THE ECONOMIC SIGNIFICANCE OF AQUATIC BIOTECHNOLOGY IN THE PRODUCTION OF CHANNEL CATFISH (*Ictalurus punctatus*) FEMALE X BLUE CATFISH (*I. furcatus*) MALE HYBRID (CB HYBRID) EMBRYOS

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THE ECONOMIC SIGNIFICANCE OF AQUATIC BIOTECHNOLOGY IN THE PRODUCTION OF CHANNEL CATFISH (*Ictalurus punctatus*) FEMALE X BLUE CATFISH (*I. furcatus*) MALE HYBRID (CB HYBRID) EMBRYOS

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VITA

Did she lose her past, has she found the present, is she in search of the future? Oyie (Gloria) Atienza Magnayon Abenina Umali Maceina treasures her past, savors the present and anticipates the future. Oyie is an only child to her parents, a sibling to eleven, an ex-wife and a wife, a mom to two, and a grand mom to three. The Philippines, Canada and the USA have been home to her. International NGOs, industry, academia, and government have employed her. She's a friend to many, an enemy to some, and a saint to none.

DISSERTATION ABSTRACT

THE ECONOMIC SIGNIFICANCE OF AQUATIC BIOTECHNOLOGY IN THE PRODUCTION OF CHANNEL CATFISH (*Ictalurus punctatus*) FEMALE X BLUE CATFISH (*I. furcatus*) MALE HYBRID (CB HYBRID) EMBRYO

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The current cost of commercially producing CB hybrid catfish fry is 325% higher than that of channel catfish due to the CB hybrid's high production costs and low hatch rates. However, CB hybrid catfish fingerlings cost 7% less to grow than channel catfish fingerlings, and net returns above variable costs are two-and-a-half times as much, because of the CB hybrid's faster growth and higher feed efficiency. Sensitivity analysis showed that income for channel catfish is most sensitive to survival rate while that for the CB hybrid catfish is to hatch rate. The second most significant factor for both in determining income is fingerling selling price.

The economic importance of ovulating agents, fungal control, and genetic improvement in CB hybrid fry production was evaluated. The CB hybrid's costs of fry

and fingerling production, and income from fingerling production were compared to those of channel catfish production. The CB hybrid's economic performance improved with use of luteinizing hormone releasing hormone analogue (LHRHa), the most promising hormone for hand stripped hybrid catfish embryo production, and use of select channel catfish female, broodstock that have been selected for enhanced reproductive performance. Use of LHRHa, and select channel catfish females showed marked improvements in spawning performance of the channel catfish female and moderate increases in hatch rate, in the production of CB hybrid catfish fry, but cost of fry production continued to be higher than that of the channel catfish production. Combining LHRHa with formalin and copper sulfate (F+CS) (alternating) showed remarkable improvements both in spawning performance and hatch rate of the CB hybrid's female channel catfish, resulting in CB hybrid's cost of fry production to be lower than that of channel catfish production. Cost of growing fry to fingerling, and income from CB hybrid catfish fingerlings were consistently superior in these comparisons.

An archetype CB hybrid production model that combines all the best parameters from recommended protocols was simulated and compared to channel catfish production. The archetype CB hybrid production was superior to channel catfish production in all physical and economic comparisons, including fry production per kilogram of female channel catfish body weight and fry production cost. Improvement in reproductive performance shifted the CB hybrid's sensitivity to risk from biological factors, hatching rate in particular, to risk associated with market conditions, specifically output selling price.

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CHAPTER 1 - COMMERCIAL PRODUCTION OF CHANNEL CATFISH (*Ictalurus punctatus*) FEMALE X BLUE CATFISH (*I. furcatus*) MALE HYBRID (CB HYBRID) EMBRYOS

Food is necessary to the existence of man… the passion between the sexes is necessary and will remain nearly in its present state… the power of population is indefinitely greater than the power in the earth to produce subsistence for man. Population, when unchecked, increases in a geometrical ratio while subsistence increases only in an arithmetical ratio.

Malthus, 1798

Over two centuries later, the world's population has increased six-fold and continues to grow, food production has kept pace, and freely functioning markets with individuals maximizing their own utilities have satisfied food demand and averted doomsday. What factors have made food available to the growing population? Technological development and efficient production are two of the major factors that helped food supply keep pace with population growth.

Abstract

This study reviewed the history and current state of catfish industry in the US and how they relate to hybrid catfish embryo production. Adoption of the channel catfish (*Ictalurus punctatus*) female x blue catfish (*I. furcatus*) male (CB hybrid) has been suggested as a strategy to improve production efficiency and safeguard the viability of the catfish industry. Research findings and improvements in CB hybrid catfish production technology were reviewed and the advantageous characteristics of the CB hybrid catfish for commercial use were highlighted.

The current commercial practice of producing CB hybrid catfish embryo was compared to commercial channel catfish production using analytical techniques in economics including breakeven analysis, and enterprise, capital and partial budgets. The enterprise budgets showed that producing CB hybrid catfish fingerling is 129% more costly than producing channel catfish fingerling. Majority of the difference in cost is attributed to fry production, CB hybrid catfish fry being 325% more costly to produce

than that of channel catfish fry. However, comparing the growth from fry to fingerling shows that CB hybrid catfish fingerlings in fact cost 7% less to grow than channel catfish fingerlings. Because of its higher feed efficiency and higher growth rate, cost of producing CB hybrid catfish is reduced once the hybrid survives to the fry stage. Efforts should, therefore, be directed at improving CB hybrid fry production efficiency.

Introduction

Given the decline in world fish stocks, the worldwide requirement for fish over the next three decades can be met through increases in aquaculture production (FAO 2000, 2002, 2004, 2006). Aquaculture is generally understood as the production and husbandry of aquatic organisms in a controlled or semi-controlled environment, giving the culturist some form of intervention in the growing process to enhance growth and survival of the culture organism. For aquaculture to be sustainable certain challenges such as improvements in growth, disease resistance, and production efficiency have to be addressed. Marrying traditional husbandry and biotechnological advances in food production will promote growth improvement and disease management. Farm management, on the other hand, will address issues related to production efficiency.

Biotechnology is the use of micro-organisms or biological substances, or the modification of cell activities, to perform specific industrial or manufacturing processes, or to produce commercial quantities of desirable substances such as crops and livestock with specified characteristics (Houghton Mifflin Co. 2000). Biotechnological techniques are being used to improve aquacultured fish, enhance natural fisheries, and protect and conserve natural resources; hence genetically modified aquatic organisms are already having an impact on global food security (Dunham 2004). Techniques developed through biotechnological research will improve production possibilities for fish farming.

Application of farm management principles will help warrant efficient use of scarce resources. Farm management concerns decision making consistent with the operator's objectives. It involves choosing technically efficient production techniques, keeping farm accounts, and maintaining viable farm operations. Usually the operator's objectives relate to business success, measured in terms of profit (Jolly and Clonts 1993).

This study includes components relating to catfish industry, farm management, and technological improvements in the production of catfish fry used in fingerling and food fish production. Bringing all these components together will show how biotechnology bears on aquaculture production, in which catfish accounts for the major proportion in the US. Specifically, the analysis will show how improvements in the channel (*Ictalurus punctatus*) female catfish x blue (*I. furcatus*) male catfish (CB hybrid) production technology will help improve the long term viability of the catfish industry.

Currently, the catfish industry experiences difficulties due to high input costs, low output prices, and competition from low-cost imports. Use of CB hybrid catfish for commercial culture could ameliorate this situation. However, the lack of fry for fingerling and food fish production prevents industry wide adoption of the CB hybrid catfish. Fry production is low and supply is unstable due to low hatch rates resulting in high fry production costs. This study will examine factors that are crucial to stable production and reliable supply of fry sufficient to support the catfish industry. This chapter will review the commercial catfish situation, Chapter 2 will investigate the use of hormones in CB hybrid embryo production, Chapter 3 will explore alternative fungal disinfectants for treating CB hybrid catfish eggs, Chapter 4 will analyze the use of genetically improved female channel catfish in the production of CB hybrid catfish embryo, and finally, Chapter 5 will analyze the risk associated with CB hybrid catfish production in comparison to channel catfish production. The objectives of this chapter are to review the history of catfish production in the United States, to evaluate the current state of the catfish industry, to compare the economic performance of the CB hybrid catfish and the channel catfish, and to show that the CB hybrid catfish can be an alternative culture organism in the catfish industry.

The Catfish Industry

The meager beginnings of what now accounts for over 70% of the country's aquaculture production dates back to the early 1900s when different state agencies conducted experimental research on catfish spawning in captivity. Although the first catfish spawning in captivity took place in 1890 (Kendall 1902, cited in Stickney 1996), it was not until the early 1910s (Shira 1917, Dunham and Smitherman 1984) that the first successful channel catfish spawning in ponds was observed. In 1916, protocols for stocking broodfish was modified to include kegs that might serve as nesting sites and facilitate collection of egg masses to hatch. In addition to using kegs, early development of catfish rearing practices included the use of paddles in hatching troughs (Clapp 1929). Current channel catfish spawning and fry production techniques used in commercial farms are very similar to those that were in place by early 1940s.

While the U.S. Biological Station in Fairport, Iowa reported the first successful catfish pond spawning, the Kansas State Fish Hatchery also claimed that distinction, about 1911, (Dunham and Smitherman 1984) and prided itself in being the only agency in the US, as of 1925, producing channel catfish for general distribution (Doze 1925). Production of catfish in private ponds was started by Vern Krehbiel in the early 1930s on a farm in Pretty Prairie, Kansas (Dunham and Smitherman 1984) using catfish domesticated and distributed by the Kansas State Fish Hatchery. By the 1960s farm raised catfish were being produced in Alabama, Arkansas, Mississippi (Dillard and Waldrop 1993) and Kansas (Dunham and Smitherman 1984).

The 1960's was the decade that farmers in economically depressed areas of the Southern United States began transforming cropland into fish ponds to grow channel catfish. Commercial channel catfish production began to develop when an Alabama farmer started processing farm-raised catfish in the early 1960s (Dillard and Waldrop 1993). Shortly thereafter, Mississippi farmers saw commercial production of catfish as an opportunity to diversify and as an alternative to traditional row crops. During these early days of commercial catfish farming, catfish grown in Mississippi had to be shipped to Arkansas and Alabama for processing due to lack of local markets at that time. Currently, Mississippi accounts for the majority of catfish production, processing and sales.

Based on the first Census of Aquaculture by the National Agricultural Statistics Survey of the USDA in 1998 (Table 1.1), catfish production was valued at $451 million, and accounted for 46% of total national aquaculture production (USDA 2000). If only food fish were considered, catfish would account for 73% of the 783.3 million pounds of the United States food fish production and 64% of the total food fish sales valued at $654.2 million. As of 2005, catfish growers reported total sales of $482 million and expect about the same revenues for 2006 (USDA 2006). Commercial catfish production in the U.S. is a major aquaculture industry that supports the agricultural economies of the south, particularly in the states of Mississippi, Arkansas, Alabama and Louisiana.

The rapid growth of the catfish industry in the 1980s and 1990s has made it a major economy booster in Southern United States, providing jobs to local communities and generating billions of dollars in economic impact to catfish processors, machinery dealers, feed mills and other businesses including chemical manufacturers, restaurants and transportation companies. The states of Mississippi, Arkansas, Alabama, and Louisiana account for 94 percent of all catfish production acreage in the US. Despite the unprecedented growth of catfish aquaculture industry, it has experienced difficulties in the recent past. Low prices received by producers in 2002 ($0.57/pound) and 2003 ($0.58/pound) have caused economic hardship for channel catfish producers. Production ponds decreased by about 10,000 acres since 2002, resulting in at least 10% decrease in production for each fish category including food size fish, brood fish, stockers, fingerlings and fry (USDA 2003). Lower feed prices in 2006 coupled with high 60- to mid 70-cent price range per pound should help catfish farmers recover from the market difficulties encountered in the last 4 years (USDA 2006).

While catfish prices improved in 2004, higher catfish feed prices and increasing fuel prices mostly negated gains. Although large commercial producers capture a significant percentage of the catfish market, numerous family-run catfish farms in poverty-stricken communities of the Southern United States support local employment and the rural economy. The volatility of the catfish market can result in serious financial losses to the domestic catfish producers and depressed economic conditions for the already impoverished rural areas in the south. This instability arises from combinations of market forces including, but not limited to, import volume and prices (Quagrainie and Engle 2002) and increasing processed feed prices (Soto and Kazmierczak 1998). Developing countries that are capable of aquaculture production at a much lower cost are the main source of alternative species, particularly tilapia, which pose even more severe competition than catfish imports. As long as local consumers do not see a rationale for paying the differential cost for domestic farm-raised catfish products, less expensive imported catfish, or any fish in general, could increasingly seize a fair percentage of the market share.

Given that catfish are the most important cultured fish in the United States, the viability of the industry can be safeguarded by developing strategies that will reduce production costs and enhance production efficiency. In the long run, this is the only way to combat foreign fish imports as only efficiency will lower production costs to a point where transportation becomes a limiting factor for foreign imports. Currently, catfish production is almost entirely based on the culture of channel catfish. Studies have shown that the adoption of the CB hybrid catfish is a promising means to increasing profitability, production efficiency and sustainability in the catfish industry (Ligeon et al. 2004a, 2004b; Chatakondi et al. 2000, Chatakondi et al. 2005).

CB Hybrid Catfish Embryo Production

Channel catfish grow to marketable size faster than any other ictalurid catfish species (Chappell 1979, Dunham and Smitherman 1984, Dunham et al. 1994, Dunham et al. in press), a quality desirable for commercial purposes. Compared to other species, the channel catfish has a higher tolerance for stress, ammonia and nitrite concentrations in water, and resistance to parasites and bacterial infections (Dunham et al. 1993, Dunham and Argue 2000). For this reason, the catfish industry relies on the channel catfish for commercial culture. Mass selection (Dunham and Smitherman 1983, Dunham et al. 1985, Padi 1995, Dunham et al. 1999, Rezk et al. 2003) and intraspecific breeding (Dunham et al. 1983b, Dunham et al. 1987, Wolters and Johnson 1995, Smitherman et al. 1996) have been the most researched methods for improving the channel catfish through genetic enhancement. Mass selection has progressively improved growth and body weight of the channel catfish, and as much as 50 percent improvement has been attained (Padi 1995, Smitherman et al. 1996) after four generations of mass selection.

Although the channel catfish accounts for majority of commercial catfish production, other species have been considered for commercial culture because they too possess characteristics that could benefit the industry. Blue catfish, having relatively fast growth, high carcass yield and remarkable seinability, is the most promising culture species next to the channel catfish (Dunham et al. 1993, Dunham and Argue 1998). Because of the superior qualities of these two species, it is not surprising that among the many interspecific catfish hybrids (Giudice 1966, Dupree et al. 1969, Dunham et al. 1987, Goudie et al. 1993), only the CB hybrid showed significant heterosis and evidence of over dominance (Dunham et al. 1982, Dunham and Brummet 1999, Dunham et al. 2000, Argue et al. 2003), which makes it superior to either the channel catfish or the blue catfish for commercial aquaculture.

<u>Advantages of the CB Hybrid Catfish for Commercial Culture</u>

The superiority and outstanding performance of the CB hybrid catfish has been extensively documented under research (Chappell 1979, Smitherman et al.1996, Li et al.2004) and commercial field trials (Ligeon et al.2004a, 2004b, 2004c; Chatakondi et al.2000, Chatakondi et al.2005). The CB hybrid catfish is more robust than the currently commercially produced channel catfish, increasing its desirability to farmers as a commercial culture species. Several indicators point to the superiority of the CB hybrid catfish over channel catfish: it grows 20-100% faster when grown at commercial densities in earthen ponds (Yant et al. 1975, Jeppsen 1995), reaches market size faster (Dunham and Smitherman 1981, Dunham et al. 1990, Smitherman et al.1996), and exhibits uniformity (Smitherman et al.1983, Argue et al.2003) both in weight (Brooks et al.1982) and in shape (Dunham et al.1982); feed conversion is 10-21% more efficient, averaging 1.35:1 for CB hybrid catfish compared to 1.56:1 for channel catfish (Yant et al.1975, Chappell 1979, Smitherman et al.1996, Li et al.2004). At all life stages, the CB hybrid catfish has a higher survival rate (Dunham et al. 1987), is 10-50% more disease resistant (Wolters and Johnson 1995, Wolters et al.1996, Dunham and Brummett 1999) and is 50-100% more tolerant of low dissolved oxygen (Dunham et al.1983a). Additionally, post-production advantages of CB hybrid catfish over channel catfish include 100% more seinability (Chappell 1979, Dunham and Argue 1998), 100% more hook and line vulnerability (Tave et al.1981) and 10% higher carcass yield (Chatakondi et al.2000, Bosworth and Wolters 2004).

The advantages of the CB hybrid catfish are beneficial to both fingerling and food fish producers. Higher growth, coupled with more efficient feed conversion, means increased live weight production at a lower cost; higher survival rate, tolerance of low dissolved oxygen and disease resistance would imply less reliance on artificial aeration and on chemicals for disease control. Moreover, producing the CB hybrid catfish commercially will not only benefit the producers but will result in spillover benefits to processors as well because the carcass yield efficiency would convert to higher dressout and fillet percentage. Overall, commercial production of the superior quality CB hybrids translates to a more efficient, competitive, and sustainable catfish industry. Despite the superior characteristics of the CB hybrid catfish, however, utilization among producers is low due to lack of fry for fingerling production, which in turn are necessary for grow-out to food fish.

The biggest hurdle to consistent commercial scale production of the CB hybrid catfish is the presence of reproductive isolating mechanisms (Tave and Smitherman 1982, Dunham and Smitherman 1987, Masser and Dunham 1998), not an uncommon phenomenon for interspecific hybridization, between the two species. Specifically, the reproductive isolating mechanism between the channel and the blue catfish appears behavioral, which relates to courtship rituals prior to spawning, making spontaneous mating problematic. Fortunately, gametes of these two species are compatible.

Procedure for Producing CB Hybrid Catfish Embryo

Production of the hybrid between the channel catfish and the blue catfish by hand stripping was reported as early as the 1960s (Giudice 1966, Dupree et al. 1969). The CB hybrid catfish, produced by crossing a channel female catfish with a blue male catfish, is easier to produce and performs better than its reciprocal hybrid (Dunham et al. 1982). The volume of literature documenting research, majority of which is done at the Auburn University Department of Fisheries and Allied Aquacultures to develop and refine methods for producing CB hybrid catfish, demonstrates its great potential for commercial culture. Two procedures for producing the CB hybrid catfish, pen spawning and artificial fertilization by hand stripping, have been extensively researched (Tave and Smitherman 1982, Dunham and Smitherman 1987, Ramboux 1990) but pen spawning was inconsistent, with low hybridization success averaging only about 20%. Success in using artificial fertilization, the more promising procedure of the two, is well known in the salmonid industry and is the recommended procedure for producing catfish hybrids because of the relatively consistent and reliable results compared to pen spawning. The procedure involves use of hormone to induce ovulation, hand stripping, and manual fertilization using blue catfish sperm (Dunham et al.2000).

During the spawning season, sexually mature female channel catfish and male blue catfish are identified. Good quality females that are good candidates for spawning are carefully selected for injection to optimize the use of hormone. A priming dose of hormone followed by the subsequent intermediate, if any, and resolving doses are administered at 12-hour intervals to induce egg maturation and ovulation. Females are checked for eggs and are expected to release eggs within 36 hours of the resolving dose depending upon temperature.

Various hormones have been utilized to induce catfish ovulation for hand stripping and artificial fertilization (Kristanto 2004). The earliest hormones used to induce ovulation in catfish were human chorionic gonadotropin (HCG) (Sneed and Clemens 1959, Giudice 1966) and carp pituitary extract (CPE) (Sundarar et al.1972, Richter and Vandenhurk 1982, Kim 1996). Studies showed that for CPE, 90% of females ovulated within 36 to 48 hours of the first injection (Bidwell et al. 1985, Lambert et al. 1999), but number of eggs was significantly less than from natural spawning and hatch was seasonal, with optimal hatch occurring in the middle of the spawning season (Lambert et al.1999). A more recent study (Kristanto 2004) reported that HCG was often ineffective in inducing ovulation and at times when ovulation occurred, fish gave eggs over a 2-day period. In contrast, a priming dose of CPE administered at 2 mg/kg female body weight followed by a resolving dose of 8 mg/kg resulted in 90% ovulation of injected female over a 6-hour period. Although CPE resulted in higher ovulation rates, eggs were of poor quality due to either over or under ripeness. These studies indicate that injection of CPE resulted in high ovulation rate but eggs were either low in number or of poor quality.

Other hormones used in ovulating catfish include gonadotropin releasing hormone (GnRH) (Silverstein et al.1999) and luteinizing hormone-releasing hormone (LHRH) (Goudie et al. 1992). While gonadotropin is a hormone secreted by the pituitary gland, GnRH is secreted by the hypothalamus. Both hormones influence gonadal activity including the onset of sexual maturity and regulation of reproductive activity. Similarly, while luteinizing hormone is a hormone produced by the pituitary gland that causes the ovary to produce one or more eggs and to secrete progesterone, LHRH is released by the hypothalamus to trigger the pituitary gland secretion of luteinizing hormone. GnRH and LHRH have almost identical chemical composition and function.

Theoretically, synthetic analogues of LHRH (LHRHa) are more effective than natural LHRH or GnRH because they are not rapidly metabolized by fish, and remain active for longer periods of time (Alok et al. 1999, Suresh et al. 2000, Linhart et al. 2000). Kristanto (2004) observed that ovulation rate for female injected with LHRHa can be as much as 30% higher than for CPE injected female, and hatch rate as well as fry per kg of female body weight was higher for GnRH and LHRHa compared to CPE. Furthermore, Kristanto (2004) concluded that overall, LHRHa was the most promising hormone for hand stripped hybrid catfish embryo production.

Given the reproductive isolating mechanism between the channel and the blue catfish, males are sacrificed to obtain the sperm needed for artificial fertilization as natural spawning is not feasible. The testes are extracted, weighed, macerated and filtered to obtain the milt. The sperm solution is made by adding 5 ml 0.9% saline to every gram of testes (Dunham et al. 2000, Kristanto 2004).

To facilitate stripping eggs, the female is immersed in an anesthetizing solution of 200 parts per million (ppm) tricaine methane sulfonate (MS222) with 200 ppm sodium bicarbonate for neutralizing water pH. The fish is then dried to prevent introduction of water and eggs are stripped into greased pie pans, limiting egg mass to 200 grams per pie pan to maintain a thin layer of eggs and ensure high fertilization rate. Eggs are fertilized by adding 2.5 ml of sperm solution per 100 grams of eggs. To activate the sperm, pond water is added to the egg-sperm mix, lightly stirring eggs while adding water to evenly distribute activated sperm.

A new procedure for determining the amount of sperm needed to fertilize eggs is currently being used in research trials. Spectrophotometry is used to calibrate sperm density. With this technique, the optimal amount of sperm required for fertilization is applied. Given the cost associated with sacrificing blue male catfish, improvements in the selection of blue sperm donor male can be another source of cost efficiency in CB hybrid catfish embryo production.

The pan of fertilized eggs is then left undisturbed for about 3 minutes to allow the eggs to adhere and form a coagulated mass. The pan is then immersed in a water-hardening trough so the eggs can form a solid mass. Once formed, the egg mass is removed from the pan and transferred to a basket in a hatching trough. Typically, a hatching trough contains several baskets that are suspended from the edge of the trough, has water flow through of 16 liters per minute, and has paddles that mimic the tail action of a male catfish guarding eggs in the wild. Eggs hatch after 5 to 7 days of incubation in the hatching trough, again, depending upon temperature.

Utilization of this artificial fertilization procedure is not common in the catfish industry (Chatakondi et al.2000, Kristanto 2004). A few farms have a small portion of their operation allotted to the production of the CB hybrid catfish for commercial purposes, and one farm is devoted to hybrid production.

Commercial Culture of CB Hybrid Catfish

Research on the superiority of the CB hybrid catfish and its potential for commercial culture is well documented. Translating this promise to actual financial and economic benefits could substantiate the claim that the CB hybrid catfish will do well under commercial settings. Ligeon (2000) looked at the commercial viability of the CB hybrid catfish, focusing on the domestic market components associated with the catfish industry. Ligeon’s thrust was to evaluate the impact of changes in variable costs and the inter-relationships of input-output markets on the cost of CB hybrid catfish production, and to analyze the rate of CB hybrid catfish commercial adoption and how it affects the profitability of each sector of the catfish industry. Furthermore, Ligeon's findings also indicated that hatch rates and factors that affect them need to be evaluated.

As a follow up and in contrast to Ligeon's (2000) analysis of market forces, this study focuses on the impact of biological spawning parameters such as ovulation, fecundity and hatch rate that are crucial in the production of CB hybrid catfish fry. The profitability of the CB hybrid catfish as a culture organism can be evaluated either on its own or in comparison to the channel catfish. Given that catfish dominates the aquaculture production in the US even when its production is almost entirely dependent on the culture of channel catfish, the logical procedure in looking at the impact of the CB hybrid on the catfish industry, in general and the catfish farmer in particular, is to evaluate if there are economic advantages to be gained by using the CB hybrid catfish in place of the channel catfish.

Economics of CB Hybrid Catfish Embryo Production

Although it is apparent that improvement in hybrid technology boosts output of producers and processors, the real measure of benefit is the economic efficiency and profitability of this technology. The economic efficiency of producing CB hybrid catfish embryos depends on the factors that help circumvent the reproductive isolating mechanism between these two species. In a very broad sense, these factors include hormone induction techniques to induce ovulation, spawning technology to obtain and fertilize eggs, and fungal treatments to take eggs beyond the larval stage. In turn, hormones and associated induction techniques affect ovulation rate, fecundity, hatch rate and the number of fry relative to female body weight. As ovulation rate, fecundity, hatch rate and fry survival increase, per fry cost of production goes down. The obvious economic trade off underlying this technological improvement is the increased costs of production due to the input and labor intensive technology versus the increased productivity derived from increased fry survival.

Application of economics and farm management principles can be used to evaluate the profitability of CB hybrid catfish adoption in commercial settings. Farm management combines the principles of economics and business to efficiently achieve the goals of the firm (Olson 2004, James and Eberle 2000, Jolly and Clonts 1993). A farm manager's goal can include any or all of debt avoidance, wealth, output or profit maximization, labor reduction, or increasing time with the family. Overall, a farm manager's job involves allocation, direction and control of limited resources to attain the farm's goal. In many cases, the farm owner hires a farm manager to more efficiently achieve the desired goals.

Business Environment

The conditions surrounding a farm business include four main components. The farm's resources include land, labor, capital, management skills, credit, and farm environment (*e.g.*, soil condition, weather). Commodity markets provide information on prices for both inputs used in the production and products sold by the farm and are therefore vital for determining profit margins. Governments with their policies and regulations, banks with their lending policies, and community groups with their interests (*e.g.,* environmental groups) are institutions that impact a farmer's decision. Improvements resulting from scientific experiments, development of advanced machinery, and acquisition of new management information comprise technology that provides knowledge base for establishing a new farm or opportunities for modifying existing farming practices.

Management

Although the management of a farm may reside in more than one person, the general manager is responsible for all management functions including planning, organization, direction and control of business activities. Planning takes place at the earliest stage of business operation. It involves goal and objective determination, assessment of the industry in which the farm will operate, inventory of resources, analysis of alternative enterprise choices, and investigation of the market situation including costs of inputs and prices of outputs.

Initial organization follows the planning stage. At this point, findings from the planning stage are used to put the business in place. Acquisition of resources, negotiation of credits, definition and division of responsibilities among players in the business, and all legal arrangements are handled at this point. Organization does not stop once the business is in place. In reality, organization is essential to the efficient performance of the business.

Executing plans made at the early stages requires the direction of the manager in coordinating all resources involved in the business. To be effective, the manager must have the necessary supervisory skills which include leadership, delegation, communication, motivation and personnel development.

Finally, the success of a farm operation depends on a well organized control and implementation of initial plans. Early on in the operation, results of implementation must be compared to initial goals and if necessary corrective actions must be taken to redirect operation towards the attainment of planned objectives. Keeping books and records will provide clues if change of plans to execute alternative measures is necessary.

Financial Accounts

Keeping financial books and records is integral to the success of any business. Records and accounts do not only facilitate meeting tax requirements but they also indicate the health of the business. Financial records serve different purposes and functions, and they are discussed in turn to define and identify their role in business and farm management.

Income statement is a summary of income and expenses showing the difference between gross income and costs of production. Sometimes called an operating statement, it measures the farm operation's flow of income, allowing the computation of profit (or loss) during the accounting period. It is a useful indicator of the operation's profitability at any given time.

Enterprise budget is specific to the operation of a single farm product, activity or enterprise, which feeds directly into the total farm budget and could be modified for partial budgeting of changes within the enterprise. It is a statement of expected income, and anticipated costs of production and the resulting net income, which shows the short term profitability of the activity and helps facilitate planning of future actions. It is specific to inputs, methods, or technology used to produce a specified targeted amount of output. It incorporates the economic and technological relationships between inputs and outputs (Olson 2004). Items included in an enterprise budget include expected output, prices and income; required input, prices and costs; and net returns; variable costs are usually listed separately from fixed costs to allow quick computations of the operation's viability indicators, an example of which is income above variable costs (Jolly and Clonts 1993).

