our initial 'shake down' of the FIPRS system. The channel catfish data of food-sized fish produced were calculated in the enterprise budget for the FIPRS to show what it might have looked like to grow fish to market-size as opposed to advanced stockers (Table 4.3). The FIPRS stood to make 45 percent more income above variable cost and 85 percent more in net returns above total cost when producing food-sized channel catfish. Although these small units are essentially experimental research plots, their significance begins to emerge when operating on a commercial scale.

Future trials to be done using the FIPRS units should also include culturing different fish in the units. Cremer et al. (2014) noted his group's production data for a commercial scale IPRS to produce 5.76 lb grass carp (a very high value market item in

China); when applied to the system in Auburn, the FIPRS produced 93,174 lb of grass carp with $32,236 of net returns above total cost and $47,758 of income above variable cost (sold at $1.90/lb according to the fish market in the Auburn area). If commercial scale tilapia production was projected utilizing the FIPRS system (in accordance with the production parameters discussed for the stocker and grow-out phases of production) the result was 115,336 lb of market sized-tilapia produced in 30 weeks which was 20 percent more than what the IRTS system produced in 2013. This resulted in $162,716 of income above variable cost and $146,716 of net returns above total cost.

Future research is needed on the carrying capacity limitations of ponds (and pond volume) when systems like the FIPRS units are installed. The fish in the raceways have the first run at the oxygen being pumped into the system but it is known that approximately 95 percent of oxygen in a pond is used by the other organisms besides fish (Boyd 2014, personal communication); the resulting effect on the biota existing outside the FIPRS is not well understood. It is thought that the FIPRS will essentially create a river within a pond driving a large amount of mixing which could be beneficial to the organisms in the pond. Regardless of the carrying capacity of the pond, there could also be behavioral limitations to each fish species preventing productive growth at a higher stocking rates. The commercial production of channel catfish, tilapia, and grass carp in the previously mentioned FIPRS production scenarios were stocked in accordance with the stocking density of the corresponding studies, which was 2.83, 1.08, and 1.65 lb per ft^3, respectively. These studies have shown these stocking densities to be appropriate for raceways without experiencing behavioral limitations from overcrowding.

Table 4.1 Tilapia and cucumber production using 4 plant GH and 1 fish GH versus 1 plant GH and 1 fish GH (ITCGS), Auburn, Alabama.

	Unit	4 plant GH 1 fish GH	1 plant GH 1 fish GH
Investment cost	$	162,476	78,640
Annual depreciation	$	21,106	10,345
Cucumber production	lb/year	191,117	47,779
Tilapia production	lb/year	23,940	23,940
Selling price per lb of tilapia	$/lb	2.10	2.10
Selling price per lb of cucumber	$/lb	1.00	1.00
Cucumber sales	$/year	191,117	47,779
Tilapia sales	$/year	50,274	50,274
Variable cost (cuc. & fish)	$/year	54,692	34,412
Income above variable cost	$	186,699	63,641
Fixed cost (cuc. & fish)	$/year	29,716	14,525
Total cost (cuc. & fish)	$/year	84,408	48,937
Net return above total cost	$	156,983	49,116

GH = greenhouse

Figure 4.1 Four years of production data for the indoor recirculating tilapia system showing improvement over time in pounds produced and cash sales.