Partial budget is an evaluation of the effect of production modifications, such as adoption of a new technology, use of new production method, adjustment of input levels within the current method of production, anticipated drop in prices of input or increase in the price of output, or change in level of targeted output. Alterations in the budget are made to the items that are affected by the changes in production, without affecting other parts of the total farm plan (James and Eberle 2000). The ease at which changes can be made in the partial budget sets it apart from the total farm budget and the enterprise budget in that it is an efficient tool for determining whether changes can possibly contribute to profits (Olson 2004).

Capital Budgeting

Capital budgeting is used to evaluate profitability of projects that involve large sums of money whose returns are expected to extend beyond a year. The most common criteria employed in determining the financial desirability of investment projects are payback period, internal rate of return, net present value and profitability index.

Payback period estimates the length of time required to recover the initial cost of the investment (Jolly and Clonts 1993). It is simple to calculate and has a high emphasis on liquidity (Olson 2004).

Net present value (NPV) uses discounted cash flow to value the projected cash flows for an investment. It is the present value of net benefits from a project, which is computed by discounting the stream of future net cash flows at the firm's required rate of return less the net investment necessary to establish the project (James and Eberle 2000). Mathematically, NPV is computed as:

$$NPV = -INV + \frac{P_1}{(1+i)} + \frac{P_2}{(1+i)^2} + \ldots + \frac{P_n}{(1+i)^n}$$

where Pj's are net cash flows, j=1, 2, 3, …, n

i is the interest rate or marginal cost of capital

n is the project's expected life

INV is the initial investment

The equation indicates that the discounted net cash flows of the project are added to the initial investment to yield the NPV. Any salvage or terminal value is included as a cash flow in the n^{th} year of the project, while the initial investment is entered into the equation as a negative value since it represents a cash outflow.

Internal rate of return (IRR) is the interest rate that equates the present value of expected future cash flows or receipts to the initial investment (INV) or cost outlay. To find the IRR for the project, the initial investment is equated to the net cash flows discounted at the interest rate that set the terms equal. The following formula is solved for the value of r=IRR

$$0 = - INV + \frac{P_1}{(1+r)} + \frac{P_2}{(1+r)^2} + \ldots + \frac{P_n}{(1+r)^n} + \frac{V_n}{(1+r)^n}$$

The P_j's, n and INV are as defined in the NPV determination. IRR or r is the interest rate that equates the sum of the net cash flows to the initial investment. As in NPV, any salvage or terminal value is included as a cash flow in the n^{th} year of the project.

Profitability index (PI) is the ratio of the present value of future net cash flows over the life of the project to the net investment. It is computed as

$$PI = \frac{\sum_{j=1}^{n} \frac{P_j}{(1+i)^j}}{INV}$$

A PI greater than or equal to 1 indicates that present value of future net cash flows is greater than the value of initial investment hence the project is worth undertaking. The P_j's, i, n and INV are as defined above.

Financial Performance

Knowing the breakeven cost of production and how costs are allocated between fixed and operating costs is highly useful. Unless a producer is aware of production costs, it will be difficult to accurately calculate prices. Breakeven cost is calculated using the following formula:

$$\text{Breakeven Cost} = \frac{\text{Cost per unit of production}}{\text{Yield per unit of production}}$$

Other breakeven analysis formulas calculate amounts attributed to variable costs and fixed expenses:

$$\text{Breakeven price to Cover Variable Expense} = \frac{\text{Operating Cost}}{\text{Yield}}$$

$$\text{Breakeven price to Cover Fixed Expense} = \frac{\text{Fixed Cost}}{\text{Yield}}$$

Materials and Methods

General Assumptions

This study assumes that the farm is operational and there is an existing market for the output, hence, planning and organizational aspects of management, institutional issues, and business and market environments do not bear on the analysis. Technological improvement resulting from the scientific research on the CB hybrid catfish is the major component of the analysis.

Assumptions for commercial levels of fry production are based on personal communications with farmers. The CB hybrid catfish operation assumes that female channel catfish brood fish injected with CPE exhibit 64% ovulation rate and that 20% of obtained eggs will hatch. The channel catfish operation assumes that fry are produced at the rate of 500,000 fry per acre of stocked brood fish.

Since the channel and the CB hybrid catfish productions will be exposed to the same input and output markets, prices are critical only in terms of each enterprise's absolute performance. Their relative performance will be mostly affected by how well the culture species perform biologically.

Procedures

An enterprise budget will be developed for both the channel and the CB hybrid catfish operations. The financial performances of the channel and the CB hybrid catfish operations will be evaluated and compared. Breakeven costs for each operation will be computed and compared to current market prices. Profitability measures including payback period, internal rate of return, net present value and profitability index computed with the aid of capital budgeting will be used to evaluate the financial desirability of the CB hybrid catfish for commercial culture. To determine if there are benefits to be gained by switching from channel catfish to CB hybrid catfish operation, a partial budget for the adoption of the CB hybrid catfish will be developed as well. Whenever applicable, graphs will be used to help describe and interpret results.

One way to set up the enterprise budgets is for the channel and CB hybrid catfish operations to share some overhead expenses such as salaries of the manager and assistant manager, certain machinery and equipment (*e.g.*, tractor, levee grader), and office overhead costs. However, this study does not deal with total farm budgets hence cost sharing between enterprises will not be applicable, and analysis will proceed by treating the two operations independently.

The capital budgets are set up such that initial investments take place in the first two years. Construction starts in the first year (year 0) while the rest of farm, hatchery, and office equipment are bought in the second year when the farm begins operations. The first cash receipts occur in the third year, and even then, they are less than the cash outflows for that year.

A partial budget for fry and fingerling production of CB hybrid catfish will be applied on the enterprise budget for the channel catfish operation to verify if there are benefits to be gained by switching from 136-acre channel catfish to 136-acre CB hybrid catfish operation. All assumptions for 50-acre CB hybrid catfish operation will hold except for target output, which will increase because of the bigger capacity of the farm.

Data

Capital outlay for construction and purchase of machinery and equipment were obtained through communication with farmers and validated through comparisons with government, university and extension websites. Variable costs came from vendors' and suppliers' websites and catalogues.

The benchmark production analysis used data from a representative farm that has an existing hybrid enterprise as part of its business operation. CPE administered at 2 mg/kg female body weight followed by a resolving dose of 8 mg/kg sold by Stoller Fisheries (www.sfishinc.com) at $285/g was used as the ovulating hormone for the commercial CB hybrid catfish operation. Total production based on the assumptions mentioned above was set at some level defined and limited by the capacity of the farm. Expected output prices were set at the going market prices. These commercial operation assumptions are shown in Table 1.2.

Results and Discussion

Detailed list of items for variable costs and fixed costs are shown in Appendix Table 1.1 for channel catfish operation and Appendix Table 1.2 for CB hybrid catfish operation while income statements are shown in Appendix Tables 1.3 and 1.4 for channel and CB hybrid catfish operations respectively.

Enterprise Budget

Based on the information used to develop the income statements, Table 1.3 and Table 1.4 show the enterprise budgets for the channel and the CB hybrid catfish operations, respectively. On a per acre basis, the CB hybrid catfish operation has much higher costs, $5,710/acre variable costs compared to the channel's $2,384/acre, and $11,750/acre total costs compared to the channel's $5,121/acre.

CB hybrid catfish production is labor intensive, requires blue male catfish sperm for fertilization, and uses hormones to ovulate the channel catfish female. Blue male catfish are not as commonly available in the market, and hence are more expensive than the channel male catfish used in channel catfish production. Unlike the channel catfish male brood fish, which may be used for spawning for at least three years, blue male brood fish have to be purchased every year until a procedure to obtain sperm without sacrificing the male becomes available. Individually stripping the channel female catfish to obtain the eggs, and the labor associated with the preparation and monitoring prior to spawning, explains the high labor requirement. Adding the cost of hormone, an input that is not required for channel catfish production, to the cost of labor and blue male brood fish, makes CB hybrid catfish production a very expensive venture. The intensive labor, the blue male brood fish and the hormones are inputs that cause costs of CB hybrid catfish fry production to be much higher than that of channel catfish production.

The enterprise budgets discussed above are for fingerling production. The cost of fry production was obtained through backward computation from the enterprise budgets. Table 1.5 shows the costs of fry production as $0.008 and $0.034 per fry for channel catfish and CB hybrid catfish, respectively. The cost of producing CB hybrid catfish fry is 325% more than that of channel catfish fry. This is mainly due to the much lower 20% hatch rate for the CB hybrid catfish compared to the 67% hatch rate for the channel catfish (Dunham et al. 1990). The low hatch rate resulting in very high cost of CB hybrid catfish fry production explains the lack of seed and farmers' aversion to CB hybrid catfish commercial adoption.

Eighty-five percent of the CB hybrid catfish fry survive to fingerling stage while survival rate for the channel catfish fry is only 60%. Cost of growing CB hybrid catfish from fry to fingerling is $0.027/fingerling, 7% lower than the $0.029/fingerling cost for the channel catfish. This comparison shows that the superior characteristics of the CB hybrid catfish bring about a reduction in production costs once it survives to the fry stage. This is reflected by food fish catfish producers' willingness to pay a premium for the CB hybrid catfish fingerling.

Breakeven Analysis

Given the higher cost of producing CB hybrid catfish fry, the breakeven price for CB hybrid catfish fingerling is expected to be higher ($0.138 in Table 1.4) than the breakeven price for the channel catfish fingerling ($0.091 in Table 1.3), as shown by their respective enterprise budgets. Under the current market price assumptions, both operations are unable to cover total expenses in the short run. However, the CB hybrid operation has less negative net returns above total expenses than the channel catfish operation, and the revenue obtained from the sales of the CB hybrid catfish fingerling almost offsets the total costs of production. This is due to the higher price farmers are willing to pay to obtain CB hybrid catfish fingerling for grow-out operation (Personal Communication, Eagle Aquaculture).

Capital Budgeting

A 20-year planning horizon is used to show initial investments and cash flows for the two operations (Table 1.6 and Table 1.7). These tables show that capital renewals periodically recur during the 20-year period. Detailed computations of financial desirability criteria are shown in Appendix Tables 1.5 and 1.6. Indicators of financial desirability (Table 1.8) for the two operations under the scenario with capital renewal at different times are based on the cash flow tables above.

Payback Period

Payback period is the number of years it takes to recover initial investment. For example, the initial investment of $813,550 for the CB hybrid catfish operation was more than offset by the net cash flowing into the CB hybrid catfish operation by year 13 (Appendix Table 1.6). The calculations show that it took slightly less than 13 years to recover all the initial investments for establishing the 50-acre CB hybrid catfish operation whereas cash flow from the 136-acre channel catfish operation was unable to make up for the initial investment over the 20-year period.

Net Present Value (NPV) and Profitability Index (PI)

Interest rates ranging from 1% to 13% at 3% intervals were used to compute NPV and PI. For channel catfish, NPV was negative and PI was less than 1 for the entire range of interest rates used in the analysis. In contrast, CB hybrid catfish is an acceptable investment even at interest rates as high as 7%, as shown by positive NPVs and PIs greater than 1. The desirability of the CB hybrid catfish increased as the marginal rate of capital, represented by the interest rate, decreased.

Internal Rate of Return (IRR)

Internal rate of return is the highest interest rate that an enterprise can bear that will just equate initial investment to the present value of expected future cash flows from the operation. The CB hybrid catfish operation had an IRR of 7% while the channel catfish operation had a negative IRR of -2%. Negative IRR translates to negative net returns to capital investment, which implies that for any positive discount rate within the 20-year period the net present value of the channel catfish operation will be negative, resulting in a profitability index of less than 1.

This capital budgeting analysis is based on a 20-year projection that includes capital renewal at different times during the projection period. Capital renewal results in negative net cash flows when total cash inflows at the rime of renewal are insufficient to offset additional capital investments, as in the case of the channel catfish operation. Every time the sign changes in a cash flow, the equation defining IRR can give up to two additional solutions, resulting in a non-unique value for IRR (Fisher and Martin 2004).

To compare the channel catfish and the CB hybrid catfish without concern for a non-unique IRR for the channel catfish operation, two additional investment scenarios are analyzed: one where all constructions and equipment have twice the original useful life, eliminating the negative numbers in cash inflows for the channel catfish operation, and one where all constructions and equipment will last throughout the 20-year period.

In all three scenarios, the CB hybrid catfish evidently outperformed the channel catfish in all financial desirability criteria (Table 1.8). The NPV, PI, IRR, and payback period unanimously indicate the financial desirability of the CB hybrid catfish for commercial culture.

Partial Budget for the Use of CB Hybrid Catfish vs. Channel Catfish

Table 1.9 shows the partial budget for the adoption of CB hybrid catfish in place of the channel catfish grown in the 136-acre production operation. All assumptions shown in Table 1.2 for the 50-acre CB hybrid catfish production are the same except for the size of operation. Since target output is set at some level defined and limited by the farm size, target output is now higher because of the larger farm capacity. The exact same farm and hatchery used in the production of channel are used in the CB operation. When hatch rate is lower, more eggs are needed to produce fry that will maximize the use of ponds, and existing hatchery is not big enough to support the incubation of eggs. If production is constrained by the size of the hatchery, fry production is limited to 7.28 million, which leaves 62 acres of pond still available for fry stocking. In the short run, the hatchery can be expanded to double the capacity. In this case, fry production can be as much as 13.42 million fry growing to 11.41 million fingerlings, which brings in an additional income of $0.90 million from fingerling sale. Although there is a tremendous increase in variable costs due to adoption, the increase in gross receipts more than offsets the increase in costs, resulting in net additional income of $3,686/acre.

Economic Benefits from Large-Scale Adoption of CB Hybrid Catfish

A parallel analysis can be made to ascertain if there are economies of scale arising from a 50-acre to 136-acre increase in operation. Since this change involves an increase in infrastructure, a more appropriate approach is to compare enterprise budgets for the two sizes of CB hybrid catfish operations to see the effect of additional capital investments on income.

The CB hybrid catfish enterprise budget for the 50-acre operation is as previously shown in Table 1.4 and the enterprise budget for the 136-acre operation is shown in Table 1.10. Net returns per acre above variable costs did not change significantly, but net returns per acre above total expenses increased 19-fold, from -$175 to $2,956. In contrast, total expenses per acre decreased by 28%, from $11,750 for the 50-acre operation to $8,466 for the 136-acre operation.

These results are indicators of production efficiency due to the bigger farm size, and reduction in average cost due to economies of scale. CB hybrid catfish commercial utilization implies that farm resources are used more efficiently since a higher production level can be realized per acre of operation.

Conclusion

Comparing channel catfish to CB hybrid catfish showed that CB hybrid catfish is a more economically desirable culture organism than channel catfish. Using payback period, profitability index, net present value and internal rate of return, the CB hybrid catfish operation exceeded the channel catfish operation in every aspect of financial desirability. This benchmark analysis has demonstrated the financial superiority of the CB hybrid catfish over the channel catfish, as shown by the lower per unit cost of growing CB hybrid catfish from fry to fingerling.

Changing the size of the CB hybrid catfish commercial operation from 50 acres to 136 acres resulted in economies of scale, as shown by the considerable reduction in total expenses per acre and by the tremendous increase in per acre net returns above total expenses. Even with a larger operation, however, the breakeven price per fingerling to cover variable costs did not show any remarkable improvement. This is because the number of fingerling produced depends on the quantity of fry produced, which requires additional inputs resulting in a significantly high variable cost.

The major conclusion that can be drawn from the above results is that CB hybrid catfish is a profitable enterprise once it has reached the fry to fingerling stage. However, these results do not countermand the reality that under the current commercial application and utilization the cost of producing CB hybrid catfish fry is much higher than that of channel catfish fry. The most important goal, therefore, is to improve efficiency in producing CB hybrid catfish fry.

TABLES

Table 1.1 Value of aquaculture products sold in the United States Census of Aquaculture 1998

Item	Value ($1000)	Proportion of Total
Catfish	$450,710	46.08%
Trout	$72,473	7.41%
Food fish, other than catfish and trout	$168,532	17.23%
Baitfish	$37,482	3.83%
Ornamental fish	$68,982	7.05%
Sport or game fish	$7,390	0.76%
Other fish	$267	0.03%
Crustaceans	$36,318	3.71%
Mollusks	$89,128	9.11%
Other animal aquaculture and algae and sea vegetables	$1,000	0.10%
Total sales	**$978,012**	**100%**

Source: National Agricultural Statistics Service, USDA 2000

Table 1.2 Assumptions for channel catfish commercial production and for using carp pituitary extract (CPE) at 2mg/kg priming dose followed by 8 mg/kg resolving dose for the ovulation of channel catfish, *Ictalurus punctatus*, females and fertilization with blue catfish, *I. furcatus*, sperm to commercially produce hybrid catfish

Parameters	Channel Catfish	CB Hybrid Catfish
Size of operation (acres)	136	50
Brood fish stocking rate (lb/acre)	1,200	7,500
Female brood fish weight (lb)	13,400	30,000
Cull rate (%)	-	25
Ovulation rate (%)	-	64
Fecundity (# eggs/kg ♀ body wt)	-	3,800
Hatch rate (%)	-	20
Survival rate from fry to fingerling (%)	60	85
Output		
Fry production (million)	12.75	5
Target output (million fingerling)	7.65	4.25
Market price (per fingerling)	$0.084	$0.1350

Notes: Production parameters and output for a 136-acre channel catfish pond and a 50-acre CB hybrid catfish pond were provided by Harvest Select as input to economic analysis. All data were obtained under commercial farm conditions.

Table 1.3 Enterprise budget for a commercial channel catfish (*Ictalurus punctatus*) operation

Size of Operation	**136 acres**	
GROSS RECEIPTS	**Total**	**Per acre**
Sale of Fingerling (7.65 million @ $0.084 each)	*$642,600*	*$4,725*
Sale of Culled Female Brood Fish (10,000 lbs @ $0.50 each)	*$5,000*	*$37*
Total Gross Receipts	**$647,600**	**$4,762**
VARIABLE COSTS		
Brood Fish	*$48,000*	*$353*
Hatchery Labor	*$20,792*	*$153*
Contractual Labor	*$36,900*	*$271*
Farm Operation Costs	*$183,160*	*$1,347*
Hatchery Costs	*$3,900*	*$29*
Repairs and Maintenance (Machinery and Equipment)	*$8,950*	*$66*
Interest on Operating Expenses	*$21,647*	*$159*
Total Variable Costs (TVC)	**$323,349**	**$2,378**
Income above variable costs	**$324,251**	**$2,384**
FIXED COSTS		
Salaries and Related Expenses	*$115,900*	*$852*
Insurance	*$6,350*	*$47*
Repairs and Maintenance (Ponds and Hatchery)	*$2,500*	*$18*
Interest on Capital Investment	*$120,067*	*$883*
Depreciation (Building and Equipment)	*$110,176*	*$810*
Office and Personnel Overhead Costs	*$18,120*	*$133*
Total fixed Costs (TFC)	**$373,113**	**$2,743**
TOTAL EXPENSES (TVC + TFC)	**$696,462**	**$5,121**
Net returns above total expenses	**-$48,862**	**-$359**
Breakeven price to cover variable costs (per fingerling sold)	**$0.042**	
Breakeven price to cover total costs (per fingerling sold)	**$0.091**	

Notes: This enterprise budget was based on Appendix Table 1.1 (Detailed Variable and Fixed Costs) and Appendix Table 1.3 (Income Statement). Gross receipts (cash farm income in Appendix Table 1.3) and interests were for a year when the farm is fully operational (Year 3 or later).

Table 1.4 Enterprise budget for using carp pituitary extract (CPE) at 2mg/kg priming dose followed by 8 mg/kg resolving dose for the ovulation of channel catfish, *Ictalurus punctatus*, females and fertilization with blue catfish, *I. furcatus*, sperm to produce hybrid catfish embryos in a commercial CB hybrid catfish operation

Size of Operation	**50 acres**	
GROSS RECEIPTS	**Total**	**Per acre**
Sale of Fingerling (4.25 million @ $0.1350 each)	*$573,750*	*$11,475*
Sale of Culled Female Brood Fish (10,000 lbs @ $0.50 each)	*$5,000*	*$100*
Total Gross Receipts	**$578,750**	**$11,575**
VARIABLE COSTS		
Brood Fish	*$81,875*	*$1,638*
Hatchery Labor	*$40,681*	*$814*
Contractual Labor	*$29,550*	*$591*
Farm Operation Costs	*$80,940*	*$1,619*
Hybrid Production Costs	*$30,610*	*$612*
Repairs and Maintenance (Machinery and Equipment)	*$3,300*	*$66*
Interest on Operating Expenses	*$18,538*	*$371*
Total Variable Costs (TVC)	**$285,494**	**$5,710**
Income above variable costs	**$293,256**	**$5,865**
FIXED COSTS		
Salaries and Related Expenses	*$115,900*	*$2,318*
Insurance	*$3,600*	*$72*
Repairs and Maintenance (Ponds and Hatchery)	*$1,500*	*$30*
Interest on Capital Investment	*$84,764*	*$1,695*
Depreciation (Building and Equipment)	*$80,188*	*$1,604*
Office and Personnel Overhead Costs	*$16,040*	*$321*
Total fixed Costs (TFC)	**$301,992**	**$6,040**
TOTAL EXPENSES (TVC + TFC)	**$587,485**	**$11,750**
Net returns above total expenses	**-$8,735**	**-$175**
Breakeven price to cover variable costs (per fingerling sold)	**$0.067**	
Breakeven price to cover total costs (per fingerling sold)	**$0.138**	

Notes: This enterprise budget was based on Appendix Table 1.2 (Detailed Variable and Fixed Costs) and Appendix Table 1.4 (Income Statement). Gross receipts (cash farm income in Appendix Table 1.4) and interests were for a year when the farm is fully operational (Year 3 or later).

Table 1.5 Fry and fingerling variable cost of production for channel catfish commercial operation, and for using carp pituitary extract (CPE) at 2mg/kg priming dose followed by 8mg/kg resolving dose for the ovulation of channel catfish, *Ictalurus punctatus*, females and fertilization with blue catfish, *I. furcatus*, sperm to commercially produce hybrid catfish

	136-acre Channel Catfish		50-acre CB Hybrid Catfish	
Variable Cost Item	*Fry*	*Fingerling*	*Fry*	*Fingerling*
Brood Fish	$48,000		$81,875	
Hatchery Labor	$20,792		$40,681	
Contractual Labor		$36,900		$29,550
Farm Operation	$21,959	$161,201	$10,370	$70,570
Hatchery / Hybrid Implement	$3,900		$30,610	
Repairs & Maintenance (Machinery & Equipment)	$2,983	$5,967	$1,100	$2,200
Interest on Operating Expenses	$7,216	$14,431	$6,179	$12,359
Total Variable Cost	**$104,850**	**$218,499**	**$170,815**	**$114,679**
Percent of Cost Reduction				
Quantity and Cost of Production				
Number (million)	12.75	7.65	5.00	4.25
Average weight (g)		30		30
Total weight (kg)		229,500		127,500
Cost of production				
each	**$0.008**	**$0.029**	**$0.034**	**$0.027**
per inch		**$0.0048**		**$0.0045**
per kg		**$0.952**		**$0.899**

Table 1.6 Twenty-year projection of cash flows for a 136-acre channel catfish (*Ictalurus punctatus*) operation

	ITEM	Year → 0	1	2	3	4	5	6
4	**Total Cash Inflow**	**$0**	**$0**	**$214,200**	**$642,600**	**$642,600**	**$642,600**	**$642,600**
10	**Total Cash Expenses**	**$0**	**$150,293**	**$523,441**	**$562,284**	**$537,015**	**$532,824**	**$525,132**
15	**Depreciation**	**$58,658**	**$110,176**	**$110,176**	**$110,176**	**$110,176**	**$110,176**	**$110,176**
20	**Initial Outlay / Recurring costs**	$758,120	$497,590	$0	$33,570	$50,710	$4,900	$44,300
27	**Taxable Income (Line 4 - Line 10 - Line 15 - Line 20)**	-$816,778	-$758,059	-$419,417	-$58,430	-$50,301	-$300	-$32,008
28	**Income Taxes (Line 27 * 6.5%)**	$0	$0	$0	$0	$0	$0	$0
30	**Total Cash Outflow** (Line 10 + Line 20 + Line 28)	**$758,120**	**$647,883**	**$523,441**	**$595,854**	**$587,725**	**$537,724**	**$569,432**
32	**Net Cash Flow** (Line 4 - Line 30)	**-$758,120**	**-$647,883**	**-$309,241**	**$51,746**	**$59,875**	**$109,876**	**$78,168**

	ITEM	Year → 7	8	9	10	11	12	13
4	**Total Cash Inflow**	**$642,600**	**$642,600**	**$642,600**	**$642,600**	**$642,600**	**$642,600**	**$642,600**
10	**Total Cash Expenses**	**$519,660**	**$512,504**	**$504,798**	**$497,151**	**$506,613**	**$522,338**	**$517,669**
15	**Depreciation**	**$110,176**	**$110,176**	**$110,176**	**$110,176**	**$109,676**	**$110,176**	**$110,176**
20	**Initial Outlay / Recurring costs**	$25,710	$25,000	$33,570	$285,610	$365,630	$58,570	$25,710
27	**Taxable Income (Line 4 - Line 10 - Line 15 - Line 20)**	-$7,946	-$80	-$944	-$245,337	-$334,319	-$43,484	-$5,955
28	**Income Taxes (Line 27 * 6.5%)**	$0	$0	$0	$0	$0	$0	$0
30	**Total Cash Outflow** (Line 10 + Line 20 + Line 28)	**$545,370**	**$537,504**	**$538,368**	**$782,761**	**$872,243**	**$580,908**	**$543,379**
32	**Net Cash Flow** (Line 4 - Line 30)	**$102,230**	**$110,096**	**$109,232**	**-$135,161**	**-$224,643**	**$66,692**	**$104,221**

	ITEM	Year → 14	15	16	17	18	19	20
4	**Total Cash Inflow**	**$642,600**	**$642,600**	**$642,600**	**$642,600**	**$642,600**	**$642,600**	**$642,600**
10	**Total Cash Expenses**	**$510,374**	**$500,768**	**$493,183**	**$486,674**	**$475,409**	**$465,706**	**$454,773**
15	**Depreciation**	**$110,176**	**$110,176**	**$110,176**	**$110,176**	**$110,176**	**$110,176**	**$62,709**
20	**Initial Outlay / Recurring costs**	$0	$38,470	$61,440	$0	$33,570	$25,710	$4,900
27	**Taxable Income (Line 4 - Line 10 - Line 15 - Line 20)**	$27,050	-$1,814	-$17,199	$50,750	$28,445	$46,008	$125,219
28	**Income Taxes (Line 27 * 6.5%)**	$1,758	$0	$0	$3,299	$1,849	$2,991	$8,139
30	**Total Cash Outflow** (Line 10 + Line 20 + Line 28)	**$512,132**	**$539,238**	**$554,623**	**$489,973**	**$510,828**	**$494,407**	**$467,812**
32	**Net Cash Flow** (Line 4 - Line 30)	**$135,468**	**$108,362**	**$92,977**	**$157,627**	**$136,772**	**$153,193**	**$179,788**

Table 1.7 Twenty-year projection of cash flows for a 50-acre CB hybrid catfish operation using carp pituitary extract (CPE) at 2mg/kg followed by 8mg/kg resolving dose

	ITEM	Year → 0	1	2	3	4	5	6
4	**Total Cash Inflow**	**$0**	**$0**	**$191,250**	**$578,750**	**$578,750**	**$578,750**	**$578,750**
10	**Total Cash Expenses**	**$0**	**$132,542**	**$456,079**	**$459,172**	**$433,439**	**$426,817**	**$416,610**
15	**Depreciation**	**$38,943**	**$80,188**	**$80,188**	**$80,188**	**$80,188**	**$80,188**	**$80,188**
20	**Initial Outlay / Recurring costs**	$504,530	$309,020	$0	$16,790	$50,710	$6,120	$84,010
27	**Taxable Income (Line 4 - Line 10 - Line 15 - Line 20)**	-$543,473	-$521,750	-$345,016	$22,600	$14,414	$65,626	-$2,058
28	**Income Taxes (Line 27 * 6.5%)**				$1,469	$937	$4,266	-$134
30	**Total Cash Outflow** (Line 10 + Line 20 + Line 28)	**$504,530**	**$441,562**	**$456,079**	**$477,431**	**$485,086**	**$437,203**	**$500,486**
32	**Net Cash Flow** (Line 4 - Line 30)	**-$504,530**	**-$441,562**	**-$264,829**	**$101,319**	**$93,664**	**$141,547**	**$78,264**

	ITEM	Year → 7	8	9	10	11	12	13
4	**Total Cash Inflow**	**$578,750**	**$578,750**	**$578,750**	**$578,750**	**$578,750**	**$578,750**	**$578,750**
10	**Total Cash Expenses**	**$411,141**	**$401,294**	**$390,622**	**$378,628**	**$376,044**	**$377,503**	**$366,255**
15	**Depreciation**	**$80,188**	**$80,188**	**$80,188**	**$80,188**	**$80,188**	**$80,188**	**$80,188**
20	**Initial Outlay / Recurring costs**	$26,930	$25,000	$16,790	$163,210	$223,540	$40,570	$26,930
27	**Taxable Income (Line 4 - Line 10 - Line 15 - Line 20)**	$60,492	$72,269	$91,151	-$43,276	-$101,022	$80,490	$105,378
28	**Income Taxes (Line 27 * 6.5%)**	$3,932	$4,697	$5,925	-$2,813	-$6,566	$5,232	$6,850
30	**Total Cash Outflow** (Line 10 + Line 20 + Line 28)	**$442,003**	**$430,991**	**$413,337**	**$539,025**	**$593,018**	**$423,305**	**$400,035**
32	**Net Cash Flow** (Line 4 - Line 30)	**$136,747**	**$147,759**	**$165,413**	**$39,725**	**-$14,268**	**$155,445**	**$178,715**

	ITEM	Year → 14	15	16	17	18	19	20
4	**Total Cash Inflow**	**$578,750**	**$578,750**	**$578,750**	**$578,750**	**$578,750**	**$578,750**	**$578,750**
10	**Total Cash Expenses**	**$355,870**	**$355,870**	**$355,870**	**$355,870**	**$355,870**	**$355,870**	**$355,870**
15	**Depreciation**	**$80,188**	**$80,188**	**$80,188**	**$80,188**	**$80,188**	**$80,188**	**$46,435**
20	**Initial Outlay / Recurring costs**	$0	$21,690	$119,150	$1,220	$15,570	$26,930	$0
27	**Taxable Income (Line 4 - Line 10 - Line 15 - Line 20)**	$142,693	$121,003	$23,543	$141,473	$127,123	$115,763	$176,446
28	**Income Taxes (Line 27 * 6.5%)**	$9,275	$7,865	$1,530	$9,196	$8,263	$7,525	$11,469
30	**Total Cash Outflow** (Line 10 + Line 20 + Line 28)	**$365,145**	**$385,425**	**$476,550**	**$366,286**	**$379,703**	**$390,325**	**$367,339**
32	**Net Cash Flow** (Line 4 - Line 30)	**$213,605**	**$193,325**	**$102,200**	**$212,464**	**$199,047**	**$188,425**	**$211,411**

Table 1.8 Financial desirability criteria (FDC) under three capital investment scenarios for a 136-acre channel catfish operation and a 50-acre CB hybrid catfish operation using carp pituitary extract (CPE) at 2mg/kg followed by 8mg/kg resolving dose

		With capital renewal at different times		Useful life is doubled		Initial investment lasts 20 years	
FDC	*i* (%)	Channel Catfish	CB Hybrid	Channel Catfish	CB Hybrid	Channel Catfish	CB Hybrid
NPV ($)	13	-1,133,749	-422,661	-790,586	-233,490	-754,614	-188,010
	10	-1,086,949	-268,217	-619,219	-21,394	-569,826	40,695
	7	-991,453	-21,831	-341,427	305,550	-272,367	391,704
	4	-811,278	376,048	111,023	818,034	209,556	939,771
	1	-480,891	1,030,002	857,096	1,638,184	1,000,874	1,813,725
PI (unitless)	13	-0.02	0.41	0.29	0.68	0.32	0.74
	10	0.05	0.64	0.46	0.97	0.50	1.06
	7	0.16	0.97	0.71	1.40	0.77	1.52
	4	0.33	1.48	1.09	2.05	1.17	2.20
	1	0.61	2.28	1.69	3.03	1.81	3.25
IRR (%)		-2%	7%	5%	10%	5%	10%
Payback period (years)		indeterminate	12.92	14.21	9.75	13.67	9.50

Table 1.9 Partial budget for the use of carp pituitary extract (CPE) under commercial settings at 2mg/kg priming dose followed by 8 mg/kg resolving dose for the ovulation of channel catfish, *Ictalurus punctatus*, females and fertilization with blue catfish, *I. furcatus*, sperm to produce hybrid catfish embryos in place of existing commercial channel catfish operation

Additional Costs:		*Additional Income:*	
Brood fish	$172,871		
Hatchery labor	$88,958		
Contractual labor	$35,546		
Feed	$23,270		
Hormones and chemicals	$77,800	Fingerling sale	$897,345
Interest on Operating Expenses	$6,103	Brood fish sale	$8,488
Total Additional Cost	*$404,549*	**Total Additional Income**	*$905,833*
Total Reduced Income	*$0*	**Total Reduced Cost**	*$0*
Total Annual Additional Cash Outflow	**$404,549**	**Total Annual Additional Cash Inflow**	**$905,833**
	Net Change in Income	***$501,285***	
	Net Change in Income per Acre	***$3,686***	

Table 1.10 Enterprise budget for using carp pituitary extract (CPE) at 2mg/kg priming dose followed by 8 mg/kg resolving dose for the ovulation of channel catfish, *Ictalurus punctatus*, females and fertilization with blue catfish, *I. furcatus*, sperm to produce hybrid catfish embryos in a commercial CB hybrid catfish operation

Size of Operation	**136 acres**	
GROSS RECEIPTS		
Sale of Fingerling (11.41 million @ $0.1350 each)	*$1,539,945*	*$11,323*
Sale of Culled Female Brood Fish (26,977 lbs @ $0.50 each)	*$13,488*	*$99*
Total Gross Receipts	**$1,553,433**	**$11,422**
VARIABLE COSTS		
Brood Fish	*$220,871*	*$1,624*
Hatchery Labor	*$109,744*	*$807*
Contractual Labor	*$72,446*	*$533*
Farm Operation Costs	*$206,430*	*$1,518*
Hybrid Production Costs	*$81,700*	*$601*
Repairs and Maintenance (Machinery and Equipment)	*$8,950*	*$66*
Interest on Operating Capital	*$27,750*	*$204*
Total Variable Costs (TVC)	**$727,891**	**$5,352**
Income above variable costs	**$825,542**	**$6,070**
FIXED COSTS		
Salaries and Related Expenses	*$115,900*	*$852*
Insurance	*$6,350*	*$47*
Repairs and Maintenance (Ponds and Hatchery)	*$2,500*	*$18*
Interest on Capital Investment	*$141,623*	*$1,041*
Depreciation (building and equipment)	*$138,979*	*$1,022*
Office and Personnel Overhead Costs	*$18,120*	*$133*
Total fixed Costs (TFC)	**$423,472**	**$3,114**
TOTAL EXPENSES (TVC + TFC)	**$1,151,362**	**$8,466**
Net returns above total expenses	**$402,071**	**$2,956**
Breakeven price to cover variable costs (per fingerling sold)	**$0.064**	
Breakeven price to cover total costs (per fingerling sold)	**$0.101**	

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CHAPTER 2 - ECONOMIC IMPORTANCE OF OVULATING AGENTS IN CHANNEL CATFISH (*Ictalurus punctatus*) FEMALE X BLUE CATFISH (*I. furcatus*) MALE HYBRID (CB HYBRID) EMBRYO PRODUCTION

Abstract

The economics of channel catfish (*Ictalurus punctatus*) fingerling production and channel catfish female x blue catfish (*I. furcatus*) male hybrid (CB hybrid) fingerling production utilizing commercial carp pituitary extract (CPE), research CPE or research luteinizing hormone releasing hormone analogue (LHRHa) protocol were compared. When CPE was used as an ovulating agent under commercial conditions, the breakeven price to cover variable and total costs were $0.064 and $0.101, respectively, per fingerling sold, which are much higher than the channel catfish operation's $0.042 and $0.091 variable and total cost breakeven prices, respectively. By following research protocols that use lower stocking rates for females, reproductive performance increased, causing female brood fish requirement to decrease by 71%. Fry production also decreased but only by 2.4%. This translates to 242% increase in fry/kg female body weight due to increased productivity of the female channel catfish. As a result, the breakeven price to cover variable production costs dropped by 38% from $0.064 to $0.040 per fingerling sold for the research CPE operation, resulting in an overall net economic gain of $1,764/acre, a 29% increase above the income from commercial CPE operation. Utilization of LHRHa rather than CPE results in another incremental gain from utilizing research findings. The net additional income above variable costs of $1,361/acre for LHRHa represents a 17% increase above the income from CPE operation. Forty-six percent of the net change in income came from the reduction in variable costs from improved production efficiency. Due to the combination of lower variable costs and higher output, the breakeven price to cover variable costs dropped by 19% from $0.040/fingerling sold for CPE operation to $0.031/fingerling sold for LHRHa operation. Comparison between the research LHRHa operation and the current practice of using CPE for commercial CB hybrid catfish production clearly highlights the potential

benefits to commercial catfish operations of using LHRHa in CB hybrid catfish embryo production. A total of 4,600 kg brood fish was needed to produce 14.1 million fry for the LHRHa operation, 88% lower than the 36,800 kg brood fish required to produce 13.42 million commercial CB hybrid catfish fry using CPE. Income increased by $3,125/acre. and the breakeven price dropped by 52% from $0.064 for commercial CPE operation to $0.031 for LHRHa operation. Except for some portion of farm operation costs and interest on operating capital, 92% of all cost reductions are attributable to fry production. As a result, fingerling production showed just a modest reduction in production cost from $0.024 to $0.020 per fingerling whereas the cost of fry production dropped by 74% from $0.034 to $0.009 per fry by employing the LHRHa technology.

Introduction

Commercial production and sale of farm-raised catfish became widespread in Southern United States in the 1960s but it was not until mid-70s that sustainable quantities of catfish were produced all year round (Dillard and Waldrop 1993). Providing a steady supply of product is essential to market expansion. To date, commercial culture of channel catfish *Ictalurus punctatus,* has developed into a mature and sustainable industry. However, market uncertainties threaten the viability of the industry. Despite the unprecedented growth of catfish aquaculture industry, it has experienced hardships in the recent past specifically due to low prices received by producers in 2002 and 2003. While catfish prices improved in 2004, higher catfish feed prices and increasing fuel prices mostly negated gains, with producers caught in the price-cost squeeze. Consumers gravitate to lower market prices hence less expensive fish substitutes may very well seize a fair amount of the market share.

Commercial Adoption of the CB Hybrid Catfish as a Strategy to Improve Catfish Industry's Competitiveness

Input and output markets as well as import situations faced by U.S. catfish producers bring to the fore the need to evaluate new production and management strategies to meet competition in coming years (Jolly et al. 2001). Given that catfish are the most important cultured fish in the United States, the viability of the industry can be safeguarded by developing strategies that will reduce production costs and enhance production efficiency. In the long run, this is the only way to combat foreign fish imports as only efficiency will lower production costs to a point where transportation becomes a limiting factor for foreign imports. Although catfish production is currently almost entirely based on the culture of channel catfish, research has shown that the hybrid between female channel catfish and male blue catfish (*I. furcatus*) (CB hybrid) is a promising technology to increase profitability, production efficiency, and sustainability in the catfish industry.

Use of Hormones in CB Hybrid Catfish Embryo Production

The superiority and outstanding performance of the CB hybrid catfish has been extensively documented (Yant et al. 1975, Chappell 1979, Dunham and Smitherman 1981, Tave et al. 1981, Brooks et al. 1982, Dunham et al. 1982, Dunham et al. 1983, Smitherman et al. 1983, Dunham et al. 1987, Dunham et al. 1990, Jeppsen 1995, Wolters and Johnson 1995, Wolters et al. 1996, Smitherman et al. 1996, Dunham and Argue 1998, Dunham and Brummett 1999, Argue et al. 2003, Li et al. 2004) and established through commercial setting field trials (Chatakondi et al. 2000, Ligeon et al. 2004, Bosworth and Wolters 2004, Chatakondi et al. 2005), making this fish in demand. Despite the superior characteristics of the CB hybrid catfish, its utilization among producers is low due to lack of fry for fingerling production.

Gametes of the channel catfish and the blue catfish are compatible but the presence of reproductive isolating mechanism between these two species renders commercial scale production of the CB hybrid catfish inconsistent (Tave and Smitherman 1982, Dunham and Smitherman 1987, Masser and Dunham 1998). To increase production of hybrid embryos, various hormones have been utilized to induce egg maturation in females (Bondari 1990) and facilitate hand stripping and artificial fertilization of eggs (Kristanto 2004). The earliest hormones used to induce ovulation in catfish were human chorionic gonadotropin (HCG) (Sneed and Clemens 1959, Giudice 1966, Tave et al. 1981, Tave and Smitherman 1982, Goudie et al. 1992, Goudie et al. 1993, Tiersch and Goudie 1993) and carp pituitary extract (Sundarar et al. 1972, Richter and Vandenhurk 1982, Kim 1996, Bart et al. 1998, Dunham et al. 1998, Dunham et al. 1999, Dunham and Argue 2000). Ninety percent of CPE-injected females ovulated within 36 to 48 hours of the first injection (Bidwell et al. 1985, Lambert et al. 1999) over a 6-hour period (Kristanto 2004) but number of eggs was significantly less than from natural spawning and hatch was seasonal (Lambert et al. 1999). Furthermore, eggs were of poor quality due to either over or under ripeness (Kristanto 2004).

Other hormones used in ovulating catfish were gonadotropin releasing hormone (GnRH)/ luteinizing hormone-releasing hormone (LHRH) (Goudie et al. 1992, Bates and Tiersch 1998, Silverstein et al. 1999) which come in a variety of forms. Synthetic analogues of LHRH (LHRHa) have also been commonly used (Alok et al. 1999, Suresh et al. 2000, Linhart et al. 2000) and because they are not rapidly metabolized by fish, they remain active for longer periods of time and are believed to be more effective than natural LHRH or GnRH. Kristanto (2004) observed that LHRHa was the most promising hormone for hand stripped hybrid catfish embryo production based on hatch rate, fry per kg of female body weight and ovulation rate which can be as much as 30% higher than for CPE-injected female. The objectives of this chapter are to compare the effect of CPE and LHRHa on the reproductive performance of the female channel catfish used in the production of CB hybrid catfish embryo, and to determine the economic improvement from the use of ovulating agents by comparing the returns from CB hybrid catfish using CPE and LHRHa production to that of channel catfish production.

Materials and Methods

Currently, available information on CB hybrid catfish commercial utilization is based on the use of CPE as the ovulating agent. Net returns to commercial production of CB hybrid catfish fingerings can be as much as 70% higher than returns to channel catfish fingerlings. Certain cultural practices observed in research CB hybrid production protocols can result in additional benefits than what is already observed under commercial settings (Lambert et al. 1999, Dunham et al. 2000, Kristanto 2004, Hutson 2006, Ballenger 2007). For example, the research brood fish stocking rate of 1,500 pounds/acre avoids the unnecessary stress female channel catfish brood fish experience under the 7,500-lb/acre commercial brood fish stocking rate. The lower research stocking rate provides favorable conditions in preparation for spawning and improves the female brood fish's reproductive performance.

Although there have been major research breakthroughs in the production of CB hybrid catfish embryo, procedures are not infallible and they do not always result in the highest possible outcome, hence a range of research spawning parameters showing minimum, average, and maximum values are presented (Table 2.1). Ovulation rate for CB hybrid catfish commercial operation using CPE as ovulating agent ranges between 40% and 85% with an average of 64%. Eggs obtained through hand stripping average 3,800 per kg female body weight and hatch at 10% to 38%, averaging at a 20% hatch rate. In comparison, female channel catfish injected with CPE under research conditions have an ovulation rate of 70% on the average, and eggs hatch at an average rate of 25%. Data on the performance of ovulating agents in the production of CB hybrid catfish embryo show that ovulation rate, fecundity and hatch rate are significantly higher for LHRHa (Kristanto 2004) than for CPE. Ovulation rate averages 85%, and 100% ovulation is not uncommon, while hatch rate averages 38% and can be as high as 75%.

Assumptions

Production assumptions for using CPE under commercial condition, and CPE and LHRHa under research conditions for producing CB hybrid catfish embryo, are shown in Table 2.2. Brood fish stocking rates of 7,500 lb/acre and 1,500 lb/acre are used for commercial and research operations, respectively. Spawning rates for CPE as ovulating agent under commercial conditions are set at the average, with ovulation rate at 64%, fecundity at 3,800 eggs/kg female body weight and hatch rate at 20%. For CPE and LHRHa as ovulating agents under research conditions, parameters are set respectively at 70% and 100% ovulation rate; 8,900 and 10,000 eggs/kg female body weight fecundity; and 25% and 38% hatch rate.

Since the commercial and research CPE, and research LHRHa CB hybrid catfish operations will all be exposed to the same input and output markets, prices are critical only in terms of each enterprise's absolute performance. Their relative performance will be mostly affected by how the ovulating hormone bears on spawning performance.

Procedures

To assess the improved productivity of female brood fish stocked at lower densities and kept under favorable spawning conditions, research and commercial operations using CPE in the production of CB hybrid catfish embryo will be compared. All production inputs including CPE as ovulating agent will be the same for both commercial and research operations, with lower brood fish stocking rate for research production being the only difference between the two operations. Partial budgets will be used to quantify the potential economic gains from the lower stocking rate.

The economic performances of LHRHa and CPE will also be compared, *ceteris paribus*[1], to evaluate economies that can be gained by using LHRHa in the commercial production of CB hybrid catfish embryo. Partial budgeting will be used to highlight the potential economic improvement resulting from the use of LHRHa.

Data

Construction, machinery, and equipment costs were based on data obtained from farmers, which were validated using government, university and extension information. Fry production generated by the spawning parameters was defined and limited by the capacity of the farm. Expected output price was set at the going market price for CB hybrid catfish fingerling. Variable costs were obtained from vendors' and suppliers' websites and catalogues.

All doses of ovulating agents are administered at per kilogram of female brood fish body weight. CPE is used at the rate of 2 mg priming dose followed by 8 mg of resolving dose and it is available on the market at $285/g (Stoller Fisheries, www.sfishinc.com) while LHRHa is used at 30μg priming dose followed by 150 μg resolving and can be purchased on the market at $450 per 25 mg (Syndell International Inc, www.syndel.com).

All spawning parameters used in the analysis were set at the average values shown in Table 2.1 except for the ovulation rate for LHRHa. To reflect Kristanto's (2004) finding that female brood fish injected with LHRHa can have as much as 30% higher ovulation rate than those injected with CPE, ovulation rate was set at 100% for analysis of CB hybrid catfish production injected with LHRHa.

[1] Farm size, stocking rates, feed conversion ratio, fry to fingerling survival rate, and market prices are set at the same levels for both CPE and LHRHa

Results and Discussion

Use of CPE as Ovulating Agent under Commercial Conditions, in CB Hybrid Catfish Production

Appendix Table 2.1 shows variable and fixed costs and Appendix Table 2.2 shows the income statement for the commercial CB hybrid catfish operation using CPE as ovulating agent. The enterprise budget is derived using information from the income statement and is shown in Table 2.3. The operation has net returns of $6,070/acre above variable costs and $3,114/acre above total costs while the breakeven price to cover variable and total costs respectively are $0.064 and $0.101 per fingerling sold. Total variable cost is $5,352/acre, much higher than the traditional channel catfish operation's variable cost of $2,384/acre (Appendix Table 2.3). Breakeven prices are also much higher than the channel catfish operation's $0.042 and $0.091 variable and total cost breakeven prices.

CB hybrid catfish production is labor intensive, requires blue male catfish sperm for fertilization and uses hormones to ovulate the channel catfish female: all these factors contribute to the CB hybrid's much higher variable costs of production. Two major research observations related to the use of ovulating agents are addressed in this analysis. First, even when CPE is used as the ovulating agent, certain cultural practices observed in research environments, care and handling of female channel catfish brood fish in particular, improve spawning performance. Second, experiments show that when LHRHa is used as the ovulating agent spawning parameters are, on the average, higher and less variable than when CPE is used. Subsequent analyses reflect the above observations in the evaluation of economic performance related to the use of ovulating agents.

Partial Budget for the Use of CPE under Research Condition vs. Use of CPE under Commercial Condition, in CB Hybrid Catfish Production

The economic tradeoff when switching to lower brood fish stocking rate is female channel catfish brood fish occupying ponds that could otherwise have been used for stocking fry vs. increased female channel catfish productivity due to favorable conditions in preparation for spawning. As a result of the higher female brood fish reproductive efficiency, female brood fish requirement decreased by 71% from 36,800 kg to 10,500 kg. Fry production also decreased but only by 2.4% from 13.42 million to 13.09 million fry. This translates to 242% increase in fry/kg female body weight due to increased productivity of the female channel catfish.

To assess the difference in economic performance of CPE as an ovulating agent under commercial and research settings, a partial budget (Table 2.4) was developed based on the assumptions shown in Table 2.2. Stocking female channel catfish at a lower rate reduced income due to lower production. However, cost reduction associated with lower number of brood stock more than offset income loss.

Variable cost for research CPE is 39% lower than variable cost for commercial CPE operation. As a result, the breakeven price to cover variable production costs dropped by 38% from $0.064 to $0.040 per fingerling sold. This comparison shows that the improved productivity of the female brood fish resulted in an overall net economic gain of $1,764/acre, a 29% increase above the income from commercial CPE operation.

Partial Budget for the Use of LHRHa vs. CPE, as Ovulating Agents in CB Hybrid Catfish Production under Research Conditions

Given the cost and the dosage required, LHRHa was $0.39/kg female body weight more expensive than CPE. However, the higher efficacy of LHRHa only requires 4,600 kg female brood fish to yield 12 million fingerlings as shown by the assumptions in

Table 2.2, while CPE requires 10,500 kg female brood fish to yield a final output of 11.13 million fingerlings.

Switching from CPE to LHRHa entails extra hatchery labor, additional contractual labor for seining and hauling, and higher fingerling feed due to the increase in output, causing an increase in variable costs. Furthermore, income from culled brood fish is reduced because of the lower number of brood fish required. On the positive side, variable costs drop due to less brood fish required for spawning, reduced feed for brood fish, and lower quantities of hormones for ovulation. In addition, interest on operating expenses also drops as overall operating costs are reduced.

Using the production assumptions shown in Table 2.2, a partial budget (Table 2.5) for the use of LHRHa in place of CPE was developed to quantify the economic benefits of the spawning efficiencies from LHRHa. The increase in cash outflow from additional cost and reduced income is more than offset by the combination of additional income from fingerling sale and reduced costs associated with a lower number of brood fish.

The net additional income above variable costs of $1,361/acre represents a 17% increase above the income from research CPE operation. Forty-six percent of the net change in income came from the reduction in variable costs from improved production efficiency. Due to the combination of lower variable costs and higher output, the breakeven price to cover variable costs dropped by 19% from $0.040/fingerling sold for CPE operation to $0.031/fingerling sold for LHRHa operation.

Partial Budget for the Use of LHRHa under Research Conditions vs. CPE under Commercial Conditions, in CB Hybrid Catfish Production

Comparison between the research LHRHa operation and the current practice of using CPE for commercial CB hybrid catfish production clearly highlights the potential benefits to commercial catfish operations of using LHRHa in CB hybrid catfish embryo production. Brood fish needed to produce 14.1 million fry for the LHRHa operation was only 4,600 kg, 88% lower than the 36,800 kg of brood fish required to produce 13.42 million commercial CB hybrid catfish fry using CPE.

Higher income for the LHRHa operation comes from the combination of higher production and lower brood fish requirement, and lower variable inputs associated with brood fish such as brood fish feed and ovulating agent. Furthermore, because of lower operating costs, interest paid to finance the operation was also reduced. On the negative side of the equation were income lost from the sale of brood fish and increased costs associated with more fingerling feed, and higher labor requirements for hatchery and fingerling seining and hauling.

Overall, the gain outweighs the loss as shown by the incremental income of $3,125/acre (Table 2.6). Income above variable costs for research LHRHa is $9,195/acre, 51% higher than $6,070/acre for the commercial CB hybrid catfish operation using CPE as the ovulating agent. The breakeven price to cover variable costs also dropped by 52% from $0.064 for commercial CPE operation to $0.031 for LHRHa operation.

The 49% reduction in variable costs, from $727,891 for CPE to $369,134 for LHRHa, can be further broken down between fry and fingerling production (Table 2.7). Except for some portion of farm operation costs and interest on operating capital, 92% of all cost reductions are attributable to fry production. As a result, fingerling production showed just a modest reduction in production cost from $0.024 to $0.020 per fingerling whereas the cost of fry production dropped by 74% from $0.034 to $0.009 per fry.

Commercial Channel Catfish Production vs. CB Hybrid Catfish Production with the Use of LHRHa under Research Conditions

Table 2.8 shows that the cost of CB hybrid catfish fry production when CPE was used as the ovulating agent under commercial conditions was 325% higher than the cost of channel catfish fry production. After switching from CPE to LHRHa and incorporating some cultural practices observed under research situations, cost of CB hybrid catfish fry production is now only 12% higher than that of channel catfish fry.

The real economic gains are realized after the fry stage. Once CB hybrid catfish fry is produced, the operation benefits from the superior qualities of the CB hybrid catfish. The cost of producing CB hybrid catfish fingerling after the fry stage is less than that of the channel catfish fingerling. The CB hybrid catfish fingerling grows to 6" at a shorter time period than what it takes for the channel catfish fingerling to grow to the same length. Due to the higher growth rate, the cost of growing CB hybrid catfish fingerling ($0.020) is 31% less than that of channel catfish fingerling ($0.029).

Catfish fingerling are priced and sold to food fish growers based on their size. In addition to the lower cost of growing CB hybrid catfish fingerling, food fish growers are willing to pay anywhere between 1.5 cents to 3 cents per inch, 7% to 114% higher than the 1.4-cent/inch average selling price for the channel catfish fingerling. The higher survival rate, faster growth and more efficient feed conversion of the CB hybrid catfish are characteristics for which food fish growers are willing to pay a higher price.

Conclusion and Recommendation

Refining procedures for CB hybrid catfish embryo production has led to improvements in spawning efficiency. Issues involving ovulating agents include, but are not limited to, the type of hormone, administration, and dosage. Following recommended types and procedures, coupled with recommended cultural practices, can result in higher yield and cost savings.

The foregoing analyses quantified the economic gains that result from the use of LHRHa, in comparison to CPE, both under commercial and research settings. If the recommended procedures for hormone use were applied in commercial settings, the benefits from using LHRHa would result in cost savings and even higher production efficiency than what was already observed when commercial CB hybrid catfish operation using CPE as ovulating agent was compared to the channel catfish operation. Industry wide application of the CB hybrid catfish production technology will result in cost and production efficiency that will help safeguard the viability of the US catfish industry.

TABLES

Table 2.1 Spawning parameters from using carp pituitary extract (CPE) at 2mg/kg priming dose followed by 8 mg/kg resolving dose under commercial and research settings, and from using luteinizing hormone releasing hormone analogue (LHRHa) at 30 μg/kg priming dose followed by 150 μg/kg resolving dose under research settings, for the ovulation of channel catfish, *Ictalurus punctatus*, females and fertilization with blue catfish, *I. furcatus*, sperm to produce hybrid catfish embryos

	Commercial Setting			**Research Setting**					
Ovulating Agent	**CPE**			**CPE**			**LHRHa**		
	Min	*Ave*	*Max*	*Min*	*Ave*	*Max*	*Min*	*Ave*	*Max*
Ovulation rate (%)	40	64	85	45	70	90	50	85	100
Fecundity (# eggs/kg ♀ body weight)	2,000	3,800	6,500	3,560	8,900	10,000	8,000	10,000	14,000
Hatch rate (%)	10	20	38	10	25	45	23	38	75

Table 2.2 Production assumptions for using CPE at 2mg/kg priming dose followed by 8 mg/kg resolving dose under commercial and research settings, and for using LHRHa at 30 μg/kg priming dose followed by 150 μg/kg resolving dose under research settings, for the ovulation of channel catfish, *Ictalurus punctatus*, females and fertilization with blue catfish, *I. furcatus*, sperm to produce hybrid catfish embryos

	Commercial Setting	**Research Setting**	
Parameters	**CPE**	**CPE**	**LHRHa**
Size of operation (acres)	136	136	136
Brood fish stocking rate (lb/acre)	7,500	1,500	1,500
Female Brood fish weight (lb)	80,930	23,110	10,190
Cull rate (%)	25	20	20
Ovulation rate (%)	64	70	100
Fecundity (# eggs/kg ♀ body wt)	3,800	8,900	10,000
Hatch rate (%)	20	25	38
Fry stocking rate (# fry/acre)	110,000	110,000	110,000
Survival rate from fry to fingerling (%)	85	85	85
Output			
Fry production (million)	13.42	13.09	14.10
Target output (million 6" fingerling)	11.41	11.13	11.99
Market price (per fingerling)	$0.1350	$0.1350	$0.1350

Table 2.3 Enterprise budget for a commercial operation using CPE at 2mg/kg priming dose followed by 8 mg/kg resolving dose for the ovulation of channel catfish, *Ictalurus punctatus*, females and fertilization with blue catfish, *I. furcatus*, sperm to produce hybrid catfish embryos

Size of Operation	**136 acres**	
GROSS RECEIPTS		
Sale of Fingerling (11.41 million @ $0.1350 each)	*$1,539,945*	*$11,323*
Sale of Culled Female Brood Fish (26,977 lbs @ $0.50 each)	*$13,488*	*$99*
Total Gross Receipts	**$1,553,433**	**$11,422**
VARIABLE COSTS		
Brood Fish	*$220,871*	*$1,624*
Hatchery Labor	*$109,744*	*$807*
Contractual Labor	*$72,446*	*$533*
Farm Operation Costs	*$206,430*	*$1,518*
Hybrid Production Costs	*$81,700*	*$601*
Repairs and Maintenance (Machinery and Equipment)	*$8,950*	*$66*
Interest on Operating Capital	*$27,750*	*$204*
Total Variable Costs (TVC)	**$727,891**	**$5,352**
Income above variable costs	**$825,542**	**$6,070**
FIXED COSTS		
Salaries and Related Expenses	*$115,900*	*$852*
Insurance	*$6,350*	*$47*
Repairs and Maintenance (Ponds and Hatchery)	*$2,500*	*$18*
Interest on Capital Investment	*$141,623*	*$1,041*
Depreciation (building and equipment)	*$138,979*	*$1,022*
Office and Personnel Overhead Costs	*$18,120*	*$133*
Total fixed Costs (TFC)	**$423,472**	**$3,114**
TOTAL EXPENSES (TVC + TFC)	**$1,151,362**	**$8,466**
Net returns above total expenses	**$402,071**	**$2,956**
Breakeven price to cover variable costs (per fingerling sold)	**$0.064**	
Breakeven price to cover total costs (per fingerling sold)	**$0.101**	

Notes: This enterprise budget was based on Appendix Table 2.1 (Detailed Variable and Fixed Costs) and Appendix Table 2.2 (Income Statement). Gross receipts (cash farm income in Appendix Table 2.2) and interests were for a year when the farm is fully operational (Year 3 or later).