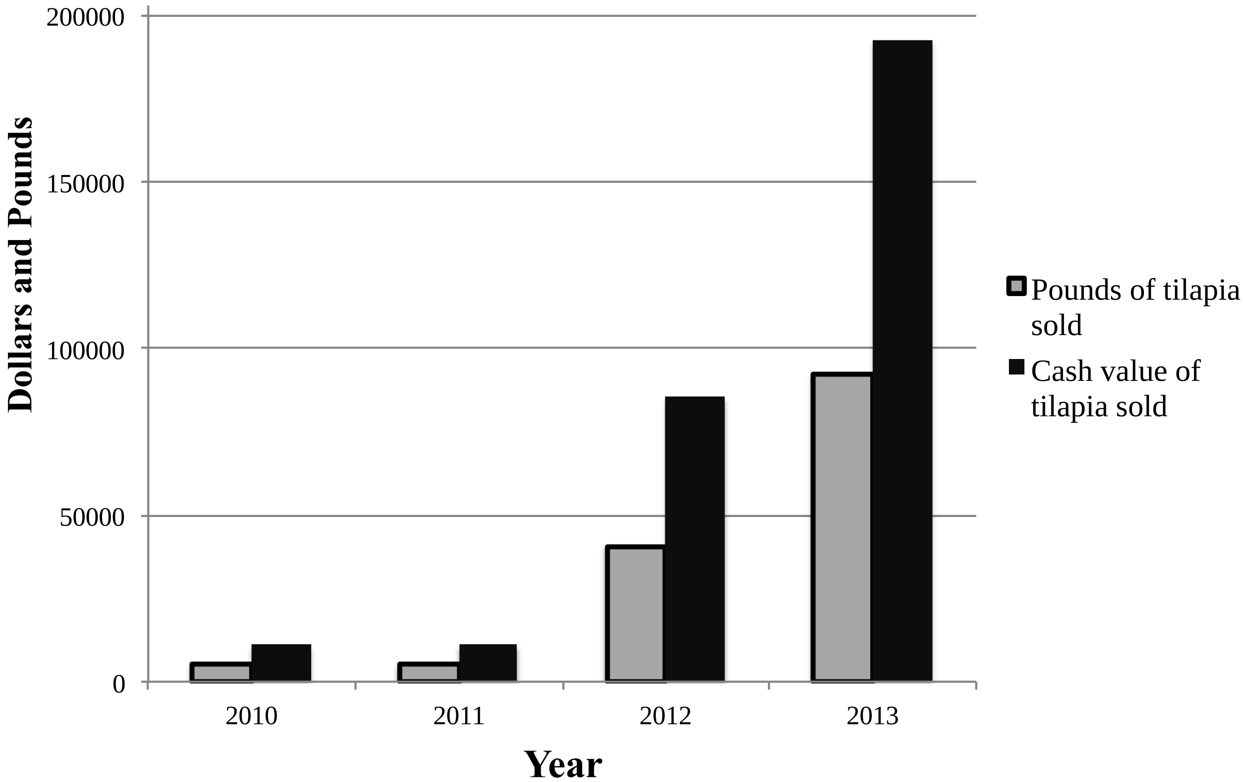


Table 4.2 Expectation production versus actual production data for the indoor tilapia recirculating system (IRTS), West Alabama, 2013.

	Unit	Expected	Actual
Stocking rate to nursery tank	fingerlings/tank	6,500	6,881
Harvest weight	lb	1.5	1.27
Survival	%	95	80
FCR		1.5	1.9
Feed amount per crop	tons	5.2	5.26
Production cycle	weeks	32	40
Fingerlings stocked	fingerlings/year	156,000	182,745
Total feed fed	ton/year	144	116
Tilapia sales	$/year	385,842	337,779
Variable cost	$/year	217,163	198,182
Income above variable cost	$/year	168,678	139,597
Fixed cost	$/year	65,866	65,866
Total cost	$/year	283,030	264,048
Net return above total cost	$/year	102,812	73,731

Table 4.3 Commercial channel catfish production versus scenario 3 production for the floating in-pond raceway (FIPRS), 24 cells, Auburn, Alabama.

	Unit	Brown 2010 food-size fish production data	Scenario 3 stocker fish production projection
Stocking density	fish/ft^3	8	11
Fingerlings stocked	fingerlings/year	79,416	128,592
Selling Price	$/lb & $/indiv.	0.90	0.40
Survival	%	95.1	99.7
Total feed fed, 24 RW	ton/year	52	19
Feed amount per crop	tons	2.16	0.81
FCR		1.5	1.6
Harvest weight	lb	1.31	0.24
Pounds harvested	lb	98,277	30,769
Production cycle	week	32	20
Catfish sales	$/year	88,449	51,282
Variable cost	$/year	55,098	33,077
Income above variable cost	$/year	33,352	18,205
Fixed cost	$/year	15,521	15,521
Total cost	$/year	70,619	48,599
Net return above total cost	$/year	17,830	2,684

Scenario 3 production can be found in the results section Table 3.6.

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