Table 2.4 Partial budget for a research operation using CPE at 2mg/kg priming dose followed by 8 mg/kg resolving dose for the ovulation of channel catfish, *Ictalurus punctatus*, females and fertilization with blue catfish, *I. furcatus*, sperm to produce hybrid catfish embryos, compared to a similar operation under commercial settings

Total Additional Cost	*$0*	**Total Additional Income**	*$0*
Reduced Income:		*Reduced Costs:*	
		Brood fish	$157,800
		Hatchery labor	$24,116
		Contractual labor	$1,781
		Feed	$31,630
Fingerling sale	$37,868	Hormones and chemicals	$54,680
Brood fish sale	$9,637	Interest	$17,433
Total Reduced Income	*$47,504*	*$47,504*	*$287,441*
Total Annual Additional Cash Outflow	**$47,504**	**Total Annual Additional Cash Inflow**	**$287,441**

Net Change in Income	***$239,937***
Net Change in Income per Acre	***$1,764***

Commercial CPE variable cost (From Table 2.3)	$727,891
Reduction in variable cost	$287,441
Research CPE variable cost	$440,450

Table 2.5 Partial budget for the use of LHRHa at 30 μg/kg priming dose followed by 150 μg/kg resolving dose in place of CPE under research settings at 2mg/kg priming dose followed by 8 mg/kg resolving dose for the ovulation of channel catfish, *Ictalurus punctatus*, females and fertilization with blue catfish, *I. furcatus*, sperm to produce hybrid catfish embryos

Additional Cost:		*Additional Income:*	
Fingerling feed	$9,194		
Contractual labor	$5,452	Fingerling sale	$115,898
Total Additional Cost	*$14,647*	**Total Additional Income**	*$115,898*
Reduced Income:		*Reduced Cost:*	
		Brood fish	$35,261
		Hatchery labor	$25,031
		Brood fish feed	$6,398
		Hormones and chemicals	$11,940
Brood fish sale	$2,153	Interest	$7,325
Total Reduced Income	*$2,153*	**Total Reduced Cost**	*$85,955*
Total Annual Additional Cash Outflow	**$16,800**	**Total Annual Additional Cash Inflow**	**$201,853**

Net Change in Income	***$185,053***
Net Change in Income per Acre	***$1,361***

Research CPE variable cost (From Table 2.4)	$440,450
Net reduction in variable cost ($85,955 - $14,647)	$71,308
LHRHa variable cost	$369,142

Table 2.6 Partial budget for the use of LHRHa at 30 µg/kg priming dose followed by 150 µg/kg resolving dose in place of CPE at 2mg/kg priming dose followed by 8 mg/kg resolving dose under commercial settings for the ovulation of channel catfish, ***Ictalurus punctatus***, females and fertilization with blue catfish, ***I. furcatus***, sperm to produce hybrid catfish embryos

Additional Costs:		*Additional Income:*	
Contractual labor	$3,671		
Fingerling feed	$6,190	Fingerling sale	$78,030
Total Additional Cost	*$9,861*	**Total Additional Income**	*$78,030*
Reduced Income:		*Reduced Cost:*	
		Brood fish	$193,061
		Hatchery labor	$49,147
		Brood fish feed	$35,030
		Hormones and chemicals	$66,620
Brood fish sale	$11,790	Interest	$24,759
Total Reduced Income	*$11,790*	**Total Reduced Cost**	*$368,618*
Total Annual Additional Cash Outflow	**$21,651**	**Total Annual Additional Cash Inflow**	**$446,648**

Net Change in Income	***$424,997***
Net Change in Income per Acre	***$3,125***

Commercial CPE variable cost (From Table 2.3)	$727,891
Net reduction in variable cost ($368,618 - $9,861)	$358,757
LHRHa variable cost	$369,134

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Table 2.7 Fry and fingerling variable cost of production for the ovulation of channel catfish, *Ictalurus punctatus*, females and fertilization with blue catfish, *I. furcatus*, sperm to produce hybrid catfish embryos using LHRHa at 30 μg/kg priming dose followed by 150 μg/kg resolving dose in place of CPE under commercial settings at 2mg/kg priming dose followed by 8 mg/kg resolving dose

Variable Cost Item	Commercial CPE		LHRHa		Cost Reduction	
	Fry	*Fingerling*	*Fry*	*Fingerling*	*Fry*	*Fingerling*
Brood fish	$220,871		$27,810		$193,061	
Hatchery Labor	$109,744		$60,605		$49,138	
Contractual Labor		$72,446		$76,117		-$3,671
Farm Operation	$28,088	$178,342	$16,411	$161,179	$11,677	$17,163
Hatchery / Hybrid Implement	$81,700		$15,080		$66,620	
Repairs & Maintenance (Machinery & Equipment)	$2,983	$5,967	$2,983	$5,967	$0	$0
Interest on Operating Expenses	$9,250	$18,500	$997	$1,994	$8,253	$16,506
Total Variable Cost	**$452,636**	**$275,255**	**$123,887**	**$245,257**	**$328,749**	**$29,998**
Percent of Cost Reduction					**91.64%**	**8.36%**
Quantity and Cost of Production						
Number (million)	13.42	11.41	14.10	11.99		
Average weight (g)		30		30		
Total weight (kg)		342,210		539,325		
Cost of production						
each	**$0.034**	**$0.024**	**$0.009**	**$0.020**		
per inch		**$0.0040**		**$0.0034**		
per kg		**$0.804**		**$0.682**		

Table 2.8 Fry and fingerling cost of production for channel catfish commercial operation, and for using CPE at 2mg/kg priming dose followed by 8mg/kg resolving dose and LHRHa at at 30 μg/kg priming dose followed by 150 μg/kg resolving dose for the ovulation of channel catfish, *Ictalurus punctatus*, females and fertilization with blue catfish, *I. furcatus*, sperm to commercially produce hybrid catfish

	Channel Catfish		**CPE CB Hybrid**		**LHRHa CB Hybrid**	
Quantity and Cost of Production	*Fry*	*Fingerling*	*Fry*	*Fingerling*	*Fry*	*Fingerling*
Number (million)	12.75	7.65	13.42	11.41	14.10	11.99
Average weight (g)		30		30		30
Total weight (kg)		229,500		342,210		539,325
Cost of production						
each	**$0.008**	**$0.029**	**$0.034**	**$0.024**	**$0.009**	**$0.020**
per inch		**$0.0048**		**$0.0040**		**$0.0034**
per kg		**$0.952**		**$0.804**		**$0.682**

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CHAPTER 3 - ECONOMICS OF FUNGAL DISINFECTANTS IN THE PRODUCTION OF CHANNEL CATFISH (*Ictalurus punctatus*) FEMALE X BLUE CATFISH (*I. furcatus*) MALE HYBRID (CB HYBRID) EMBRYO

Abstract

The economics of using iodine or formalin alternated with copper sulfate (F+CS) to control fungus on channel catfish (*Ictalurus punctatus*) female X blue catfish (*I. furcatus*) male hybrid (CB hybrid) eggs was examined. The enterprise budget for the commercial CB hybrid catfish operation (based on ovulating females with carp pituitary extract (CPE)) using iodine (iodine (CPE)) had net returns of $1,689/acre above variable costs and -$1,521/acre above total costs while the breakeven price to cover variable and total costs respectively were $0.103 and $0.168 per fingerling sold. The hatch rate for the commercial iodine (CPE) was extremely low, depressing total output to the point where it is not economically viable to invest in the production of CB hybrid catfish fry. However, when research protocols are implemented, variable costs for research iodine (CPE) were 39% lower than variable costs for commercial iodine (CPE) operation, mainly due to reduction in costs associated with female broodstock. The breakeven price to cover variable production costs dropped by 46% from $0.103 to $0.052 per fingerling sold and net returns to variable costs increased by 198%, from $1,689/acre to $5,036/acre.

Under research conditions, variable costs for F+CS (CPE) are a mere 8% lower than variable costs for iodine (CPE) operation. However, the efficacy of F+CS as chemical disinfectant for controlling fungus in CB hybrid eggs decreased female brood fish requirement by 36% from 12,152 kg to 7,818 kg and increased production by 41% from 9.69 million to 13.64 million fry. The benefit from using F+CS resulted in 119% increase in fry/kg female body weight. The breakeven price to cover variable production costs dropped by 35% from $0.052 for iodine (CPE) to $0.034 for F+CS (CPE) per fingerling sold. Finally, this comparison shows that the improvement in hatching success due to the efficacy of F+CS resulted in a significant net economic gain of $3,539/acre, a

70% increase above the income from the use of iodine. Complementing the improved disinfectant technology F+CS with improved ovulating technology, luteinizing hormone releasing hormone analogue (LHRHa), drops the breakeven price to cover variable production costs by 18% from $0.034 to $0.028 per fingerling sold and increases income above variable costs by $974/acre.

Utilization of F+CS (LHRHa) production protocol rather than the standard commercial iodine (CPE) production protocol results in an incremental income of $7,860/acre. Decomposing the net change in income due to cultural practices, ovulating agent, and fungal control shows that $3,347/acre, 43% of the incremental income, is due to research cultural practices, $974/acre (12%) from the ovulating agent, and $3,539/acre (45%) from improved fungal control. Adhering to all aspects of research protocol, including cultural practices, and recommended ovulating agents and fungal control in the production of CB hybrid catfish, F+CS (LHRHa) surpasses the traditional channel catfish in economic efficiency as evidenced by the 12.5% lower fry production cost.

Introduction

Relative to naturally pond-spawned channel catfish eggs, hand stripped eggs used in channel catfish(*Ictalurus punctatus*) female x blue catfish (*I. furcatus*) male (CB hybrid) embryo production exhibit lower level of fertility as sometimes they are damaged during stripping, or they may not be fully mature when the females are artificially induced to ovulate. As a result, hand stripped eggs are highly vulnerable to fungal infestation. Unfertilized eggs provide excellent substrate for fungus which spreads to fertilized eggs, causing the majority of the embryos to die and significantly lowering hatch rate. Without fungal treatment, 40 to 100% of fertilized channel x blue hybrid eggs can be lost to fungus (*Saprolegnia sp* and *Achlya sp*) (Lambert et al. 1999).

In general, commercial catfish hatcheries contend with occurrence of bacteria and fungus, which have a high growth propensity in the presence of unfertilized and dead eggs. Over-handling, overcrowding, and adverse environmental factors such as high temperatures and poor water quality also result in egg stress and death (Bosworth et al. 2005). CB hybrid catfish production is predisposed to the incidence of dead eggs because of damage sustained during stripping, and treatments that are most effective for controlling fungus on naturally produced channel catfish eggs are often unable to control fungus on hybrid catfish eggs.

Fungi that target dead eggs appear either as a white or a brown cottony film layer. Without intervention, fungus can overrun a whole egg mass killing healthy eggs, or potentially infest the entire hatching trough causing every egg mass to be infected. Physically removing dead eggs is helpful, but it is tedious, time consuming and will not completely solve the problem. A more effective way to control fungal infections is through the use of chemical disinfectants.

Use of Chemical Treatments to Control Fungal Infections

When using chemical treatments to control fungus, some biological, environmental, and physical factors have to be considered (Bosworth et al. 2005).The egg is covered by a membrane that protects the developing fry. If the right concentration of chemical is used, and the length and frequency of application are observed, the fry is protected until it hatches from the egg. Chemical applications should be discontinued upon hatching as fry are vulnerable to chemical disinfectants.

Concentration of the chemical treatment in water is a major determinant of effectiveness. Volume of water to be treated must be precisely known and exposure to the chemical treatment must be controlled in terms of water exchange rate. Chemical disinfectants can be applied either as flush treatment (water flows continuously during treatment) or bath treatment (water is turned off during treatment). Flush treatment is recommended over bath treatment as it involves less risk of over exposure to the chemical. When using a flush treatment, chemical concentration depends on the water flow rate. Higher chemical concentration of the treatment should be used at higher flow rates because higher flow rates provide for shorter contact time between the egg mass and the chemical solution.

Various chemical agents have been recommended as treatments for fungal infections in fish eggs, the most commonly studied are iodine, hydrogen peroxide, formalin, copper sulfate, and salt (Marking et al. 1994, Waterstrat and Marking 1995, Schreier et al. 1996, Rach et al. 1998, Arndt et al. 2001, Barnes et al. 2003, Small and Wolters 2003, Rach et al. 2004,) Several studies have used iodine (Walser and Phelps 1994), hydrogen peroxide (Small and Wolters 2003, Rach et al. 2004, Small 2004), formalin (Clemens and Sneed 1958, Walser and Phelps 1994), and salt (Clemens and Sneed 1958) specifically on channel catfish eggs while Chatakondi et al. (2003) and Small and Chatakondi (2006) looked at the efficacy of the above chemical disinfectants in treating fungus on CB hybrid catfish eggs.

Small and Chatakondi (2006) found that hatch rates were highest for CB hybrid eggs treated with formalin, copper sulfate, or iodine, and that the use of hydrogen peroxide significantly reduced hatching rates. Ongoing antifungal research on CB hybrid catfish eggs has shown that formalin treatments were consistent in controlling fungus resulting in hatch rates that are 2 to 4 times higher than the standard iodine treatments (Dunham, personal communication). Additionally, formalin in combination with copper sulfate (F+CS) is more effective than iodine or formalin and copper sulfate alone. Formalin is an FDA-approved aquaculture drug for the control of fungi on all fish eggs that can be used at a maximum rate of 2000 ppm for a 15-minute flush treatment.

Povidone iodine has been determined by FDA as a low regulatory priority and is permissible at a rate of 100 ppm for 10 minutes. Copper sulfate is under the subject of an Investigational New Animal Drug (INAD) exemption, wherein regulatory action has been deferred pending the outcome of ongoing research, and can be used at rates as high as 30-40ppm. These chemical disinfectants have been suggested as choices to reduce fungal infestation and to subsequently improve hatch rates in channel catfish eggs (Walser and Phelps 1993; Rach et al. 1998, 2004; Small and Wolters 2003; Small 2004) and CB hybrid catfish eggs (Chatakondi et al. 2003, Small and Chatakondi 2006). The objectives of this chapter are to compare the effect of iodine and F+CS on the hatchability of CB hybrid catfish eggs, and to determine the maximum potential benefits that can be gained if commercial CB hybrid catfish fry production were to switch from iodine to F+CS for fungal control.

Materials and Methods

Ovulating agents are essential for CB hybrid catfish embryo production (Lambert et al. 1999). For this reason, research hatch rates used in the analysis of economic benefits from iodine and F+CS as fungal controls were from experiments that used either carp pituitary extract (CPE) or luteinizing hormone releasing hormone analogue (LHRHa) for the ovulation of female catfish. Many commercial catfish hatcheries use iodine for fungal control and existing commercial CB hybrid operations use CPE as ovulating agent hence commercial hatch rates are based on iodine and CPE under commercial conditions. In all instances, the chemical disinfectant is applied as flush treatment up to 7 days after fertilization, after which use is discontinued as eggs begin to hatch.

Four major research observations related to the production of CB hybrid embryos are addressed in this analysis. Even when iodine is used as the antifungal agent, certain cultural practices observed in research environments improve production outcome. First, lower brood fish stocking density, and care and handling of female channel catfish brood fish improve their spawning performance. Secondly, lower density of eggs at incubation allows better water circulation and increased egg survival. Thirdly, experiments demonstrate that when F+CS is used hatch rates improve substantially. Finally, use of F+CS, in conjunction with LHRHa, results in much improved hatch rates. Eggs obtained using LHRHa as the ovulating agent are more robust and exhibit higher fertilization rates (Kristanto 2004), reducing the number of unfertilized eggs that are susceptible to fungus. These observations will be addressed in the evaluation of economic performance related to the use of antifungal agents.

Assumptions

Range of hatch rates for the use of iodine and F+CS are shown in Table 3.1 while production assumptions for using iodine and F+CS are shown in Table 3.2. Brood fish stocking rates of 7,500 lb/acre and 1,500 lb/acre are used for commercial and research operations, respectively. These analyses are conducted on CB hybrid catfish production using either CPE or LHRHa as the ovulating agent. Spawning parameters under commercial conditions are set at the average, with cull rate at 25%, ovulation rate at 64%, fecundity at 3,800 eggs/kg female body weight, and hatch rate at 11%. For iodine and F+CS using CPE as ovulating agent (Iodine (CPE) and F+CS (CPE)) under research conditions, parameters are set at 20% cull rate, 70% ovulation rate, 8,900 eggs/kg female body weight fecundity for both, and 16% and 35% hatch rate, respectively. For F+CS under research conditions using LHRHa as ovulating agent (F+CS (LHRHa)), parameters are set at 20% cull rate, 85% ovulation rate, 10,000 eggs/kg female body weight fecundity and 55% hatch rate.

Research loading rate is set at 233,000 eggs while commercial loading rate is set at 280,000 eggs per 100 gallons of water in the paddle wheel hatching trough. High commercial loading is subject to overcrowding which exacerbates the effect of fungal infestation. Large egg masses or egg masses that overlap extensively limit water circulation and promote transfer of diseases between egg masses. The 11% commercial hatch rate shown in Table 3.2 reflects the effect of hatchery loading rate commonly used in commercial hatcheries.

Except for the price of the antifungal agent, CB hybrid catfish production using iodine will be exposed to the same input and output markets as the CB hybrid catfish production using F+CS, hence input and output prices are critical only in terms of each enterprise's absolute requirements and performance. Their relative performance will be mostly affected by the cost of the antifungal agent and how it bears on the CB hybrid catfish production hatching success.

Procedures

The first two observations discussed in assumption above are incorporated in the analysis by comparing two operations that use iodine as antifungal agent and CPE as ovulating agent, one under commercial conditions and the other under research conditions. The differences in cultural practices are reflected in cull rate, ovulation rate, fecundity of the female brood fish, and hatch rate. The last two observations will be evaluated by comparing F+CS (CPE) to Iodine (CPE) and to F+CS (LHRHa).

To evaluate the increased hatching success when F+CS is used as the antifungal agent to combat fungal incidence in CB hybrid catfish egg masses, the economic performance of F+CS (CPE) will be compared to Iodine (CPE) under research setting. Except for antifungal agents, all production inputs including CPE as ovulating agent will be the same for both research operations. CPE is used at the rate of 2 mg/kg female body weight for the priming dose followed by 8 mg/kg female body weight for the resolving dose (2 mg/kg – 8 mg/kg).

To quantify the maximum potential benefits that could be gained from using F+CS in commercial productions, commercial CB hybrid catfish production and research production using F+CS (LHRHa) will be compared. The gap in economic performance will be decomposed into the benefit from hormone, research cultural practices, and antifungal agent. LHRHa is used at the rate of 30 μg/kg female body weight for the priming dose and 150 μg/kg female body weight for the resolving dose. Partial budgets will be used to quantify the economic gains in each of the above comparisons.

Data

Construction, machinery, and equipment costs were based on data obtained from farmers, which were validated using government, university and extension information. Fry production generated by the spawning parameters was defined and limited by the capacity of the farm. Expected output price was set at the going market price for CB hybrid catfish fingerling. Variable costs were obtained from vendors' and suppliers' websites and catalogues.

Quantities of antifungal agents are based on volume of water to be treated. Iodine is used at the rate of 100 ppm, and applied in the morning, noon and night for 7 days. Formalin in conjunction with CS is used on day 1, day 6 and day 7 at the rate of 100 ppm 3 times a day; for days in between, CS is used in the morning and evening at the rate of 32 ppm and formalin is used at noon at 100 ppm. All spawning parameters used in the analysis were set at the average values and are shown in
Table 3.2.

Results and Discussion

Use of Iodine (CPE) as Chemical Disinfectant to Control Fungus under Commercial Conditions, in CB Hybrid Catfish Production

The enterprise budget for the commercial CB hybrid catfish operation using iodine as chemical disinfectant to control fungus is shown in Table 3.3. The operation has net returns of $1,689/acre above variable costs and -$1,521/acre above total costs while the breakeven prices to cover variable and total costs respectively are $0.103 and $0.168 per fingerling sold. The hatch rate for the commercial CB hybrid catfish operation using iodine (CPE) for fungal control is extremely low that it depresses total output to the point where it is not economically efficient to invest in the production of CB hybrid catfish fry. Iodine is the traditional treatment for fungal infestation in channel catfish hatcheries. When commercial channel catfish producers ventured into CB hybrid catfish production, they evidently relied on iodine to control fungus on CB hybrid catfish egg masses. However, traditional treatments that are effective for controlling fungus on naturally produced channel catfish eggs are unable to control fungus on hybrid catfish eggs hence low hatching success in CB hybrid catfish fry production has prompted operators to shift to formalin.

The commercial iodine (CPE) CB hybrid catfish enterprise has a total variable cost of $5,177/acre, which is much higher than the traditional channel catfish operation's variable cost of $2,378/acre (Appendix Table 3.1). Breakeven prices are also much higher than the channel catfish operation's $0.042 and $0.091 variable and total cost breakeven prices. CB hybrid catfish production is labor intensive, requires blue male catfish sperm for fertilization and uses hormones to ovulate the channel catfish female: all these factors contribute to the CB hybrid's much higher variable costs of production. Inattention to standard protocols in the production of CB hybrid could be a waste of valuable production resources.

Partial Budget for the Use of Iodine (CPE) under Research Condition vs. Use of Iodine (CPE) under Commercial Condition, in CB Hybrid Catfish Production

A partial budget (Table 3.4) that compares the economic performance of iodine as antifungal agent under commercial and research settings was developed based on the assumptions shown in Table 3.2. Variable costs for research iodine operation ($431,508) are 39% lower than variable costs for commercial iodine operation ($704,031), mainly due to reduction in costs associated with female broodstock. The breakeven price to cover variable production costs dropped by 50% from $0.103 to $0.052[2] per fingerling sold. This comparison shows that the improved productivity of the female brood fish and the higher hatch rate due to better conditions for incubation resulted in an overall net economic gain of $3,347/acre, a 98% increase in net returns to variable costs.

Partial Budget for the Use of F+CS (CPE) vs. Iodine (CPE), as Antifungal Agents in CB Hybrid Catfish Production under Research Conditions

Table 3.5 compares the economic performance of F+CS to iodine as antifungal agent under research settings. The assumptions shown in Table 3.2 were used to generate the economic outcome of the production operations for the two antifungal agents. Variable costs for F+CS operation ($397,221) are a mere 8% lower than variable costs for iodine operation ($431,508). Although brood fish and costs associated with brood fish decreased significantly due to lower brood fish requirement, the high level of output increased the costs associated with fingerling, specifically fingerling feed, and contractual labor for seining and hauling fingerling. Because of the efficacy of F+CS as chemical disinfectant for controlling fungus in CB hybrid eggs, female brood fish requirement decreased by 36% from 12,152 kg to 7,818 kg while production increased by 41% from 9.69 million to 13.64 million fry. As a result, fry/kg female body weight

[2] $431,508 (variable cost from Table 3.4) / 8,240,000 (number of fingerling from Table 3.2)

increased by 119% from using F+CS. Higher fry/kg female body weight reflects improved hatch rate. The breakeven price to cover variable production costs dropped by 35% from $0.052 for iodine (CPE) to $0.034 for F+CS (CPE) per fingerling sold. Finally, this comparison shows that the improvement in hatching success due to the efficacy of F+CS resulted in a significant net economic gain of $3,539/acre, a 70% increase above the income from the use of iodine.

Partial Budget for the Use of F+CS (CPE) vs. F+CS (LHRHa), as Antifungal Agents in CB Hybrid Catfish Production under Research Conditions

The trade off between LHRHa and CPE is the higher cost of LHRHa vs. higher quality eggs that have a higher fertilization rate (Kristanto 2004), which may be more responsive to antifungal treatment. Lower number of unfertilized eggs reinforces the efficacy of the fungal chemical disinfectant. A partial budget (Table 3.6) that compares the economic performance of F+CS (LHRHa) to F+CS (CPE) under research settings was developed based on the assumptions shown in Table 3.2. Due to the higher fertilization rate of eggs from females injected with LHRHa, the requirement for female channel catfish is reduced resulting in lower costs associated with brood fish. Changes in the production income and expenses resulted in 14% net variable cost reduction and 11% increase in returns to variable costs. The breakeven price to cover variable production costs dropped by 18% from $0.034 to $0.028 per fingerling sold. This comparison shows an overall net economic gain of $974/acre.

Potential Economic Improvement from the Use of F+CS in the Commercial Production of CB Hybrid Catfish

Lack of observation on the use of F+CS under commercial setting prevents direct evaluation of the economic improvements that could result from its use in the commercial production of CB hybrid catfish. By using the comparisons between commercial and research use of iodine, and F+CS (CPE) and F+CS (LHRHa) the difference in economic performance between iodine (CPE) under commercial conditions and F+CS (LHRHa) under research conditions can be decomposed among research cultural practices, ovulating agent, and fungal control.

A partial budget showing the difference in economic performance between the use of iodine (CPE) in commercial CB hybrid production and the use of F+CS (LHRHa) under research operation is shown in Table 3.7. Commercial income from CB hybrid production could potentially increase by $1.07 million per year for this size of operation, if certain cultural practices were incorporated in conjunction with the application of F+CS as antifungal agent. Tables 3.4, 3.5, and 3.6 are used to show the decomposition, which is summarized in Table 3.7, of net change in income due to cultural practices, ovulating agent, and fungal control. Forty-three percent of the $7,860/acre ($3,347/acre incremental income) is due to research cultural practices (from Table 3.4), 12% ($974/acre) is due to ovulating agent (from Table 3.6) and the remaining 45% ($3,539/acre which is attributable to fungal control) is equivalent to the net change in income when iodine was compared to F+CS under research conditions (from Table 3.5).

CB Hybrid Catfish Production using F+CS (LHRHa) for Fungal Control vs. Commercial Channel Catfish Production

CB hybrid catfish fry production has been costlier than channel catfish fry production due to the low hatch rates. The economic performance of the CB hybrid catfish is highly dependent on hatching success. Therefore, the key to improving CB hybrid production is to control factors that influence hatch rates, particularly the incidence of fungus in egg masses during incubation.

In instances when hatching success is high, the cost of producing CB hybrid catfish could very well be lower than that of channel catfish. The foregoing analysis on the use of F+CS (LHRHa) shows that the $0.028 breakeven price to cover variable costs per fingerling sold is 33% lower than the $0.042 (Appendix Table 3.1) for the traditional commercial channel catfish operation. Furthermore, due to the higher number of fingerlings produced the $0.059 breakeven price to cover total costs per fingerling sold is 35% lower than the corresponding $0.091 breakeven price for the channel catfish operation.

Production costs for F+CS (LHRH) as fungal control can be broken down between fry and fingerling production cost. Except for interest on operating expenses and costs associated with brood fish all costs show as cost increase in Table 3.8, particularly for fingerling production. When compared to the traditional channel catfish operation, per unit fry production cost is 12.5% lower for the F+CS (LHRHa) because of the combined effect of lower brood fish requirement and higher fry production. As under all other scenarios where cost of CB hybrid catfish fry production is much higher than channel, once the hybrid has passed the fry stage the per unit cost of growing the CB hybrid catfish to the fingerling stage is always lower than the channel catfish due to its higher survival rate and faster growth rate. This comparison underscores the importance of hatching success and emphasizes that availability of CB hybrid fry for fingerling and food fish production is vital to the commercial adoption of the hybrid catfish.

Conclusion and Recommendation

Inconsistent hatching success is the primary reason why the CB hybrid catfish is not widely utilized for commercial production despite its suitable characteristics for pond culture. Fungal infestation is a major deterrent to hatching success. Chemical disinfectants that are most effective for controlling fungus on naturally produced channel catfish eggs are often unable to control fungus on CB hybrid catfish eggs. Up to 100 % of fertilized channel x blue hybrid eggs can be lost if fungus (*Saprolegnia sp* and *Achlya* *sp*) is left uncontrolled. Controlling fungus on CB hybrid catfish egg masses is vital to refining procedures for CB hybrid catfish embryo production.

Results from ongoing studies show that F+CS is the most promising chemical disinfectant for controlling fungus on CB hybrid catfish eggs. It is effective and consistent, and on the average results in 50% or higher hatching success. Controlling incidence of fungus on CB hybrid catfish egg masses will improve hatch rates and provide a reliable and steady supply of fry for fingerling and food fish production. If the proper protocol for controlling fungus along with recommended cultural practices were used by commercial producers, CB hybrid catfish commercial production will be consistent and farmers' competitiveness will be buffered against market uncertainties.

TABLES

Table 3.1 Hatch rates from using iodine and formalin + copper sulfate (F+CS) to control the incidence of fungus in the production of channel catfish, *Ictalurus punctatus* X blue catfish, *I. furcatus* (CB hybrid catfish) embryos obtained by using CPE at 2mg/kg priming dose followed by 8 mg/kg resolving dose for the ovulation of channel catfish females and fertilization with blue catfish sperm; and from using F+CS to control the incidence of fungus in the production of channel CB hybrid catfish embryos obtained by using LHRHa at 30 µg/kg priming dose followed by 150 µg/kg resolving dose for the ovulation of channel catfish females and fertilization with blue catfish sperm

	Application	Hatch Rates		
	Flush Treatment for 15 minutes	Min	Ave	Max
Iodine (CPE)	100 ppm morning, noon, night; days 1 to 7	5%	11%	40%
F+CS (CPE)	F - 100 ppm morning, noon, night; days 1, 6, 7 F - 100 ppm noon; days 2 to 5 CS - 32 ppm morning and night; days 2 to 5	5%	35%	55%
F+CS (LHRHa)	F - 100 ppm morning, noon, night; days 1, 6, 7 F - 100 ppm noon; days 2 to 5 CS - 32 ppm morning and night; days 2 to 5	10%	55%	75%

Table 3.2 Production assumptions for using iodine under commercial and research settings, and for using formalin + copper sulfate (F+CS) under research settings to control fungal infestation in the production of channel catfish, *Ictalurus punctatus* X blue catfish, *I. furcatus* (CB hybrid catfish) embryos obtained by using CPE at 2mg/kg priming dose followed by 8 mg/kg resolving dose for the ovulation of channel catfish females and fertilization with blue catfish sperm; and for F+CS under research settings to control fungal infestation in the production of CB hybrid catfish embryos obtained by using LHRHa at 30 μg/kg priming dose followed by 150 μg/kg resolving dose for the ovulation of channel catfish females and fertilization with blue catfish sperm

	Commercial Setting	Research Setting		
Parameters	**Iodine (CPE)**	**Iodine (CPE)**	**F+CS (CPE)**	**F+CS (LHRHa)**
Size of operation (acres)	136	136	136	136
Brood fish stocking rate (lb/acre)	7,500	1,500	1,500	1,500
Female Brood fish weight (lb)	87,789	26,735	17,200	8,410
Cull rate (%)	25	20	20	20
Ovulation rate (%)	64	70	70	85
Fecundity (# eggs/kg ♀ body wt)	3,800	8,900	8,900	10,000
Hatch rate (%)	11	16	35	55
Fry stocking rate (# fry/acre)	110,000	110,000	110,000	110,000
Survival rate from fry to fingerling (%)	85	85	85	85
Output				
Fry production (million)	8.01	9.69	13.64	14.30
Target output (million fingerling)	6.81	8.24	11.56	12.16
Market price (per fingerling)	$0.1350	$0.1350	$0.1350	$0.1350

Table 3.3 Enterprise budget for a commercial operation using iodine to control fungal infestation in the production of channel catfish, *Ictalurus punctatus* X blue catfish, *I. furcatus* embryos obtained by using CPE at 2mg/kg priming dose followed by 8 mg/kg resolving dose for the ovulation of channel catfish females and fertilization with blue catfish sperm

Size of operation	**136 acres**	
GROSS RECEIPTS		
Sale of Fingerling (6.81 million @ $0.1350 each)	*$919,148*	*$6,758*
Sale of Culled Female Brood Fish (29,263 lbs @ $0.50 each)	*$14,632*	*$108*
Total Gross Receipts	**$933,779**	**$6,866**
VARIABLE COSTS		
Brood Fish	*$239,591*	*$1,762*
Hatchery Labor	*$119,045*	*$875*
Contractual Labor	*$43,241*	*$318*
Farm Operation Costs	*$160,580*	*$1,181*
Hybrid Production Costs	*$91,680*	*$674*
Repairs and Maintenance (Machinery and Equipment)	*$8,950*	*$66*
Interest on Operating Capital	*$40,944*	*$301*
Total Variable Costs (TVC)	**$704,031**	**$5,177**
Income above variable costs	**$229,748**	**$1,689**
FIXED COSTS		
Salaries and Related Expenses	*$115,900*	*$852*
Insurance	*$6,350*	*$47*
Repairs and Maintenance (Ponds and Hatchery)	*$2,500*	*$18*
Interest on Capital Investment	*$154,817*	*$1,138*
Depreciation (building and equipment)	*$138,979*	*$1,022*
Office and Personnel Overhead Costs	*$18,120*	*$133*
Total fixed Costs (TFC)	**$436,666**	**$3,211**
TOTAL EXPENSES (TVC + TFC)	**$1,140,696**	**$8,387**
Net returns above total expenses	**-$206,917**	**-$1,521**
Breakeven price to cover variable costs (per fingerling sold)	**$0.103**	
Breakeven price to cover total costs (per fingerling sold)	**$0.168**	

Table 3.4 Partial budget for using iodine under research setting vs. iodine under commercial setting to control fungal infestation in the production of channel catfish, *Ictalurus punctatus* X blue catfish, *I. furcatus* embryos obtained by using CPE at 2mg/kg priming dose followed by 8 mg/kg resolving dose for the ovulation of channel catfish females and fertilization with blue catfish sperm

Additional Cost		*Additional Income*	
Contractual labor	$9,069	Fingerling sale	$192,780
Total Additional Cost	*$9,069*	**Total Additional Income**	*$192,780*
Reduced Income		*Reduced Cost*	
		Brood fish	$166,627
		Hatchery labor	$19,982
		Feed	$14,940
		Hormones and chemicals	$58,110
Brood fish sale	$10,176	Interest	$21,933
Total Reduced Income	*$10,176*	**Total Reduced Cost**	*$281,592*
Total Annual Additional Cash Outflow	**$19,245**	**Total Annual Additional Cash Inflow**	**$474,372**

Net Change in Income	**$455,127**
Net Change in Income per Acre	**$3,347**

Commercial iodine (CPE) variable cost	$704,031
Net reduction in variable cost	$272,523
Research iodine (CPE) variable cost	$431,508

Table 3.5 Partial budget for using formalin + copper sulfate (F+CS) vs. iodine to control fungal infestation in the production of channel catfish, *Ictalurus punctatus* X blue catfish, *I. furcatus* embryos under research setting obtained by using CPE at 2mg/kg priming dose followed by 8 mg/kg resolving dose for the ovulation of channel catfish females and fertilization with blue catfish sperm

Additional Cost:		*Additional Income:*	
Contractual labor	$21,108		
Fingerling feed	$35,594	Fingerling sale	$448,673
Total Additional Cost	*$56,701*	**Total Additional Income**	*$448,673*
Reduced Income:		*Reduced Cost:*	
		Brood fish	$26,023
		Hatchery labor	$35,333
		Brood fish feed	$4,722
		Hormones and chemicals	$12,040
Brood fish sale	$1,589	Interest	$12,871
Total Reduced Income	*$1,589*	**Total Reduced Cost**	*$90,988*
Total Annual Additional Cash Outflow	**$58,291**	**Total Annual Additional Cash Inflow**	**$539,661**
Net Change in Income	**$481,370**		
Net Change in Income per Acre	**$3,539**		
Research iodine (CPE) variable cost	$431,508		
Net reduction in variable cost	$34,287		
F+CS (CPE) variable cost	$397,221		

Table 3.6 Partial budget for using formalin + copper sulfate (F+CS) to control fungal infestation in the production of channel catfish, *Ictalurus punctatus* X blue catfish, *I. furcatus* (CB hybrid catfish) embryos obtained by using LHRHa at 30 µg/kg priming dose followed by 150 µg/kg resolving dose for the ovulation of channel catfish females and fertilization with blue catfish sperm under research settings vs. F+CS to control fungal infestation in the production CB hybrid catfish embryos obtained by using CPE at 2mg/kg priming dose followed by 8 mg/kg resolving dose for the ovulation of channel catfish females and fertilization with blue catfish sperm under research settings

Additional Cost:		*Additional Income:*	
Contractual labor	$3,779		
Fingerling feed	$6,372	Fingerling sale	$80,325
Total Additional Cost	*$10,151*	**Total Additional Income**	*$80,325*
Reduced Income:		*Reduced Cost:*	
		Brood fish	$23,989
		Hatchery labor	$21,215
		Brood fish feed	$4,353
		Hormones and chemicals	$8,080
Brood fish sale	$1,465	Interest	$6,140
Total Reduced Income	*$1,465*	**Total Reduced Cost**	*$63,777*
Total Annual Additional Cash Outflow	**$11,616**	**Total Annual Additional Cash Inflow**	**$144,102**

Net Change in Income	**$132,486**
Net Change in Income per Acre	**$974**

F+CS (CPE) variable cost	$397,221
Net reduction in variable cost	$53,626
F+CS (LHRHa) variable cost	$343,595

Table 3.7 Partial budget for using formalin + copper sulfate (F+CS) under research setting to control fungal infestation in the production of channel catfish, *Ictalurus punctatus* X blue catfish, *I. furcatus* (CB hybrid catfish) embryos obtained by using LHRHa at 30 µg/kg priming dose followed by 150 µg/kg resolving dose for the ovulation of channel catfish females and fertilization with blue catfish sperm vs. iodine under commercial setting to control fungal infestation in the production of CB hybrid catfish embryos obtained by using CPE at 2mg/kg priming dose followed by 8 mg/kg resolving dose for the ovulation of channel catfish females and fertilization with blue catfish sperm

Additional Cost:		*Additional Income:*	
Contractual labor	$33,956		
Fingerling feed	$57,260	Fingerling sale	$721,778
Total Additional Cost	*$91,215*	**Total Additional Income**	*$721,778*
Reduced Income:		*Reduced Cost:*	
		Brood fish	$216,639
		Hatchery labor	$76,530
		Brood fish feed	$39,308
		Hormones and chemicals	$78,230
Brood fish sale	$13,230	Interest	$40,944
Total Reduced Income	*$13,230*	**Total Reduced Cost**	*$451,651*
Total Annual Additional Cash Outflow	**$104,445**	**Total Annual Additional Cash Inflow**	**$1,173,429**
Net Change in Income		**$1,068,983**	
Due to cultural practices		*$455,127*	
Due to ovulating agent		*$132,486*	
Due to Fungal Control		*$481,370*	
Net Change in Income per Acre		**$7,860**	
Due to cultural practices per acre		*$3,347*	
Due to ovulating agent per acre		*$974*	
Due to Fungal Control per acre		*$3,539*	
Commercial iodine (CPE) variable cost		$704,031	
Net reduction in variable cost		$360,436	
F+CS (LHRHa) variable cost		$343,595	

Table 3.8 Fry and fingerling variable cost of production for channel catfish commercial operation, and for using formalin + copper sulfate (F+CS) to control fungal infestation in the production of channel catfish, Ictalurus punctatus X blue catfish, I. furcatus (CB hybrid catfish) embryos obtained by using LHRHa at 30 µg/kg priming dose followed by 150 µg/kg resolving dose for the ovulation of channel catfish females and fertilization with blue catfish sperm

	Channel Catfish		**CB Hybrid Catfish**		**Cost Reduction**	
Variable Cost Item	*Fry*	*Fingerling*	*Fry*	*Fingerling*	*Fry*	*Fingerling*
Brood Fish	$48,000		$22,952		$25,048	
Hatchery Labor	$20,792		$42,516		-$21,724	
Contractual Labor		$36,900		$77,197	$0	-$40,297
Farm Operation	$21,959	$161,201	$16,118	$162,412	$5,841	-$1,211
Hatchery / Hybrid Implement	$3,900		$13,450		-$9,550	
Repairs & Maintenance (Machinery & Equipment)	$2,983	$5,967	$2,983	$5,967	$0	$0
Interest on Operating Expenses	$7,216	$14,431	$0	$0	$7,216	$14,431
Total Variable Cost	**$104,850**	**$218,499**	**$98,019**	**$245,576**	**$6,831**	**-$27,077**
Percent of Cost Reduction					**-33.74%**	**133.74%**
Quantity and Cost of Production						
Number (million)	12.75	7.65	14.30	12.16		
Average weight (g)		30		30		
Total weight (kg)		229,500		364,650		
Cost of production						
each	**$0.008**	**$0.029**	**$0.007**	**$0.020**		
per inch		**$0.0048**		**$0.0034**		
per kg		**$0.952**		**$0.673**		

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CHAPTER 4 - ECONOMIC CONTRIBUTION OF GENETIC IMPROVEMENT IN CHANNEL CATFISH (*Ictalurus punctatus*) FEMALE X BLUE CATFISH (*I. furcatus*) MALE HYBRID (CB HYBRID) EMBRYO PRODUCTION

Abstract

The economics of channel catfish (*Ictalurus punctatus*) fingerling production, commercial channel catfish female X blue catfish (*I. furcatus*) male hybrid (CB hybrid) fingerling production, CB hybrid fingerling production using randomly bred (normal) channel catfish, and CB hybrid fingerling production using selected (select) channel catfish females were compared. The normal female CB hybrid catfish operation has net returns of $2,982/acre above variable costs and -$97/acre above total costs. The breakeven prices to cover variable and total costs are $0.064 and $0.138 per fingerling sold, each one being 52% higher than the traditional channel catfish operation's breakeven prices of $0.042 and $0.091, respectively. Use of select female channel catfish resulted in 247% increase in fry/kg female body weight. Improved production efficiency was reflected by less brood fish and more fry which emphasizes the importance of fry per kg body weight of female brood fish. The net additional income of $5,543/acre above variable costs represents an 86% increase over that of the normal female operation's income above variable costs of $2,982/acre. . Total variable cost for select female operation is 19% higher than normal female operation's variable costs but total fingerling output is 107% higher. As a result, breakeven price per fingerling sold to cover variable costs is 42% lower for the select operation, $0.037/fingerling vs. $0.064/fingerling for the normal operation. Production cost of commercial CB hybrid catfish fry using normal channel catfish injected with CPE was 325% higher than that of traditional channel catfish fry production. This 325% cost difference dropped to 75% with the use of select females injected with 20 μg/kg priming dose followed by 100 μg/kg resolving dose LHRHa. Although cost of producing CB hybrid catfish fry was 75% higher than channel catfish fry, the cost of fingerling production from fry to fingerling was lower for the CB hybrid than the channel catfish. Growing this CB hybrid catfish fry to

fingerling costs $0.021 each, 28% less than the $0.029 cost per fingerling for channel catfish.

Introduction

Compared to terrestrial livestock industries, catfish culture is relatively young and lags in the application of genetics and breeding principles (Tucker and Robinson 1990). Genetic enhancement has been employed in the development of better quality and higher yielding livestock and is also being used to improve genetic traits of catfish to boost production and industry output.

Approaches to genetic improvement include selection, polyploidy, crossbreeding, hybridization, and transgenesis (Dunham 2004). Selection (Bondari 1983, Dunham and Smitherman 1983a, Padi 1995, Dunham and Brummet 1999, Rezk et al. 2003), intraspecific crossbreeding (Dunham et al. 1983, Dunham et al. 1987, Wolters and Johnson 1995) and interspecific hybridization (Kim 1996, Smitherman et al. 1996, Lambert et al. 1999, Li et al. 2004) have been used to genetically improve catfish.

Selection

The goal in selection is to drive the population average towards a desired attribute or phenotypic level. Breeding programs involving selection can require several generations to produce desired results hence selection can be an expensive approach to genetic improvement. Additionally, selective breeding requires thorough record keeping and a control population against which the results of the selection process will be compared (Tucker and Robinson 1990, Tave 1993, Dunham 2004). Channel catfish, *Ictalurus punctatus,* the primary culture species in the catfish industry, has been selected for improved growth and body weight (Padi 1995, Smitherman et al. 1996, Dunham and Brummet 1999, Rezk et al. 2003).

Intraspecific Crossbreeding

Intraspecific crossbreeding or simply crossbreeding is the mating of broodstock from different strains within the same species. Crossbreeding aims to identify broodstock combinations that create offspring with traits superior to their parents (Tave 1993, Dunham 2004). Crossbreeding does not always result in better performing offspring and the offspring of strain A female x strain B male can very well be different from the offspring of the reciprocal cross.

In eleven different crosses using ten channel catfish strains, only six crossbreeds were superior to both parents (Dunham and Smitherman 1983b). Some of the observed improvements in crossbred channel catfish females were expressed heterosis for spawning rates in ponds (Dunham et al. 1983) and early sexual maturity (Smitherman and Dunham 1985).

Interspecific Hybridization

Similar to intraspecific crossbreeding, interspecific hybridization, or simply hybridization, aims at heterotic performance of offspring relative to their parents. Unlike crossbreeding which crosses broodstock from different strain within the same species, hybridization crosses broodstock from two different species.

Of the thirty plus different hybrids evaluated among different catfish species (Giudice 1966, Dupree et al. 1969, Thomas and Tucker 1985, Dunham et al. 1987, Goudie et al. 1993), only the cross between female channel catfish and male blue catfish, *I. furcatus,* (CB hybrid) showed significant heterosis and evidence of overdominance (Dunham et al. 1982, Dunham and Brummet 1999, Dunham et al. 2000, Argue et al. 2003) for growth and other traits. Compared to the channel catfish, CB hybrid catfish exhibits improved growth rate, higher dress out percentage, increased disease resistance, and greater resistance to low dissolved oxygen concentrations (Smitherman and Dunham 1985).

The Catfish Industry and the CB Hybrid Catfish

Catfish production, which is almost entirely based on the culture of channel catfish, has suffered a price-cost squeeze since the turn of the century due to lower prices received by producers and higher costs of inputs, feed in particular. More importantly, the catfish industry has been threatened by competition from imports.

Given that catfish represents over 70% of the US aquaculture food production, it is important for the country, in general, and even more important economically in the south. The livelihood of many rural families in Mississippi, Louisiana, Arkansas and Alabama depends on this industry. The viability of the catfish industry must be safeguarded by developing strategies that will reduce production costs and enhance production efficiency.

The superiority and outstanding performance of the CB hybrid, which is extensively documented (Yant et al. 1975, Chappell 1979, Dunham and Smitherman 1981, Tave et al. 1981, Brooks et al. 1982, Dunham et al. 1982, Dunham et al. 1983, Smitherman et al. 1983, Dunham et al. 1987, Dunham et al. 1990, Jeppsen 1995, Wolters and Johnson 1995, Wolters et al. 1996, Smitherman et al. 1996, Dunham and Argue 1998, Dunham and Brummett 1999, Argue et al. 2003, Li et al. 2004), and established through commercial field trials (Chatakondi et al. 2000, Ligeon et al. 2004, Bosworth and Wolters 2004, Chatakondi et al. 2005), makes the CB hybrid in demand and useful for commercial aquaculture. Despite the superior characteristics of the CB hybrid, utilization among producers remains low because the reproductive isolating mechanism between the channel catfish and the blue catfish continues to be an impediment to the production of sufficient quantities of fry needed for commercial production (Tave and Smitherman 1982, Dunham and Smitherman 1987, Dunham et al. 1998, Masser and Dunham 1998, Argue et al. 2003).

Genetic Enhancement to Increase CB Hybrid Embryo Production

Various catfish research strategies continue to improve production of hybrid embryos particularly through reproduction. Use of lines or strains that have been improved for reproductive traits either through selection or crossbreeding is one such strategy. Certain lines of channel catfish have better reproductive performance than others (Dunham and Smitherman 1984, Ballenger 2007). Fecundity, for example, was found to be significantly improved by utilizing crossbred AR (Auburn x Rio Grande) channel catfish females and also crossbred ARMK (AR x MK (Marion x Kansas)) channel catfish females (Dunham and Smitherman 1984). Female channel catfish that have been crossbred or selected (select) for enhanced reproductive performance usually exhibit better secondary sexual characteristics such as well-rounded, distended abdomen, darkened coloration, and reddish urogenital area (Bart et al. 1998; Dunham et al. 1999) that are favorable for induction of ovulation, thus reducing the number of culled female brood fish. Overall, select female broodstock also have higher fecundity (Dunham and Smitherman 1984, Ballenger 2007).

All other things being equal, using select broodstock should improve CB hybrid catfish embryo production. The objectives of this chapter are to compare the overall reproductive performance of select female channel catfish and randomly bred (normal) channel catfish, and to determine the potential benefits that can be gained if commercial CB hybrid catfish embryos were to be produced using eggs from select female channel catfish.

Materials and Methods

Select broodstock exhibit superior spawning characteristics compared to normal female channel catfish that have not been selected for improved reproductive performance. Ballenger (2007) observed that certain lines, particularly AU-13, exhibited lower cull rate, and higher spawning percentage and fecundity when producing hybrid embryos. For the current analysis, AU-13 will represent select broodstock and AU-7 normal broodstock. Based on Ballenger's results, Table 4.1 shows average spawning parameters from using LHRHa[3] at 20 μg/kg priming dose followed by 100 μg/kg resolving dose (20 μg/kg - 100 μg/kg LHRHa) for the ovulation of normal and select female channel catfish broodstock. Both normal and select broodstock exhibit 80% ovulation rate but normal broodstock are culled at the rate of 20% while select broodstock are mostly suitable for induction of ovulation, eliminating the need to cull prior to hormone injection. For normal broodstock, eggs obtained through hand stripping average 9,130 per kg female body weight and hatch at 11%. In comparison, select female broodstock have a fecundity of 11,693 eggs per kg female body weight and hatch rate can be more than 100% higher than that of normal broodstock.

Assumptions

Production assumptions for using normal and select broodstock injected with 20 μg/kg - 100 μg/kg LHRHa for producing CB hybrid catfish embryos are shown in Table 4.2. Female brood fish are stocked at 1,500 lb/acre. Parameter assumptions for normal female brood fish based on AU-7 (normal) spawning performance include 20% cull rate, 80% ovulation rate and 11% hatch rate. Select female brood fish parameters based on AU-13 (select) performance are set at 80% ovulation rate, 24% hatch rate and 0% cull rate.

[3] Luteinizing hormone releasing hormone synthetic analogue

Since both the normal and select CB hybrid catfish operations will all be exposed to the same input and output markets, prices are critical only in terms of each enterprise's absolute economic performance. Their relative performance will be mostly affected by the choice of female brood fish used in the production of CB hybrid catfish embryo.

Procedures

To isolate the effect of genetics, two CB hybrid embryo production operations were compared, *ceteris paribus*[4], based on the findings of Ballenger (2007) with one operation using normal female (AU-7) channel catfish and the other using select female (AU-13) channel catfish. An enterprise budget was developed for the baseline normal female channel catfish operation. To assess the contribution of genetically improved female channel catfish used in the production of CB hybrid catfish embryo, a partial budget was used to quantify the economic benefits resulting from the use of select female channel catfish in place of normal female channel catfish.

Data

Initial cost outlay for construction, machinery and equipment were extrapolated from actual farm data and validated against government, university and extension information. Production activities were planned around the size of the farm, therefore the final output depends on how ponds were allocated between broodstock and fingerling. Expected output price was set at the going market price of $0.1350/fingerling for CB hybrid catfish. Costs of all other inputs were obtained from company catalogues and vendors' websites. LHRHa is available at Syndell International for $450 per 25 mg. At the rate of 20 μg/kg - 100 μg/kg, 1,000 mg of LHRHa are needed for the normal

[4] Farm size, stocking rates, feed conversion ratio, fry to fingerling survival rate, and market prices are set at the same levels for both normal and select female channel catfish

operation while 750 mg are needed for the select operation, a $4,500 reduction in input costs for using genetically improved female channel catfish brood stock. Except for the strain of female channel catfish, all production inputs are the same for the two operations.

Results and Discussion

Use of Normal Female Channel Catfish Broodstock in CB Hybrid Catfish Production under Research Conditions

For the normal female CB hybrid catfish operation, Appendix Table 4.1 shows variable and fixed cost items and Appendix Table 4.2 shows the income statement. Information shown in the income statement was used to construct the enterprise budget shown in Table 4.3. Total variable cost for the normal female CB hybrid operation is $2,699/acre, 13% higher than the traditional channel catfish operation's variable cost of $2,378/acre (Appendix Table 4.3). The normal female CB hybrid catfish operation has net returns of $2,982/acre above variable costs and -$97/acre above total costs. The breakeven prices to cover variable and total costs are $0.064 and $0.138 per fingerling sold, each one being 52% higher than the traditional channel catfish operation's respective breakeven prices of $0.042 and $0.091.

The hatch rate for the AU-7 female channel catfish is extremely low. For this particular situation, a high number of eggs are needed to produce fry that will maximize the use of ponds. In the short run, the hatchery can be expanded to double the capacity but even then, the hatchery is not big enough to support the number of eggs needed to fill the fry ponds. In this analysis, fry production suffers from very low hatch rate and is constrained by the size of the hatchery. The number of fry is limited to 6.70 million, leaving 59 acres of pond still available for fry stocking. As a result, the breakeven prices are much higher than those of the channel catfish operation. Generally, CB hybrid operations have to contend with intensive labor use, sacrifice blue male catfish to acquire sperm for fertilization of channel female catfish eggs, and use hormones to ovulate the channel catfish female. All these factors contribute to the high variable costs of producing CB hybrid catfish fry. The use of genetically improved strains shows the economic benefits of using female that are bred for their reproductive performance. The results from the analysis that uses AU-13 female channel catfish in the production of CB hybrid catfish fry are shown below.

Partial Budget for the Use of Select vs. Normal Female Channel Catfish in CB Hybrid Catfish Production under Research Conditions

The economic tradeoff when using select female in place of normal female channel catfish is the higher cost of select female brood fish vs. the incremental income from their higher productivity. Because of the superior secondary sexual characteristics of select females that are favorable for induction of ovulation (Bart et al. 1998; Dunham et al. 1999), female brood fish requirement decreased by 40% from 10,400 kg to 6,200 kg, while utilizing all the available ponds for fry stocking. As expected, production increased by 107% from 6.7 million to 13.9 million fry. The benefit from using select female channel catfish resulted in 247% increase in fry/kg female body weight. Improved production efficiency was reflected by less brood fish and more fry which emphasizes the importance of fry per kg body weight of female brood fish. Using the assumptions shown in Table 4.2, a partial budget for the use of select in place of normal female channel catfish brood fish in the production of CB hybrid catfish embryo was developed to quantify the economic benefits of the spawning efficiencies from using genetically improved broodstock (Table 4.4).

Changes in the cost side can be broken down into cost reduction attributed to less brood fish and cost increase due to more fry. Select brood fish are more expensive,

$3.50 per pound, compared to normal brood fish that cost $2 per pound. Partly due to scarcity and generally because of the high price of select female catfish brood stock, their use in commercial catfish production is uncommon. One would expect that it will cost more to use select female in place of the normal strain because they are 75% more expensive than the latter. However, brood fish requirements are reduced from 10,400 kg normal female to 6,200 kg select female because of the superior sexual characteristics of the latter. Naturally, costs associated with brood fish, such as brood fish feed and hormones used for ovulation, and interest on operating costs are also reduced. Aggregate cost reduction due to lower broodstock requirement amounted to $33,571. Increased fry production, on the other hand, resulted in more fingerling feed and additional contractual labor for seining and hauling fingerling totaling an additional cost of $104,412. Altogether, the combined cost adjustments resulted in net cost increase of $70,841. Although there was a tremendous increase in fingerling feed cost due to higher fry production, hatchery labor for fry production did not increase because there were fewer eggs that were tended in the production of higher number of fry. This is due to the higher fertilization and hatching success of select channel catfish female eggs.

On the income side, returns from sale of culled brood fish were lost, but revenue from higher fingerling production increased by $826,200. Combining all changes in costs and income generated a net gain of $753,822 in annual cash inflow. The increase in costs and the income reduction from culled brood fish were more than offset by the additional income from fingerling sales.

The net additional income of $5,543/acre above variable costs represents an 86% increase over that of the normal female operation's income above variable costs of $2,982/acre. Total variable cost for select female operation is 19% higher than normal female operation's variable costs but total fingerling output is 107% higher. As a result, breakeven price per fingerling sold to cover variable costs is 42% lower for the select operation, \$0.037/fingerling[5] vs. \$0.064/fingerling for the normal operation (Table 4.3).

Partial Budget for the Use of Select Female Channel vs. Normal Female Channel Catfish under Commercial Conditions, in the Production of CB Hybrid Catfish

The enterprise budget for a commercial CB hybrid catfish operation (Appendix Table 4.4) was used to compare the commercial practice of using normal female channel catfish to the select female channel catfish operation. The comparison underscores some potential benefits to commercial catfish operations of using select female in CB hybrid catfish embryo production. Production of 13.9 million CB hybrid catfish fry using select strain injected with 20 μg/kg - 100 μg/kg LHRHa requires 6,200 kg female brood fish, almost 83% less than the 36,800 kg brood fish needed to produce a slightly lower output of 13.42 million CB hybrid commercial fry using normal female injected with 2 mg/kg priming dose followed by 8 mg/kg resolving dose (2 mg/kg - 8 mg/kg) of CPE[6].

Higher income for the select operation comes from the combination of higher output and lower cost. Table 4.5 shows that reduced cost in brood fish and all associated variable inputs such as brood fish feed and ovulating agent exceeds the additional cost associated with fingerling feed and labor. Although income from sale of culled brood fish is lost, the additional income from sale of fingerling far exceeds the income foregone. Furthermore, because of lower operating costs, interest paid to finance the operation is also reduced.

Overall, the gain outweighs the loss as shown by the partial budget when select female is compared to commercial hybrid production using normal female channel

[5] \$437,868/11.82 M fingerling
[6] Carp Pituitary Extract

catfish (Table 4.5). Variable costs dropped from $727,891 to $437,865 resulting in an overall significant 40% net cost reduction of $290,036. The incremental income of $2,455/acre above variable costs is 40% higher than that of the commercial CB hybrid catfish operation using randomly bred female channel catfish. The breakeven price also dropped by 42% from $0.064 for commercial normal operation to $0.037 for the select operation.

The 40% reduction in variable costs can be further broken down between fry and fingerling production (Table 4.6). Except for farm operation costs and interest on operating capital, 90% of all cost reductions are attributable to fry production. Cost of fingerling production dropped by 12% from $0.024 to $0.021 per fingerling while cost of fry production dropped by 59% from $0.034 to $0.014 per fry.

Commercial Channel Catfish Production vs. CB Hybrid Catfish Production with the Use of Select Female Channel Catfish

The $0.037 and $0.071 breakeven prices to cover variable and total costs for select female CB hybrid catfish operation are 12% and 22% lower than the corresponding $0.042 and $0.091 breakeven prices for the traditional commercial channel catfish operation (Appendix Table 4.3). This shows a tremendous improvement over the 52% higher breakeven prices to cover variable and total costs when CB hybrid catfish operation using normal female brood fish was compared to the traditional commercial channel catfish operation.

Production cost of commercial CB hybrid catfish fry using normal channel catfish injected with CPE was 325% higher than that of traditional channel catfish fry production (Appendix Table 4.5). Using select females injected with 20 μg/kg - 100 μg/kg LHRHa reduced this cost difference to 75%. Although cost of producing CB hybrid catfish fry was 75% higher than channel catfish fry, the cost of fingerling production from fry to fingerling was lower for the CB hybrid than the channel catfish. Growing this CB hybrid catfish fry to fingerling costs $0.021 each, 28% less than the $0.029 cost per fingerling for channel catfish.

Conclusion and Recommendation

Genetic enhancement with the goal of improving spawning efficiency is one of the research thrusts in refining procedures for CB hybrid embryo production. The use of select lines or strains enhances production of CB hybrid catfish embryos (Ballenger 2007).

The current analysis quantified the economic gains that result from the use of select female channel catfish injected with 20 μg/kg - 100 μg/kg LHRHa first by *ceteris paribus* comparison to normal females to highlight the economic benefits of spawning efficiencies from using genetically improved broodstock. The second comparison was between the select operation and the current commercial CB hybrid practice of using normal female injected with 2 mg/kg - 8 mg/kg CPE to show the significant reduction in fry production cost. Finally, comparison between traditional channel catfish production and CB hybrid catfish production using select female channel catfish injected with 20 μg/kg - 100 μg/kg LHRHa highlighted the benefits that can be gained from adoption of CB hybrid for commercial culture.

The use of genetically improved strains of female channel catfish results in improved spawning, which contributes to increased production and cost efficiency. Use of select lines of female brood fish along with recommended research cultural practices in commercial production of CB hybrid will create a positive economic impact in the catfish market. This will result in more efficient production that will safeguard individual farmers' enterprise. As for the industry as a whole, production of the CB hybrid catfish will promote competitiveness in the wake of market uncertainties including low prices received by producers, high input prices and prevalence of less expensive imported catfish which takes a fair number of consumers away from the domestic catfish market.

TABLES

Table 4.1 Spawning parameters from using normal[7] and select[8] female channel catfish, *Ictalurus punctatus*, injected with LHRHa at 20 μg/kg priming dose followed by 100 μg/kg resolving dose in the production of eggs for fertilization with blue catfish, *I. furcatus*, sperm to produce hybrid catfish embryos

	Normal	**Select**
Cull Rate (%)	20	0
Ovulation Rate (%)	80	80
Fecundity (# eggs/kg ♀ body weight)	9,130	11,693
Hatch rate (%)	11	24

Table 4.2 Production assumptions for the use of normal[7] and select[8] female channel catfish, *Ictalurus punctatus*, injected with LHRHa at 20 μg/kg priming dose followed by 100 μg/kg resolving dose in the production of eggs for fertilization with blue catfish, *I. furcatus*, sperm to produce hybrid catfish embryos

Parameters	**Normal**	**Select**
Size of Operation (acres)	136	136
Brood fish stocking rate	1,500 lb/ac	1,500 lb/ac
Female brood fish weight (lb)	22,804	13,580
Cull rate	20%	0%
Ovulation rate	80%	80%
Fecundity (eggs/kg ♀ body wt)	9,130	11,693
Hatch Rate	11%	24%
Fry stocking rate	110,000	110,000
Survival Rate (fry to fingerling)	85%	85%
Output		
Fry Production (million)	6.70	13.90
Target Output (million fingerling)	5.69	11.82
Market Price (per fingerling)	$0.1350	$0.1350

[7] randomly bred broodstock
[8] broodstock that have been crossbred or selected for enhanced reproductive performance

Table 4.3 Enterprise budget for the use of normal[7] channel catfish, *Ictalurus punctatus*, female injected with LHRHa at 20 μg/kg priming dose followed by 100 μg/kg resolving dose in the production of eggs for fertilization with blue catfish, *I. furcatus*, sperm to produce hybrid catfish embryos

Size of Operation	**136 acres**	
GROSS RECEIPTS	**Total**	**Per Acre**
Sale of Fingerling (5.70 million @ $0.1350 each)	*$768,825*	*$5,653*
Sale of Culled Female Brood Fish (7,601 lbs @ $0.50 each)	*$3,801*	*$28*
Total Gross Receipts	**$772,626**	**$5,681**
VARIABLE COSTS		
Brood Fish	*$62,236*	*$458*
Hatchery Labor	*$99,062*	*$728*
Contractual Labor	*$36,169*	*$266*
Farm Operation Costs	*$116,470*	*$856*
Hybrid Production Costs	*$21,130*	*$155*
Repairs and Maintenance (Machinery and Equipment)	*$8,950*	*$66*
Interest on Operating Capital	*$23,010*	*$169*
Total Variable Costs (TVC)	**$367,027**	**$2,699**
Income above variable costs	**$405,598**	**$2,982**
FIXED COSTS		
Salaries and Related Expenses	*$115,900*	*$852*
Insurance	*$6,350*	*$47*
Repairs and Maintenance (Ponds and Hatchery)	*$2,500*	*$18*
Interest on Capital Investment	*$136,884*	*$1,007*
Depreciation (building and equipment)	*$138,979*	*$1,022*
Office and Personnel Overhead Costs	*$18,120*	*$133*
Total fixed Costs (TFC)	**$418,733**	**$3,079**
TOTAL EXPENSES (TVC + TFC)	**$785,760**	**$5,778**
Net returns above total expenses	**-$13,134**	**-$97**
Breakeven price to cover variable costs (per fingerling sold)	**$0.064**	
Breakeven price to cover total costs (per fingerling sold)	**$0.138**	

Table 4.4 Partial budget for the use of select[8] in place of normal[7] channel catfish, *Ictalurus punctatus*, female injected with LHRHa at 20 μg/kg priming dose followed by 100 μg/kg resolving dose in the production of eggs for fertilization with blue catfish, *I. furcatus*, sperm to produce hybrid catfish embryos under research conditions

Additional Cost:		*Additional Income:*	
Contractual labor	$38,868		
Fingerling feed	$65,544	Fingerling sale	$826,200
Total Additional Cost	*$104,412*	**Total Additional Income**	*$826,200*
Reduced Income:		*Reduced Cost:*	
		Brood fish	$4,804
		Hatchery labor	$4,617
		Brood fish feed	$4,568
		Hormones and chemicals	$4,580
Brood fish sale	$1,537	Interest	$15,003
Total Reduced Income	*$1,537*	**Total Reduced Cost**	*$33,571*
Total Annual Additional Cash Outflow	**$105,949**	**Total Annual Additional Cash Inflow**	**$859,771**

Net Change in Income	**$753,822**
Net Change in Income per Acre	**$5,543**

Normal operation variable cost (from Table 4.3)	$367,027
Net reduction in variable cost	-$70,841
Select operation variable costs	$437,868

Table 4.5 Partial budget for the use of select[8] channel catfish, *Ictalurus punctatus*, female injected with LHRHa at 20 μg/kg priming dose followed by 100 μg/kg resolving dose in place of normal[7] channel catfish female injected with CPE at 2 mg/kg priming dose followed by 8 mg/kg resolving dose under commercial settings, in the production of eggs for fertilization with blue catfish, *I. furcatus*, sperm to produce hybrid catfish embryos

Additional Cost:		*Additional Income:*	
Contractual labor	$2,591		
Fingerling feed	$4,370	Fingerling sale	$55,080
Total Additional Cost	*$6,961*	**Total Additional Income**	*$55,080*
Reduced Income:		*Reduced Cost:*	
		Brood fish	$163,439
		Hatchery labor	$15,303
		Brood fish feed	$33,352
		Hormones and chemicals	$65,150
Brood fish sale	$11,225	Interest	$19,742
Total Reduced Income	*$11,225*	**Total Reduced Cost**	*$296,986*
Total Annual Additional Cash Outflow	**$18,186**	**Total Annual Additional Cash Inflow**	**$352,066**

Net Change in Income	**$333,881**
Net Change in Income per Acre	**$2,455**

Commercial Normal operation variable cost (from Appendix Table 4.4)	$727,891
Net reduction in variable cost	$290,026
Select operation variable costs	$437,865

Table 4.6 Fry and fingerling variable cost of production for the use of normal[7] channel catfish female injected with CPE at 2 mg/kg priming dose followed by 8 mg/kg resolving dose under commercial settings, vs. select[8] channel catfish, *Ictalurus punctatus*, female injected with LHRHa at 20 μg/kg priming dose followed by 100 μg/kg resolving dose under research settings, in the production of eggs for fertilization with blue catfish, *I. furcatus*, sperm to produce hybrid catfish embryos

Variable Cost Item	**Normal CPE**		**Select LHRHa**		**Cost Reduction**	
	Fry	*Fingerling*	*Fry*	*Fingerling*	*Fry*	*Fingerling*
Brood fish	$220,871		$57,432		$163,439	
Hatchery Labor	$109,744		$94,441		$15,303	
Contractual Labor		$72,446		$75,038		-$2,591
Farm Operation	$28,088	$178,342	$16,972	$160,478	$11,117	$17,863
Hatchery / Hybrid Implement	$81,700		$16,550		$65,150	
Repairs & Maintenance (Machinery & Equipment)	$2,983	$5,967	$2,983	$5,967	$0	$0
Interest on Operating Expenses	$9,250	$18,500	$2,669	$5,338	$6,581	$13,161
Total Variable Cost	**$452,636**	**$275,255**	**$191,047**	**$246,821**	**$261,589**	**$28,434**
Percentage Cost Reduction					**90.20%**	**9.80%**
Number (million)	13.42	11.41	13.9	11.815		
Average weight (g)		30		30		
Total weight (kg)		342,210		354,450		
Cost of production						
each	**$0.034**	**$0.024**	**$0.014**	**$0.021**		
per inch		**$0.0027**		**$0.0035**		
per kg		**$0.804**		**$0.696**		

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CHAPTER 5 - COMPARATIVE RISK ASSESSMENT OF CHANNEL CATFISH (*Ictalurus punctatus*) AND CHANNEL CATFISH FEMALE X BLUE CATFISH (*I. furcatus*) MALE HYBRID (CB HYBRID) EMBRYO PRODUCTION

Abstract

The sensitivity of channel catfish (*Ictalurus punctatus*) fry and fingerling production, and channel catfish female X blue catfish (*I. furcatus*) male hybrid (CB hybrid) fry and fingerling production under commercial (commercial CB hybrid), hormone regimen (CB hybrid CPE and CB hybrid LHRHa), fungal treatment (CB hybrid iodine (CPE) and CB hybrid F+CS (LHRHa)), and female channel catfish line (CB hybrid normal and CB hybrid select) scenarios were compared. A CB hybrid production model that utilizes all the best parameters from each scenario (CB hybrid archetype) was simulated and also compared to channel catfish production. Channel catfish shows fry/kg and cost/fry stochastic dominance over commercial CB hybrid, while commercial CB hybrid dominates channel catfish in cost/fingerling and income. Commercial CB hybrid income is high and stable but it is highly sensitive to risk from variability in hatching rates. Although income from channel catfish production is sufficient to cover operating costs, the operation is unable to recover investment costs over a 20-year planning horizon if a new farm were to be initiated. CB hybrid LHRHa is dominant to channel catfish, commercial CB hybrid, and CB hybrid CPE in terms of fingerling production cost and NPV but channel catfish continues to dominate in fry/kg and cost /fry. By controlling fungus and increasing hatch rates, F+CS (LHRHa) shows 1st degree dominance over iodine (CPE) in all comparisons, and cost/fry and income 1st degree dominance and fry/kg 2nd degree dominance over channel catfish. CB hybrid select dominates channel catfish in fry/kg, cost fingerling and income, but still has higher cost/fry than channel catfish. CB hybrid archetype dominates channel catfish in all comparisons, including fry/kg. When enhancement of the culture organism's reproductive performance reduced the risk from biological factors, output price becomes the main source of risk in the production of CB hybrid catfish.

Introduction

The perceptible reason why the channel catfish (*Ictalurus punctatus*) female x blue catfish (*I. furcatus*) male (CB hybrid) is not widely utilized for commercial production despite its superior characteristics for pond culture is the lack of seed resulting from inconsistent hatching success. However, research on CB hybrid catfish production has shown that hatching success can be high, fry production can be economically efficient, and fingerling production costs are generally below that of the channel catfish. The underlying reason for the low utilization of the CB hybrid could very well be that farmers are risk averse hence production uncertainty deters them from switching from the traditional channel catfish to the CB hybrid catfish.

Risk and Uncertainty in Farm Management Decisions

Every aspect of life involves risk and uncertainty (Knight 1921) and at any given point in time, income from farming is more likely exposed to risk than the income of a salaried employee. To understand the workings of the economic system we must examine the meaning and significance of uncertainty. Farm management, which involves risk and uncertainty, concerns decision making that is consistent with the operator's objectives relating to business success (Olson 2004, James and Eberle 2000), usually measured in terms of profit (Jolly and Clonts 1993). Profit is a return to risk management (James and Eberle 2000), hence farm management does not necessarily have to avoid risk but instead should manage it. Risk management must balance the exposure and tolerance of a farm to risk by taking into consideration the sources of risk, the ability to take risks, and the income potential of different production strategies (Olson 2004).

Farmers make choices based on available information, but changes can occur between the time the decision is made and the time the yield is harvested and sold. The farmer's job is to minimize the effects of outcomes that are unfavorable. Knight (1921) was the first to make a distinction between risk and uncertainty but it was von Mises (1949) who analyzed and classified them in terms of probabilities. In CB hybrid production the probability of unfavorable weather is a source of risk in the artificial fertilization of the channel female catfish. For example, if temperatures remain low until the early part of May, spawning season could be delayed and number of spawning runs can be reduced to two instead of the usual three. Although temperature is a source of risk, long term records that show expected temperature and their probabilities are available to all farmers in this situation. The probabilistic nature of risk factors affecting production results in output variability and uncertainty.

Sources of Risk

Farm management is predisposed to several types and sources of risk, the most obvious of which is production risk. Like any crop and livestock production, CB hybrid catfish production is dependent on biological processes that are subject to weather and diseases. Input and product markets are also a source of risk because price changes are beyond the control of the farmer and they can upset income and expenses of the farm operation. If the level of catfish production for a certain year drops due to hurricane, it is possible that the demand for catfish could drive catfish selling price up, assuming all other things (*e.g.*, consumers' income, complement and substitute products) remain constant. But if in anticipation of low outputs catfish were imported, this would take away the opportunity to sell at higher prices that could have made up for losses due to low output. Financial risks are involved when the farm operation relies on borrowing to meet cash flow needs. Depending on the farm's ability to finance its operation, there is the chance of losing equity if the farm borrows continuously against the same net worth. Institutional risk involves banks and credit availability; government and price support, statutory compliance or import policies; and stakeholders that lobby for health or environmental concerns. The risk due to technological change particularly applies to the use of CB hybrid. Adoption of the CB hybrid could be very expensive but like any new innovation, those who adopt may gain production efficiency and market competitiveness against imports, but they also run the risk that the change will not work at the commercial level. Those who hesitate to adopt may lose the price advantage and, as the catfish industry becomes vulnerable, they eventually run the risk of losing their business.

Risk Analysis

Risk analysis includes both risk assessment and measurement, and response to risk in terms of control and management. Information on factors affecting the farm's operation including the risks associated with these factors are needed for the farm manager to make a decision on how to manage both the factors and the risks associated with them. Risk management incorporates the sources of risk, the operation's ability to take risks, and the income potential of different production strategies (Olson 2004) in the decision process.

Risk analysis is non-trivial (Anderson 2003), and neither are methods for analyzing risk settled (MacCrimmon 1999, Chambers and Quiggin 2000). Commonly used risk measures in field applications are mean-variance analysis, range of observations, and coefficient of variation. The more analytical methods for computing risk involve probability distributions of both inputs and output of the production process. Risk decisions are based on personal preferences that are highly dependent on utility function (Friedman and Savage 1948) and attitude towards risk (Antle 1987). A risk taker will opt for a risky alternative with a high income over a more probable lower income. In contrast, a risk-averse farmer will place his operation in a secure position by choosing an alternative that has a high probability of a positive return even if it were small. In between the risk taker and the risk-averse is the risk-neutral farmer who will select an alternative with the highest expected return and will be indifferent to the level of risk for outcomes that have the same expected returns.

Decision making strategies under risk and uncertainty include marginal gain and loss analysis, where risk is incorporated in marginal utility analysis (Young 1979); payoff matrix which shows the benefit and penalties of choices; decision tree analysis which presents expected values of alternative choices based on the probability of possible outcomes in each choice. Game theory extends beyond the decision of the farmer based on his production operation and includes interactions with other agents (*e.g.*, other farmers, input sellers, output buyers) such that he chooses a strategy to maximize his return given the strategies of other agents (von Neumann and Morgenstern 1944, Dutta 2000). Stochastic dominance has been extensively studied (Whitmore 1970, Meyer 1977, Bawa 1978, Falk and Levy 1989, Anderson 1996, Fong et al. 2005) and seems to be the most widely used strategy for making risky decisions in agriculture (Klemme 1985, Hien et al. 1997, Caballe and Esteban 2006, Urcola HA and Lowenberg-DeBoer J 2007) and aquaculture (Tveteras 1999) as well.

James and Eberle (2000) explained the interpretation of stochastic dominance when comparing cumulative probability distributions of alternative actions, under the assumption that more is better than less. In Figure 5.1, cumulative probability is plotted on the vertical axis and uncertain outcome (*e.g.*, income) on the horizontal axis. The probability density function of alternative A lies to the left of both B and C at all income levels, which shows that B and C are dominant to the 1st degree over A at all income levels. However, it is not so clear whether B is better than C because their income levels cross at some probability level greater than zero. Note that B is better than C at lower probabilities, but the reverse is true at higher probabilities. The area between the two curves determines which of the two alternatives is better: if the area in which B dominates is greater than the area in which C dominates then the expected income of B is greater than the expected income of C. In this case, individuals who are risk averse will prefer B over C. This type of preference is called 2^{nd} degree stochastic dominance which assumes that the decision maker is risk averse. If the opposite is true about the area between the two curves, the choice of risk-averse individuals would depend on how they weigh the trade-off between higher income with C and less risk with B.

Stochastic dominance comparison will be used in this study to compare income as well as other measures of production efficiency. Using the example in Figure 5.1, B is said to be dominant to A for desirable variables such as net returns, income above variable costs, and physical productivity measures. Conversely, A is said to be dominant to B for unfavorable variables such as cost of producing a unit of output.

In risk analysis models, variability of the output is expressed in terms of the risk associated with the inputs, the variables in the models that influence the level of output. The inputs are expressed as probability distributions, such that if an input is desirable, the risk associated with it is equal to its probability of non-occurrence. Probabilistic observations from the input distributions are used to generate the output of the model, which can then be likewise expressed as a probability distribution. A probability distribution function of a variable is generated by computing the relative likelihood of every possible value the variable can take. When all the possible values are known the resulting probability function is objective because it has been theoretically established from observed historical data. In reality, not all values of a variable are known. In the absence of a large number of observations, subjective probabilities (Anscombe and Aumann 1963, von Neumann and Morgenstern 1944, Kadane and Larkey 1982, Machina and Schmeidler. 1992) based on expert opinion may be used (Mosleh et al. 1987, Cooke 1991, Clemen and Winkler 1999, O' Hagan 2005) to simulate probability distribution functions.

This study will use risk and sensitivity analysis to evaluate channel catfish and CB hybrid catfish. The objectives of this chapter are to compare the riskiness of fry and fingerling productions of channel catfish and CB hybrid catfish operations, and to determine the sensitivity of these operations to production and market factors.

Materials and Methods

This analysis relies heavily on economic analysis results from preceding chapters. The economic analysis of ovulating agents compared the use of carp pituitary extract (CPE), the ovulating agent used in commercial operations in the production of CB hybrid to luteinizing hormone releasing hormone analogue (LHRHa), the most promising hormone for hand stripped hybrid catfish embryo production based on hatch rate, fry per kg of female body weight and ovulation rate (Kristanto 2004). Iodine, used under commercial settings to control fungal incidence, and formalin alternated with copper sulfate (F+CS), the recommended chemical disinfectant that results in at least 2 to 4 times higher hatch rates than the standard commercial iodine treatments (Dunham, personal communication), were compared for their economic performance. Economic comparison for genetics was between AU-7 representing randomly bred female channel catfish (normal) and AU-13 representing a select line of female (select) that exhibit improved reproductive performance including lower cull rate, and higher spawning percentage and fecundity when producing CB hybrid embryos (Ballenger 2007). In all cases, CB hybrid production was compared to channel catfish production.

Most of the risk variables defined for CB hybrid production do not have long term historical data for which objective probability distributions can be constructed. In some cases, there are experimental data for which statistical measures are available so that probability distributions can be generated through simulation using the mean and standard deviation of the sample. Still, in other cases, there are not enough observations to warrant the computation of variance but the range of observations shows some minimum and maximum values. In this case, subjective probability distributions can be constructed based on expert opinion.

Assumptions

Economic analyses using enterprise budgets and partial budgets compared the profitability of different catfish production scenarios. Table 5.1 shows variables and their values for different production scenarios analyzed. Commercial scenarios compared were the traditional channel catfish and commercial CB hybrid production. All research scenarios were on CB hybrid production, and scenarios were divided into hormone, fungal control and genetics. Except for iodine fungal control using CPE as ovulating agent (iodine (CPE)) and genetics using randomly bred female channel catfish (normal), all research CB hybrid scenarios performed better than the traditional channel catfish and commercial CB hybrid productions. Iodine (CPE) and normal were only used as a basis for comparison to evaluate improvements in CB hybrid protocol from the use of F+CS and a select line of female channel catfish, respectively.

The production output and income measures shown in Table 5.1 were based on production parameters obtained from representative commercial farms and a limited number of experimental data, and on average fingerling prices for channel and CB hybrid catfish. These point estimates of output are specific to the parameters used and do not include the risk associated with, for example, hatching success, which can be high or low and not fixed at the values shown in Table 5.1. Probability distributions for prices and production parameters (model inputs) will be generated. These input probability distributions will be sampled to generate the probability distribution of the production outputs and income (model outputs).

Procedures

Risks associated with different catfish production scenarios will be estimated using @Risk (Palisade 2005). Values for both the input and output variables will be simulated to support probability distribution estimation. Latin hypercube is the sampling method of choice. This technique forces samples drawn to correspond more closely with the input distribution hence it requires fewer samples and converges faster on the true statistics of the input distribution.

Table 5.2 shows the built in @Risk distributions and distribution parameters that are used for each input. Scenarios are classified into general scenarios and specific scenarios. The general scenarios are commercial, CB hormone research (hormone), CB fungal control research (fungus), and CB genetics research (genetics). Under commercial, the specific scenarios are traditional channel catfish production (channel) and commercial CB hybrid catfish production (commercial CB); under hormone are CB hybrid productions using CPE and LHRHa; under fungus are productions using F+CS with CPE or LHRHa as ovulating agents, F+CS (CPE) and F+CS (LHRHa) respectively; and under genetics are normal and select. Risk analysis will be performed for scenarios that showed initial evidence of improvement over commercial CB based on economic results shown in Table 5.1. The first step to this risk analysis is to evaluate risk for each scenario and compare specific scenarios within the general scenarios, for example, 1st step comparison will compare channel catfish to commercial CB hybrid under commercial, CPE CB hybrid to LHRHa CB hybrid under hormone, and so on, using stochastic dominance as the criterion for choosing between alternative production scenarios. The second step is to compare the scenario that is superior within a general research category to channel to evaluate the risk and benefits involved, if any, if one were to switch from the traditional production and use the protocol for the CB hybrid scenario being compared. For example, if CPE CB hybrid were the dominant specific scenario under hormone, it will be compared to channel catfish under commercial to evaluate the risk and benefits from switching to CPE CB hybrid. The third and final step is to simulate a production scenario that will incorporate all improvements in the CB hybrid production protocol (archetype model) arising from hormone, fungal control and genetics. The archetype model will combine the best of the distribution parameters for hormone, fungal control, and genetics and use those best parameters in concert. This will measure the risk reduction to the CB hybrid protocol and show the benefits from biotechnological improvement in CB hybrid research.

The economic production model used to generate results shown in Table 5.1 will be used to simulate values for both the input and output variables. The input variables are defined as stochastic cells in the model using the function arguments specified in Table 5.2. This risk analysis hypothesizes that the economic results shown in Table 5.1 will prevail in repeated applications of the CB hybrid protocol, subject to the risk posed by the input variables. To generate probability distributions which will be used to establish stochastic dominance 10,000 iterations of the model are executed using Latin hypercube sampling.

Results and Discussion

Commercial production of CB hybrid catfish was compared to the traditional commercial production of channel catfish using stochastic dominance as criterion for ascertaining net returns superiority between the two operations. Sensitivity analysis was presented using standardized regression coefficients to determine sensitivity of net returns to risk variables represented by the factors of production.

Comparative Risk Assessment of the CB Hybrid to the Channel Catfish under Commercial Settings

Channel catfish fry production showed stochastic dominance over CB hybrid production for probabilities less than 80%, the area where production is between 9 million and 20 million fry (Figure 5.2). The histograms (Figure 5.3) show that CB hybrid fry production has more variability, showing a 2% chance of getting fry less than 9 million, but also a 16% chance of getting more fry than channel when fry production exceeds 20 million. Simulated fry production ranged from 9 million to 20 million with a mean of 18 million for the channel, and 7 to 21 million with a mean of 16 million fry for the hybrid.

The productivity of female brood fish is expressed in terms of fry per kilogram (fry/kg) of female body weight. The fry/kg production distributions (Figure 5.4) show that channel catfish production is higher at all levels of probability than the CB hybrid. As shown by Figure 5.2 the channel was superior to the CB hybrid in terms of total fry production, but by less than an order of magnitude. Even at the point where the distance between the two cumulative probability distributions was widest, channel catfish fry production was less than twice as much as the CB hybrid, while fry/kg could be more than 10 times greater for the channel than the CB hybrid. This is due to the much lower production parameters of the CB hybrid.

For an equal level of fry production, the CB hybrid will need a much higher number of females to compensate for the low spawning rate, fecundity and hatch rate. As a consequence, the high production cost and low number of CB hybrid fry result in a very high fry per unit cost. Channel catfish fry production cost dominates that of CB hybrid. The tight cumulative probability distribution for the cost of producing channel catfish fry (Figure 5.5) shows that cost is low and very stable with a 95% probability that fry per unit cost will fall between \$0.006 and \$0.013. The fry production cost for the CB hybrid is high and very volatile, showing a 95% probability that cost can go from \$0.02 to \$0.07 per fry, with a 5% chance that it could be as low as \$0.011 or as high as \$0.14.

Whereas fry production suffers from unfavorable spawning parameters, fingerling production benefits from the desirable culture characteristics of the CB hybrid catfish. Despite the low fry production relative to the channel catfish, CB hybrid production surpasses the channel catfish performance at the fingerling stage. Figure 5.6 shows that CB hybrid is dominant to channel catfish at all probability levels of fingerling production. Due to the CB hybrid's faster growth, and higher resistance to diseases and tolerance of low dissolved oxygen, it has a higher chance for survival beyond the fry stage than the channel catfish. Consequently, CB hybrid per unit cost of fingerling production dominates that of channel catfish as shown by Figure 5.7, in which cost of producing CB hybrid fingerlings is always less than that of channel catfish. The narrow spread of CB hybrid fingerling costs ($\sigma = 0.006$) limits cost values between \$0.024 and \$0.054 while the channel catfish fingerling costs lie between \$0.019 and \$0.105, with a greater variability of $\sigma = 0.011$.

The bottom line for any farm production activity is the net income that the enterprise generates. The cumulative probability distribution of net present value (NPV) of net returns to CB hybrid dominates that of channel catfish at all probability levels (Figure 5.8). Additionally, there is a relatively small (11%) probability that the CB hybrid will get negative net returns while there is a considerable 85% chance for the channel catfish net returns dropping below zero. Computation of net returns was based on capital budgeting, which uses start up costs in today's prices and net cash flows for a 20-year planning horizon discounted at 10%. This implies that if a farmer were to start a catfish farm now, it will be safer and more profitable for him to invest in the CB hybrid. The biggest burden for the channel catfish enterprise is the inability to recover initial investments. Nonetheless, today's channel catfish farmers survive because existing farms have been established in the past when investment costs were much lower than what it would be to start a farm at this present time. To account for the continued farming of channel catfish Figure 5.9 shows that 87% of the time income above variable costs is positive for the channel catfish. As could already be surmised based on the net returns comparison, CB hybrid per acre income above variable costs dominates that of the channel catfish.

Part of the risk analysis is to examine the sensitivity of income to the factors of production. Sensitivity of NPV to factors of production is analyzed using the regression sensitivity analysis provided by @Risk, which uses standardized regression coefficients. Determination of relative importance of explanatory variables is facilitated with the use of standardized coefficients because comparison of standardized coefficients will be similar to comparing *t* values (Bring 1994). Use of standardized coefficients eliminates problems encountered when variables are measured in different units or different scales. Figure 5.10 shows that survival rate has the biggest influence on channel catfish's income due to the channel catfish's vulnerability to diseases while hatch rate is the most significant factor affecting the profitability of the CB hybrid as hatching success is a major determinant of fry supply for fingerling and food fish grow out. Fingerling price is significant to both, more so for the CB hybrid than the channel. The channel catfish operation depends on fecundity for fry. The large quantities of eggs are an advantage to the channel catfish fry production, thus hatch rate is not as critical for the channel as it is for the CB hybrid. Knowing the sensitivity of output to risk variables to which they are exposed helps set some guidelines on setting research priorities.

In summary, CB hybrid fry production shows a higher risk compared to the traditional channel catfish fry production based on fry/kg and per unit cost of fry production. In contrast to fry production, CB hybrid fingerling production showed stochastic dominance at all levels of production, and showed very small variability in per unit cost compared to the channel catfish operation. Existing channel catfish farms continue to survive and cover operating costs, but initiating a catfish farm given today's building material costs, labor costs, and market conditions will take more than 20 years before investment costs are recovered. Low fingerling production costs already bring about a higher NPV for the CB hybrid. Improved hatch rates will ensure stable fry production and reduce risk involved in the commercial use of CB hybrid catfish.

Risk Assessment of CB Hybrid Catfish Production Using CPE as Ovulating Agent Compared to CB Hybrid Catfish Production Using LHRHa as Ovulating Agent

LHRHa is the most promising hormone for hand stripped hybrid catfish fry production based on hatch rate, fry per kg of female body weight and ovulation rate. As shown by the number of fry per kilogram of female body weight (Figure 5.11), CB hybrid catfish production that used LHRHa as ovulating agent (CB hybrid LHRHa) is dominant at all probability levels to CB hybrid production that used CPE (CB hybrid CPE). Comparison of cumulative probability distributions for CB hybrid LHRHa and channel catfish production, however, shows that channel catfish is still dominant to CB hybrid LHRHa in terms of fry/kg for probabilities less than 73% where production is less than 2,800 fry per kilogram of female body weight and, overall, the area in which channel catfish dominates CB hybrid LHRHa is bigger than the area in which CB hybrid LHRHa dominates channel catfish. Fry/kg in excess of 2,800, where CB hybrid LHRHa produces more fry/kg than channel catfish, translates to 13% probability of CB hybrid LHRHa producing fry at a lower cost than the channel catfish. Overall, however, cost per fry for the channel catfish is dominant to CB hybrid LHRHa (Figure 5.12).

CB hybrid LHRHa fingerling cost dominates the channel catfish due to the hybrid's higher resistance to diseases and faster growth rate (Figure 5.13). LHRHa as ovulating agent improves CB hybrid fry production and reduces production cost; therefore net returns are higher for CB hybrid LHRHa due to improvements in hatch rate, fry per kg of female body weight and ovulation rate. NPV of net returns shows stochastic dominance of CB hybrid LHRHa over that of CB hybrid CPE with net returns ranging from $1.48 million to $15.49 million for CB hybrid LHRHa, and -$1.79 million to $13.92 million with one tenth of 1% chance of a negative return for CB hybrid CPE (Figure 5.14). NPV for CB hybrid LHRHa is evidently dominant and can be up 6 to 8 times greater than the channel catfish's over the range of NPV values and at all levels of probability.

Research protocols for use of LHRHa improve the economic performance of CB hybrid catfish. Fry production cost is less variable for CB hybrid LHRHa than commercial CB hybrid. Although cost of producing fry remains lower for channel catfish than CB hybrid, the gap between channel catfish and CB hybrid fry costs decreased dramatically. Under commercial settings, CB hybrid fingerling production cost shows less variability over the range of values than channel catfish, but CB hybrid LHRHa shows even lower variability and dominance over both commercial CB hybrid and channel catfish. CB hybrid LHRHa income is even more attractive than that of channel catfish as shown by the 1st degree dominance of the NPV.

Risk Assessment of Antifungal Agents used in the Production of CB Hybrid Catfish Fry

Formalin alternated with copper sulfate (F+CS) is the recommended therapeutant for controlling fungal incidence in CB hybrid catfish eggs. It is more effective than iodine, and formalin or copper sulfate used on its own. When used in combination with LHRHa as ovulating agent (F+CS (LHRHa)), hatching success of CB hybrid catfish eggs improves remarkably. To substantiate these statements, F+CS (LHRHa) fry/kg (Figure 5.15) shows 1st degree stochastic dominance over iodine when CPE is used as ovulating agent (iodine (CPE)), and the area in which it dominates channel catfish is much larger than the area in which channel catfish dominates.

The biggest disadvantage of CB hybrid catfish production is the vulnerability of eggs to fungus. Use of an effective antifungal agent improves CB hybrid catfish hatching success. The improvement in hatch rates due to F+CS resulted in lower fry production cost for CB hybrid F+CS (LHRHa) than channel catfish (Figure 5.16). NPV for CB hybrid has consistently been superior to that of channel catfish mainly due to its robustness as a culture organism. Figure 5.17 shows 1st degree dominance of both CB hybrid F+CS (LHRHa) and CB hybrid iodine (CPE) over channel catfish NPV, with CB hybrid F+CS (LHRHa) being dominant to both.

Risk Assessment of a Select Line of Female Channel Catfish Used in the Production of CB Hybrid (Select CB Hybrid) Catfish Embryo

Not all female channel catfish are equivalent reproductively. Some are products of long term selection to improve reproductive performance. AU-13 is a line of female channel catfish that has been selected for reproductive traits, exhibiting lower cull rate, and higher spawning percentage and fecundity when used in the production of CB hybrid catfish embryos. Select CB hybrid fry/kg production is 1st degree dominant to that of commercial CB hybrid (Figure 5.18). Stochastic dominance is not as straight forward between channel catfish and select CB hybrid fry/kg productions. Measurement of the area between the two curves confirms that the area in which select CB hybrid dominates is greater than the area in which channel catfish dominates.

Although there is a small probability (11%) that select CB hybrid will be able to produce fry at a lower cost, overall, channel catfish still has lower cost of fry production than select CB hybrid (Figure 5.19). Select CB hybrid is more dominant in terms of fry/kg production but total fry production is still not enough to compensate for the high costs incurred to produce CB hybrid fry. The stochastic dominance of select CB hybrid NPV over channel catfish (Figure 5.20) mainly comes from the fry to fingerling phase of the CB hybrid. Although use of select female channel catfish is an improvement to using randomly bred females, hatch rates remain to be the limiting factor in the stable production of CB hybrid catfish fry.

Risk Assessment of CB Hybrid Catfish Embryo Production Using Recommended Research Protocols

The majority of the scenarios presented above showed that embryo production is the biggest hurdle in CB hybrid catfish production. Net returns from CB hybrid catfish are always higher than that from channel catfish because of the hybrid's superior characteristics as a culture organism. However, lack of CB hybrid fry for fingerling and food fish grow out remains an issue.

LHRHa, F+CS, and select line of female channel catfish contribute to improved production of CB hybrid fry. Cultural practices observed under research conditions such as lower brood fish stocking rate also increase productivity of the female channel catfish. LHRHa is an improvement over CPE as an ovulating agent but fry production remains inferior to channel catfish as shown by lower fry/kg and higher cost/fry. Select female line showed 2nd degree stochastic dominance in terms of fry/kg but channel catfish continues to be superior in terms of cost/fry. F+CS (LHRHa) CB hybrid showed 2nd degree stochastic dominance in terms of fry/kg and 1st degree stochastic dominance in terms of cost/fry.

Combining all procedures and recommended protocols for hormone, fungal control, and female brood fish strain and handling increases the CB hybrid's overall economic performance. A CB hybrid production model that utilizes all the best parameters from each scenario (CB hybrid archetype) was simulated and compared to the traditional channel catfish production. The CB hybrid archetype dominates channel catfish in all comparisons (Figures 5.21 to 5.24).

Results of sensitivity analysis of NPV to factors of production for the CB hybrid archetype are shown in Figure 5.10. Incorporating all the recommended procedures for CB hybrid production eliminates physical production parameters as limiting factors to income. Fingerling price, which is a function of market forces and beyond the farmer's control, now becomes the biggest source of risk and the major determinant of income. The current market situations support this analysis, as farmers continue to face market volatility due to import volumes and fluctuating selling prices.

Conclusion and Recommendation

The analysis confirmed the superiority of the CB hybrid over channel catfish as a culture organism, as shown by the physical production and economic performance of the CB hybrid fingerling. The minimal risk observed once the CB hybrid has reached the fry stage is an indication that the CB hybrid can improve the viability and sustainability of the catfish industry. Hatching success drives the CB hybrid's economic output, and despite the apparent risk due to hatch rate variability, the CB hybrid still dominates the channel catfish in economic performance. Continued improvement of the current available protocol for producing CB hybrid fry will further reduce risk and increase fry production stability. If production procedures incorporate the best recommended practices for CB hybrid protocol, source of risk shifts from the physical and biological processes, and becomes directed to market situations.

The catfish industry in the southern United States continues to survive, but future growth as the industry stands now will not be as dramatic as it was in the past. Diseases and water quality issues continue to be a problem. Massive quantities of fish are lost to diseases. Drugs and therapeutants need to be approved before they can be used in production of fish for human consumption and to date, farmers do not have adequate drugs to counter problems posed by diseases. In the face of environmental concerns, water quality treatment of effluents can be an issue. Internalizing costs of environmental pollution by treating discharge from production processes can be a tremendous addition to production costs. All these problems along with increasing feed costs, high labor costs, and large volumes of imported catfish continue to threaten income of catfish farmers. In the long run, improvements in production efficiency are the only way to safeguard the viability and sustainability of the catfish industry. The CB hybrid may not be a panacea but it is certainly an improvement over the traditional culture species channel catfish.

TABLES

Table 5.1 Production parameters, output, costs and income from different production scenarios using channel catfish for the commercial channel scenario, and channel female x blue male catfish for all CB hybrid scenarios

	Commercial		CB Hormone Research		CB Fungal Control Research			CB Genetics Research	
	Channel	CB Hybrid	CPE	LHRHa	Iodine (CPE)	F+CS (CPE)	F+CS (LHRHa)	Normal	Select
Production Parameters									
Cull rate (%)	-	25	20	20	20	20	20	20	0
Ovulation rate (%)	-	64	70	100	70	70	85	80	80
Spawning rate (%)	50	-	-	-	-	-	-	-	-
Fecundity (# eggs/kg ♀)	8,380	3,800	8,900	10,000	8,900	8,900	10,000	9,130	11,693
Hatch rate (%)	50	20	25	38	16	35	55	11	24
Survival rate (%)	60	85	85	85	85	85	85	85	85
Production output									
Fry/kg	2,100	365	1,246	3,044	797	1,740	3,741	646	2,252
Fry (million)	12.75	13.42	13.09	14.1	9.69	13.6	14.3	6.7	13.9
Fingerling (million)	7.65	11.41	11.13	11.99	8.24	11.56	12.16	5.70	11.82
Cost of Production									
Per fry	$0.008	$0.034	$0.015	$0.009	$0.024	$0.011	$0.007	$0.032	$0.014
Per fingerling	$0.029	$0.024	$0.022	$0.020	$0.024	$0.021	$0.020	$0.027	$0.021
Per inch of fingerling	$0.0050	$0.0040	$0.0036	$0.0034	$0.0040	$0.0035	$0.0034	$0.0045	$0.0035
Per kg of fingerling	$0.952	$0.804	$0.718	$0.682	$0.799	$0.699	$0.673	$0.910	$0.696
Fingerling selling price	0.084	0.1350	0.1350	0.1350	0.1350	0.1350	0.1350	0.1350	0.1350
Income Measures									
Net Returns	-$1,084,697	$2,460,815	$3,455,703	$4,464,043	$1,166,480	$4,018,643	$4,935,878	-$764,460	$4,021,100
Above VC (per acre)	$2,384	$6,070	$7,834	$9,195	$5,036	$8,575	$9,549	$2,982	$8,525
Above TC (per acre)	-$359	$2,956	$4,849	$6,263	$1,986	$5,620	$6,808	-$97	$5,557

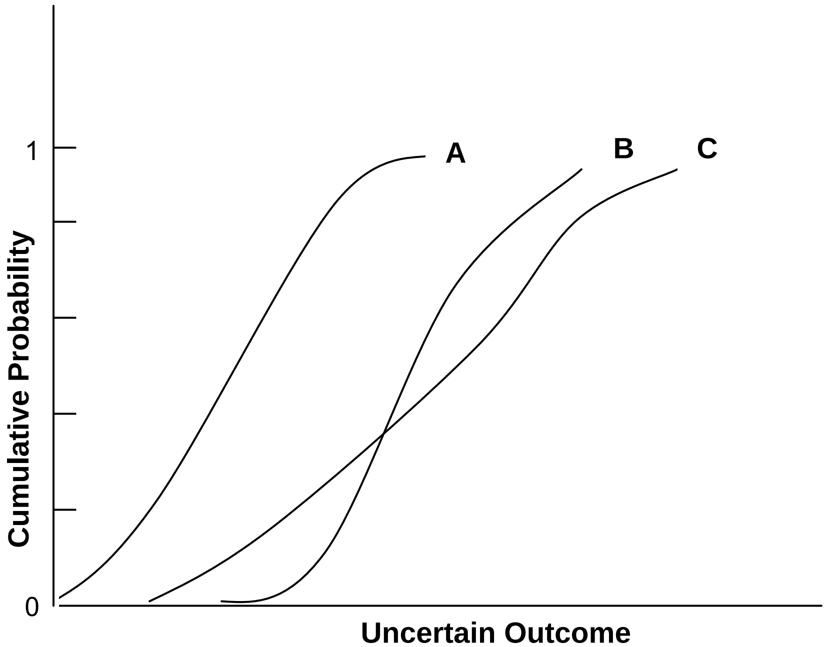
Table 5.2 Distribution functions and function arguments defined for model input parameters

	Commercial		Hormone	
	Channel	CB Hybrid	CPE	LHRHa
Parameters				
Cull rate	-	RiskTriang(10, 25, 50)	RiskTriang(10, 20, 40)	RiskTriang(10, 20, 40)
Ovulation rate	-	RiskTriang(40, 64, 85)	RiskTriang(45, 70, 90)	RiskNormal(85, 31, RiskTruncate(50,100))
Spawning rate	RiskTriang(40, 50, 70)	-	-	-
Fecundity	RiskTriang(6000, 8380, 12000)	RiskTriang(2000, 3800, 6500)	RiskTriang(3560, 8900, 10000)	RiskNormal(10000, 607, RiskTruncate(8000, 14000))
Hatch rate	RiskTriang(45, 55, 80)	RiskTriang(10, 20, 38)	RiskTriang(10, 25, 45)	RiskNormal(38, 11.6, RiskTruncate(23, 75))
Survival rate	RiskTriang(20, 50, 80)	RiskTriang(75, 85, 90)	RiskTriang(75, 85, 90)	RiskTriang(75, 85, 90)
Price per inch	RiskTriang(0.010, 0.014, 0.015)	RiskTriang(0.015, 0.0225, 0.030)	RiskTriang(0.015, 0.0225, 0.030)	RiskTriang(0.015, 0.0225, 0.030)

	Fungus		Genetics	Archetype
	F+CS (CPE)	F+CS (LHRHa)	Select	
Parameters				
Cull rate	RiskTriang(10, 20, 40)	RiskTriang(10, 20, 40)	RiskTriang(0, 20, 20)	RiskTriang(0, 20, 20)
Ovulation rate	RiskTriang(45, 70, 90)	RiskNormal(85, 31, RiskTruncate(50,100))	RiskTriang(60, 80, 100)	RiskTriang(60, 85, 100)
Spawning rate	-	-	-	-
Fecundity	RiskTriang(3560, 8900, 10000)	RiskNormal(10000, 607, RiskTruncate(8000, 14000))	RiskTriang(60, 80, 100)	RiskTriang(60, 80, 100)
Hatch rate	RiskTriang(10, 35, 55)	RiskTriang(23, 55, 75)	RiskNormal(24, 23, RiskTruncate(15, 70))	RiskTriang(23, 55, 75)
Survival rate	RiskTriang(75, 85, 90)	RiskTriang(75, 85, 90)	RiskTriang(75, 85, 90)	RiskTriang(75, 85, 90)
Price per inch	RiskTriang(0.015, 0.0225, 0.030)	RiskTriang(0.015, 0.0225, 0.030)	RiskTriang(0.015, 0.0225, 0.030)	RiskTriang(0.015, 0.0225, 0.030)

FIGURES

Figure 5.1 Illustration of Stochastic Dominance in comparing alternative choices



Source: James and Eberle 2000

Figure 5.2 Cumulative probability distributions of channel catfish and commercial CB hybrid catfish fry production

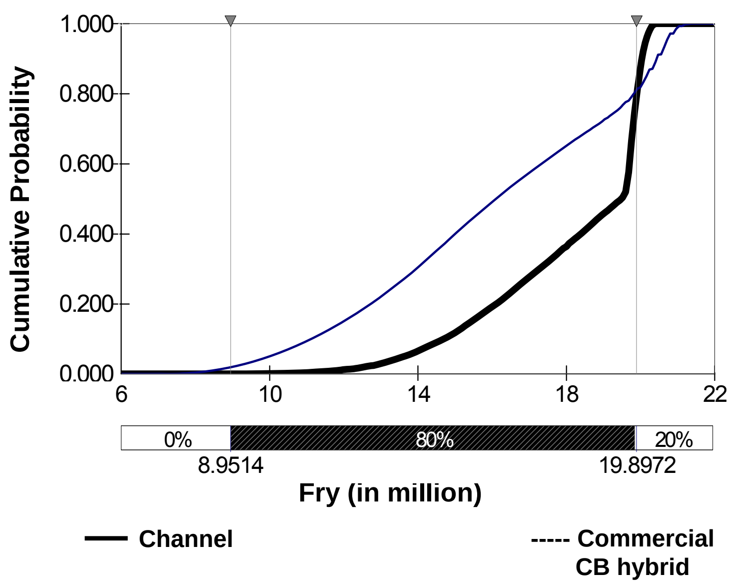


Figure 5.3 Relative frequency distribution of channel catfish and commercial CB hybrid catfish fry production

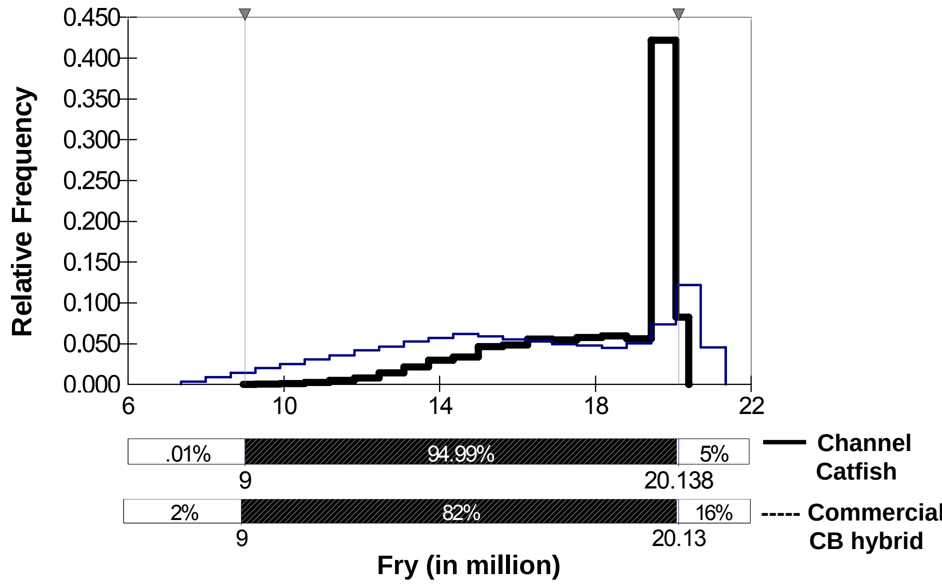


Figure 5.4 Cumulative probability distributions of channel catfish and commercial CB hybrid catfish production of fry per kilogram (fry/kg) of female channel catfish body weight

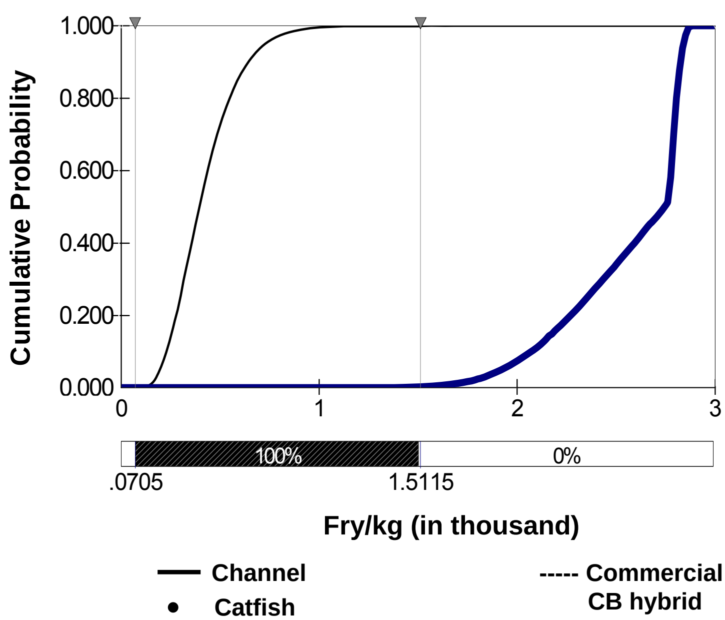


Figure 5.5 Cumulative probability distributions of per unit cost of fry production (cost/fry) for channel catfish and commercial CB hybrid catfish

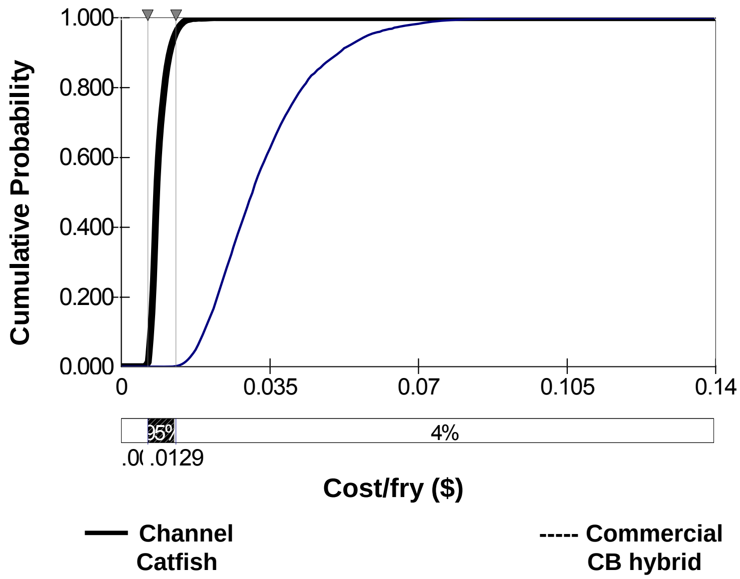


Figure 5.6 Cumulative probability distributions of channel catfish and commercial CB hybrid catfish fingerling production

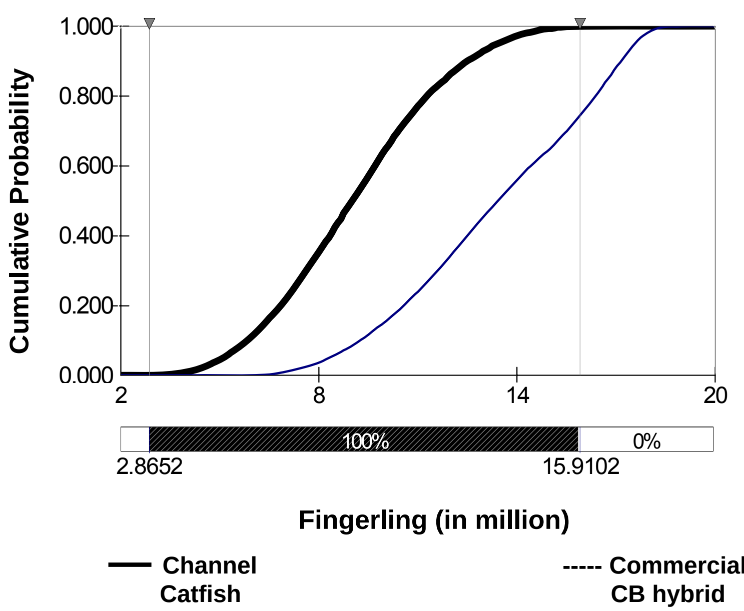


Figure 5.7 Cumulative probability distributions of the per unit cost of fingerling production (cost/fingerling), net of fry cost, for channel catfish and commercial CB hybrid catfish

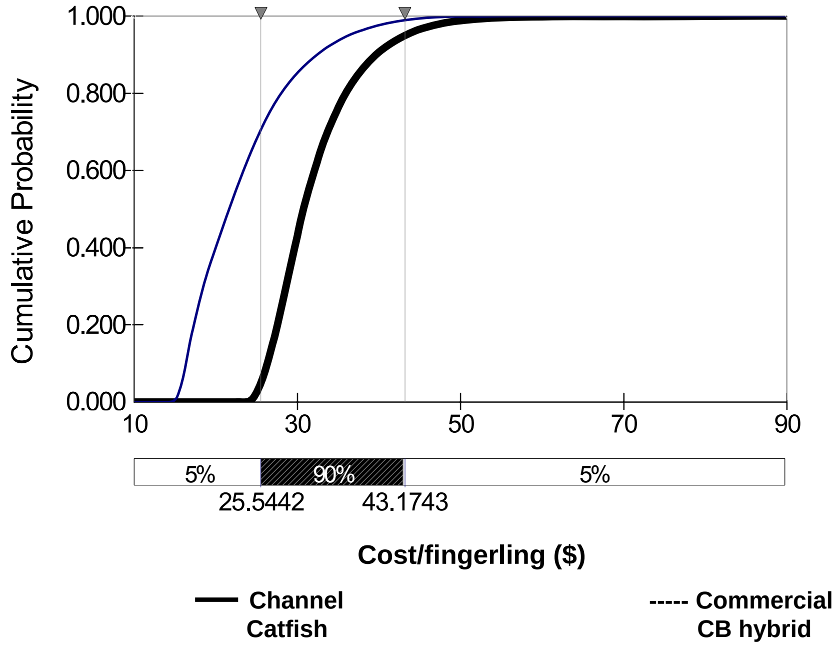


Figure 5.8 Cumulative probability distributions of the net present value of net returns (NPV), over a 20-year planning horizon discounted at 10%, for channel catfish and commercial CB hybrid catfish

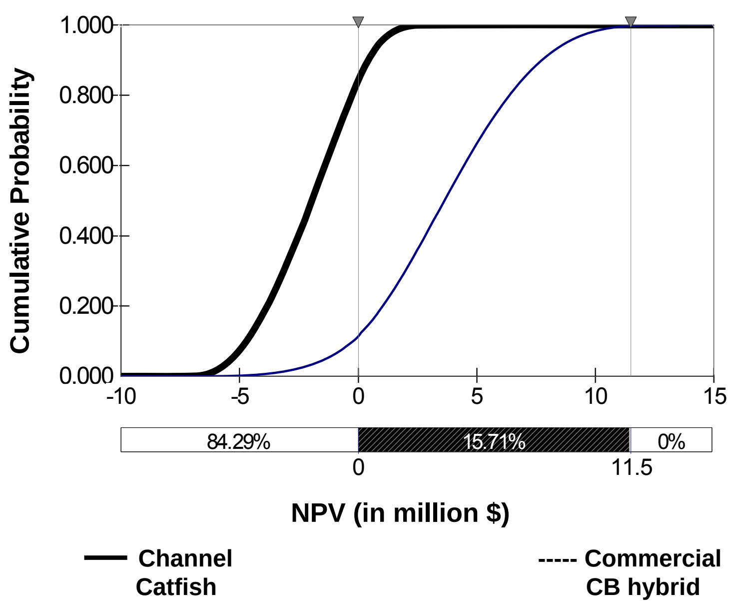


Figure 5.9 Cumulative probability distributions of income above variable costs (IVC) for channel catfish and commercial CB hybrid catfish

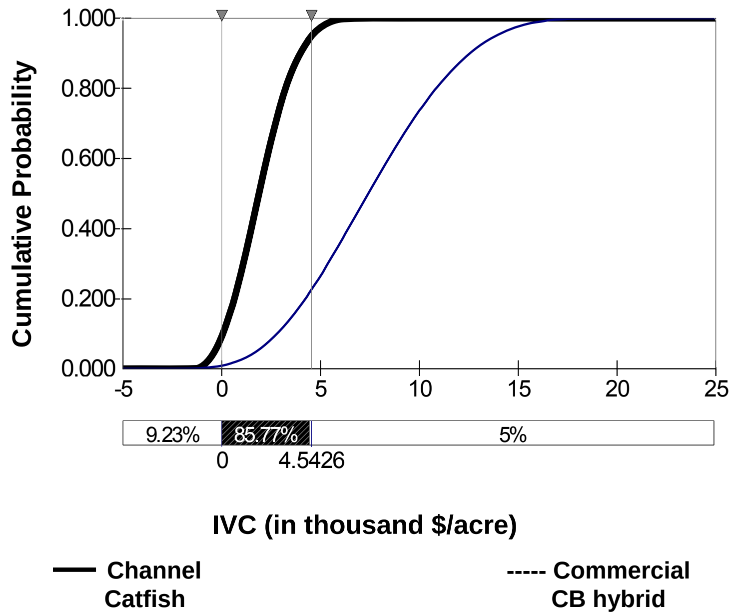


Figure 5.10 Regression sensitivity to risk variables in the economic production model of net present value of net returns for channel catfish and commercial CB hybrid catfish

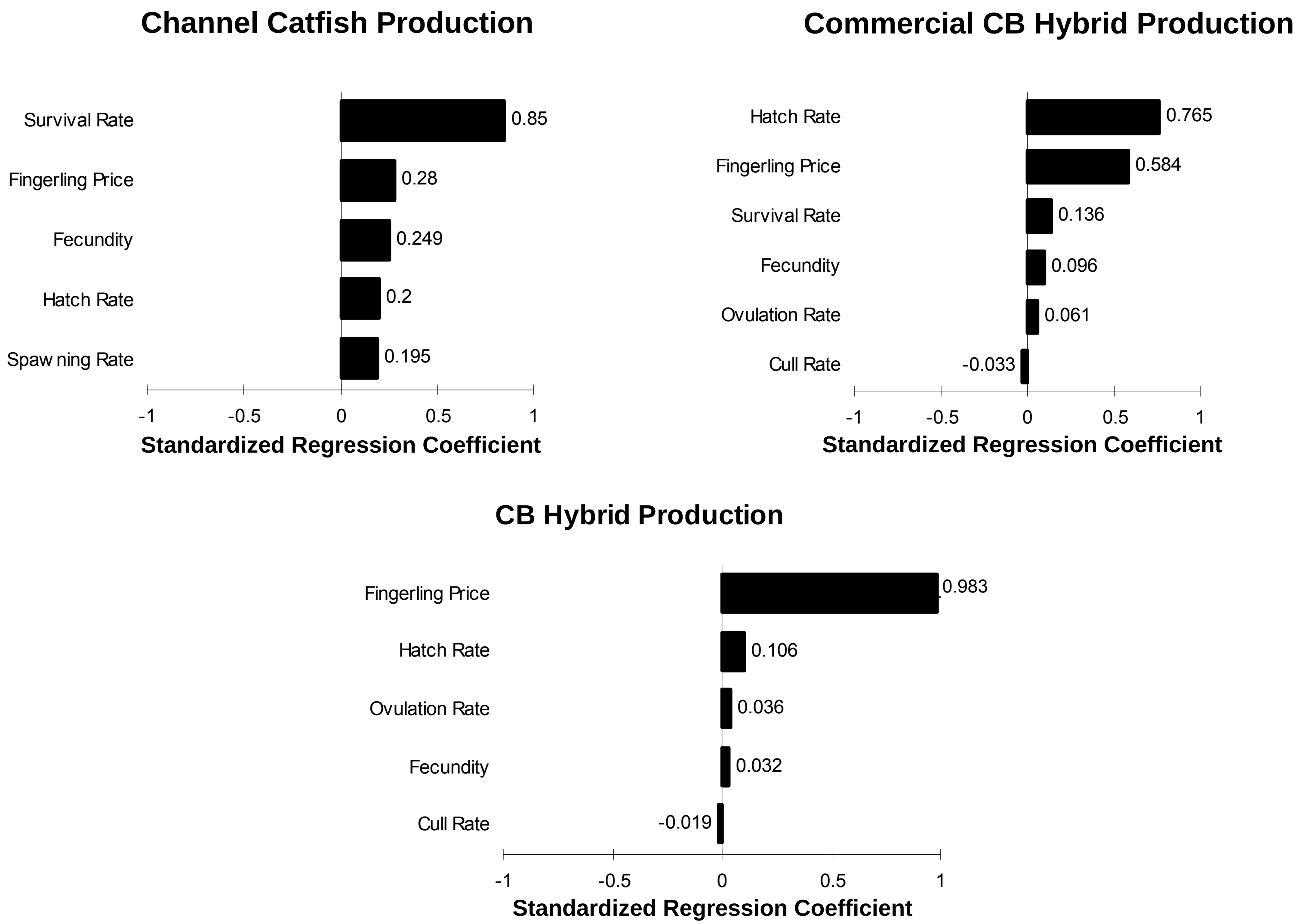


Figure 5.11 Cumulative probability distributions of channel catfish, CB hybrid CPE and CB hybrid LHRHa production of fry per kilogram (fry/kg) of female channel catfish body weight

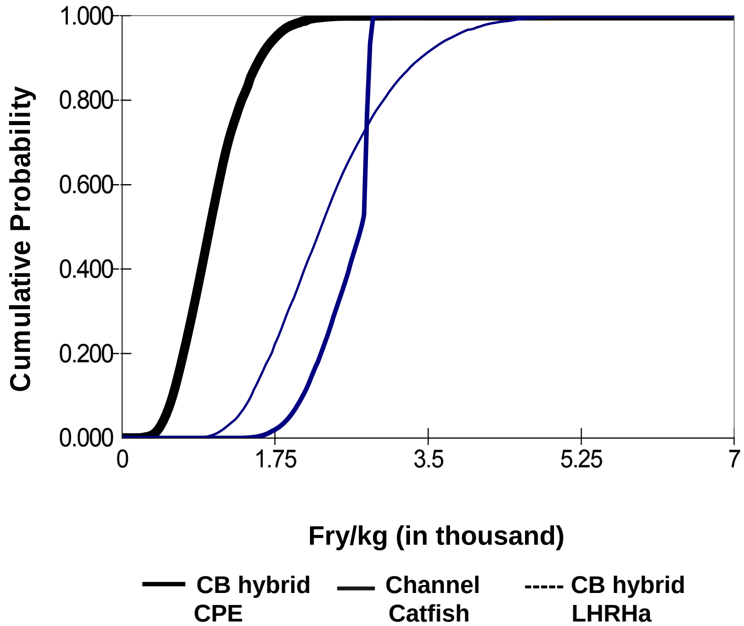


Figure 5.12 Cumulative probability distributions of per unit cost of fry production (cost/fry) for channel catfish and CB hybrid LHRHa

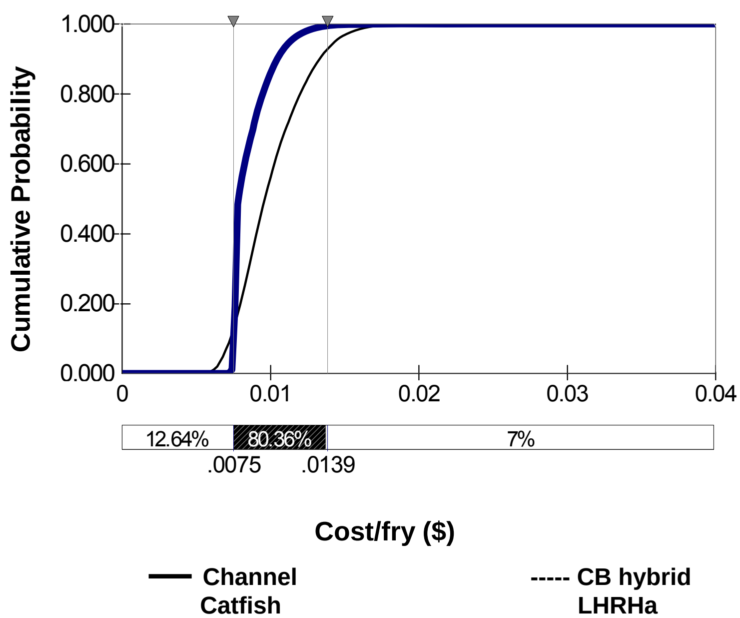


Figure 5.13 Cumulative probability distributions of the per unit cost of fingerling production (cost/fingerling), net of fry cost, for channel catfish, CB hybrid CPE, and CB hybrid LHRHa

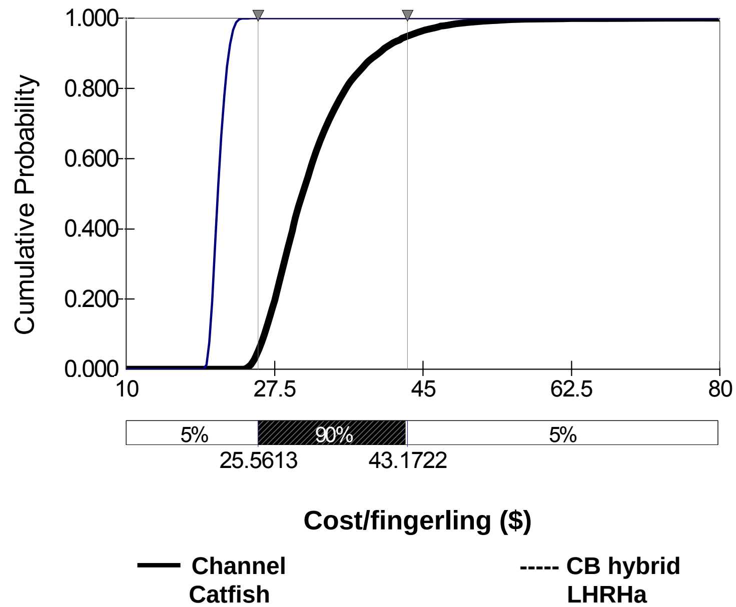


Figure 5.14 Cumulative probability distributions of the net present value of net returns (NPV), over a 10-year planning horizon discounted at 10%, for channel catfish, CB hybrid CPE, and CB hybrid LHRHa

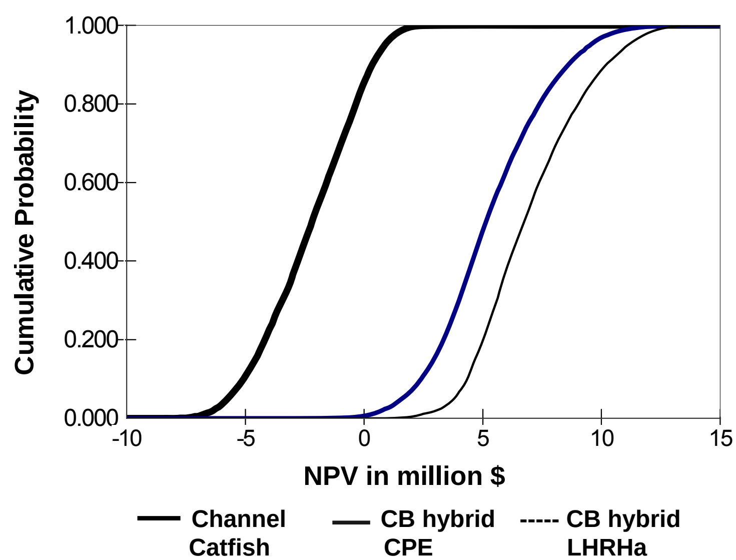


Figure 5.15 Cumulative probability distributions of channel catfish, CB hybrid iodine (CPE) and CB hybrid F+CS (LHRHa) production of fry per kilogram (fry/kg) of female channel catfish body weight

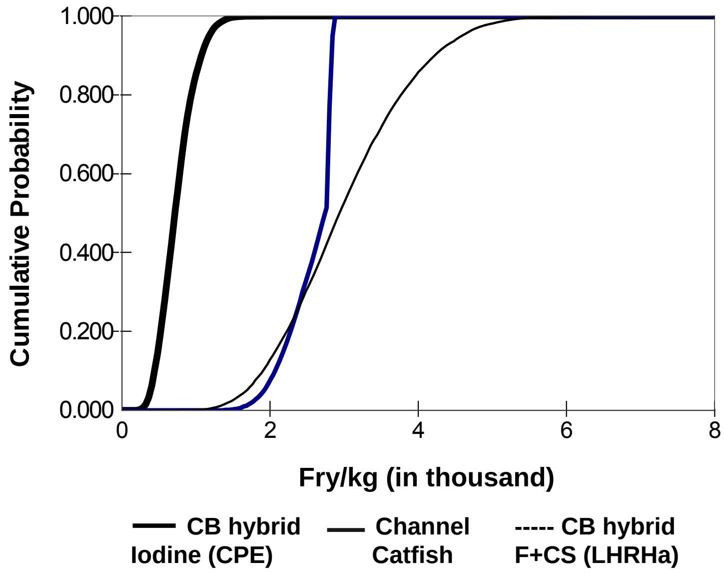


Figure 5.16 Cumulative probability distributions of per unit cost of fry production (cost/fry) for channel catfish and CB hybrid LHRHa

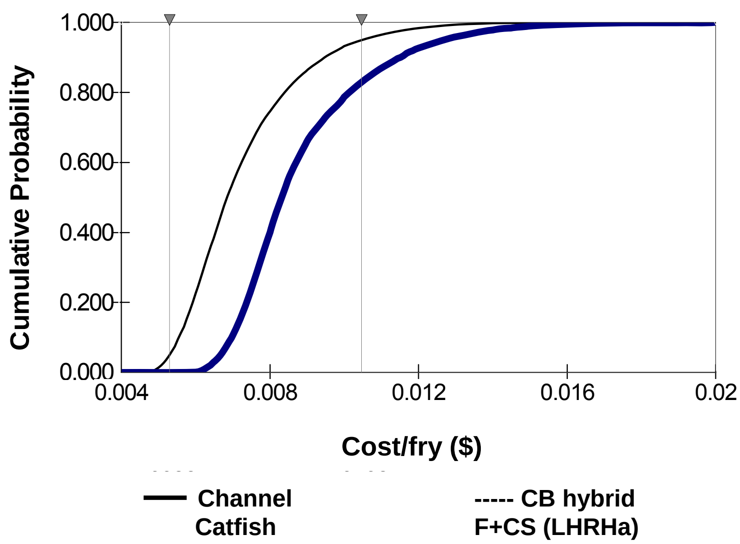


Figure 5.17 Cumulative probability distributions of the net present value of net returns (NPV), over a 20-year planning horizon discounted at 10%, for channel catfish, CB hybrid iodine (CPE), and CB hybrid F+CS (LHRHa)

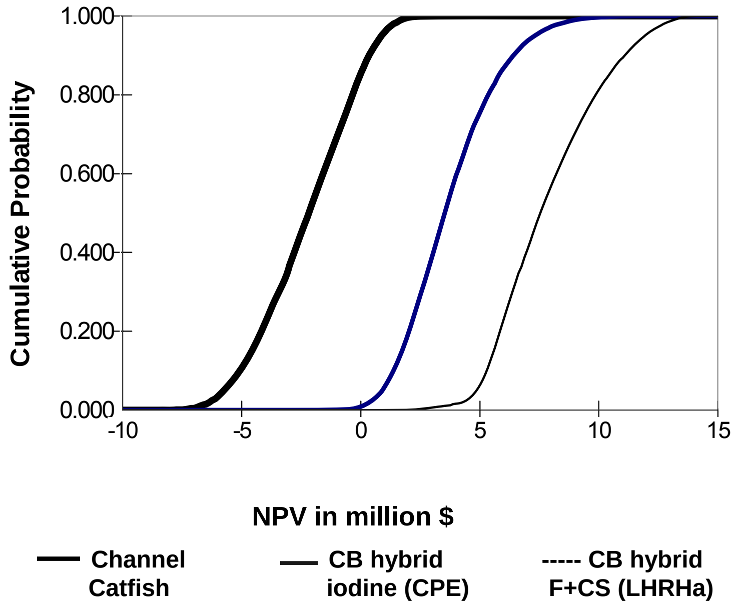


Figure 5.18 Cumulative probability distributions of channel catfish, commercial CB hybrid, and select CB hybrid production of fry per kilogram (fry/kg) of female channel catfish body weight

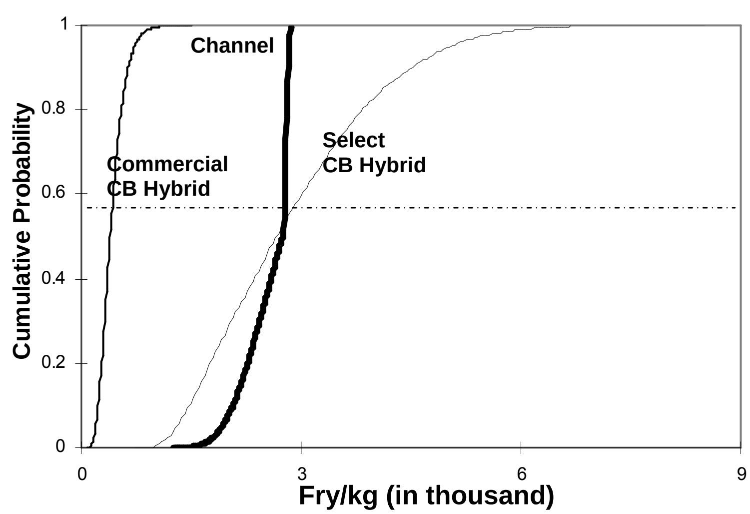


Figure 5.19 Cumulative probability distributions of per unit cost of fry production (cost/fry) for channel catfish and CB hybrid select

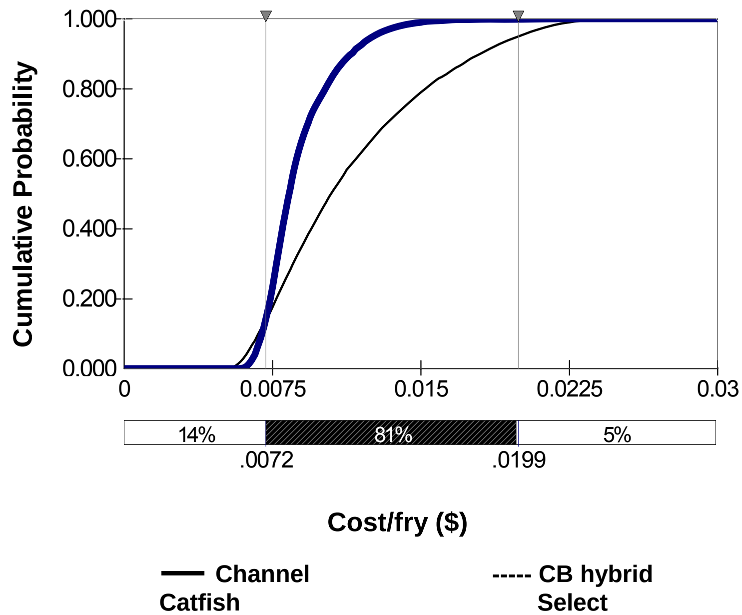


Figure 5.20 Cumulative probability distributions of the net present value of net returns (NPV), over a 20-year planning horizon discounted at 10%, for channel catfish and CB hybrid select

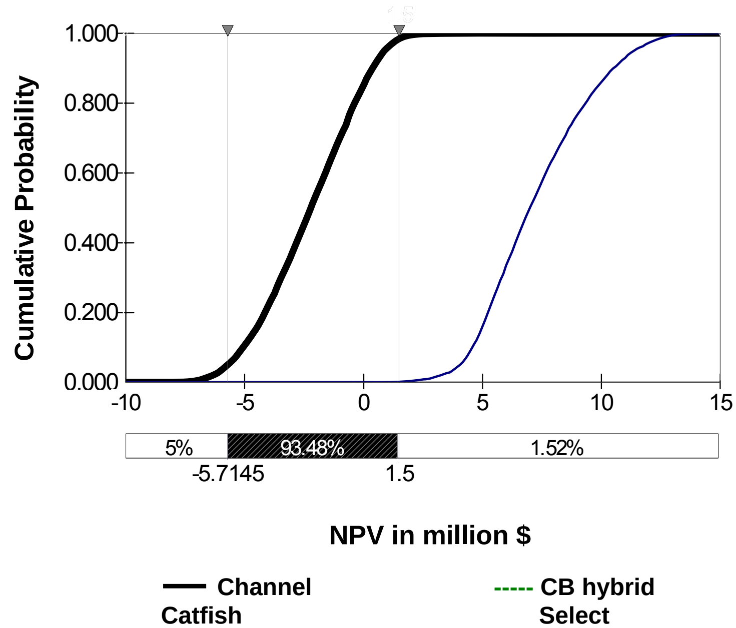


Figure 5.21 Cumulative probability distributions of fry per kilogram (fry/kg) of female channel catfish body weight for channel catfish and CB hybrid production that uses best recommended practices (CB hybrid archetype)

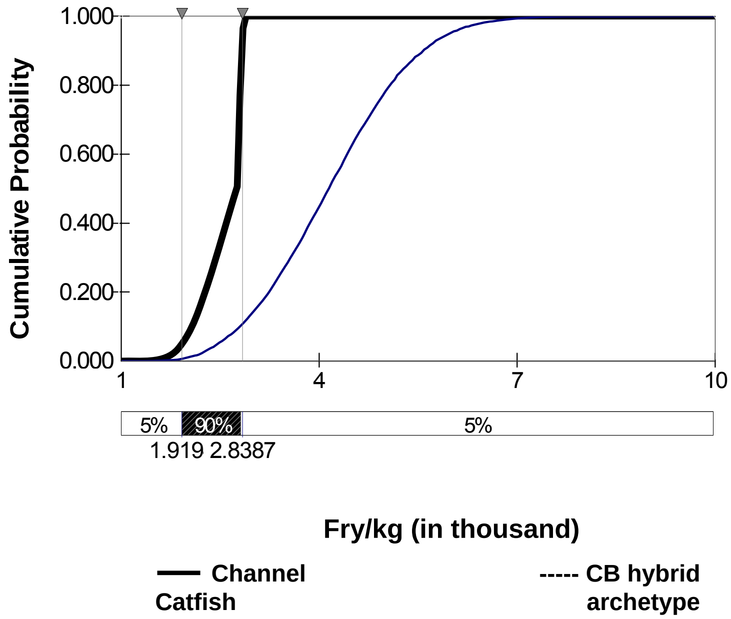


Figure 5.22 Cumulative probability distributions of per unit cost of fry production (cost/fry) for channel catfish and CB hybrid production that uses best recommended practices (CB hybrid archetype)

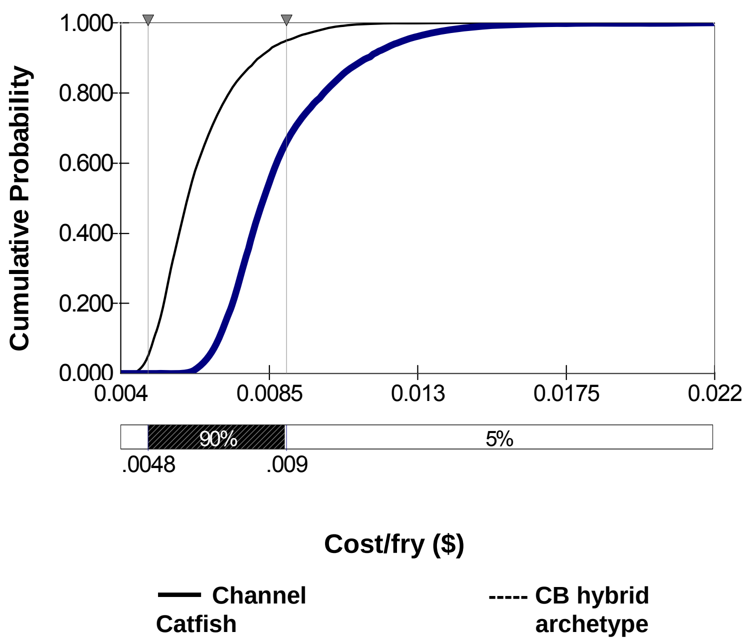
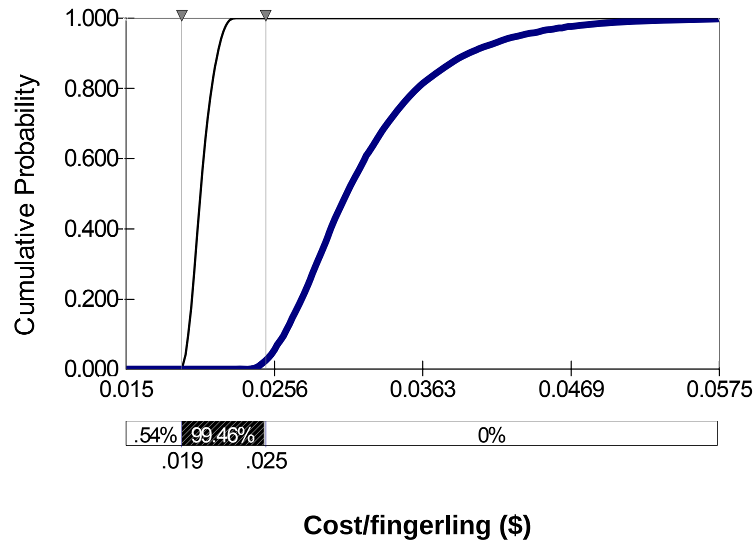
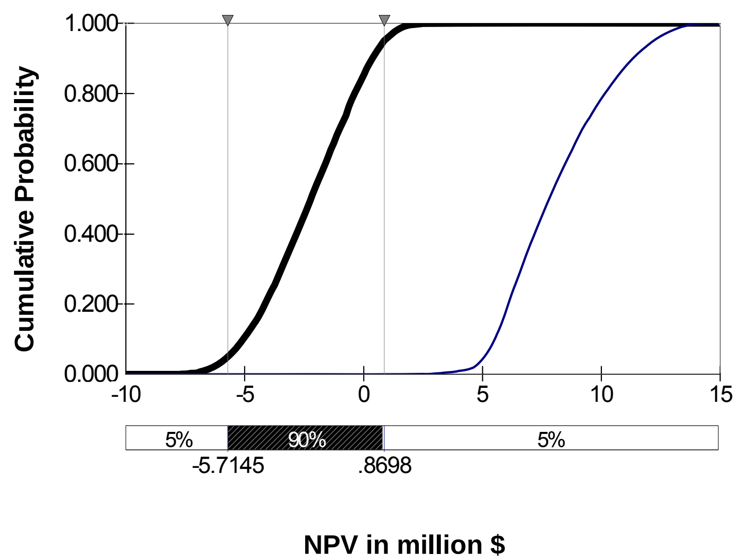


Figure 5.23 Cumulative probability distributions of per unit cost of fingerling production (cost/fingerling) for channel catfish and CB hybrid production that uses best recommended practices (CB hybrid archetype)



— Channel Catfish **----- CB hybrid archetype**

Figure 5.24 Cumulative probability distributions of the net present value of net returns (NPV), over a 20-year planning horizon discounted at 10%, for channel catfish and CB hybrid production that uses best recommended practices (CB hybrid archetype)



— Channel Catfish **----- CB hybrid archetype**

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DISSERTATION CONCLUSION

Culture of the CB hybrid catfish is more economically desirable than that for channel catfish based on payback period, profitability index, net present value and internal rate of return, mainly owing to the low per unit cost of growing CB hybrid catfish from fry to fingerling. However, under its current commercial application and utilization, cost of producing CB hybrid fry is much higher than that of channel catfish due to low CB hybrid embryo hatch rates observed under commercial conditions.

Use of LHRHa, the most promising hormone for hand stripped hybrid catfish embryo production, showed marked improvements in spawning performance of the channel catfish female resulting in reduced cost of fry production. Genetically improved female channel catfish injected with LHRHa made a further contribution to the reduction of fry production cost. Use of formalin alternated with copper sulfate as fungal disinfectant improved hatch rates to the point where CB hybrid fry production cost was lower than that of channel catfish fry production.

Using recommended protocols for CB hybrid production will improve hatch rates and provide a reliable and steady supply of CB hybrid fry for fingerling and food fish production. Adhering to the currently recommended protocol will reduce risk and increase fry production stability in commercial use of the CB hybrid. If commercial applications incorporate the best recommended practices for CB hybrid protocol, source of risk shifts from the physical and biological processes, and becomes directed to market situations.

The catfish industry in the southern United States continues to survive but future growth, as the industry stands now, will not be as dramatic as it was in the past. Improvements in production efficiency are the only way to safeguard the viability and sustainability of the catfish industry. The CB hybrid may not be a panacea, but it is certainly an improvement over the traditional channel catfish.

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APPENDICES

APPENDIX TO CHAPTER 1

Appendix Table 1.1 Variable and fixed costs for 136-acre channel catfish operation

	Unit	Quantity	Price or Cost	Value or cost
VARIABLE COSTS				
Female channel catfish brood fish	lb	10,950	$2.00	*$21,900*
Male channel catfish brood fish	lb	13,050	$2.00	*$26,100*
Brood Fish				**$48,000**
Hatchery Labor	person days	345	$52.00	*$17,940*
Payroll Tax Expense (11.5%)				*$2,063*
Workmen's Compensation (4.4%)				*$789*
Hired Labor				**$20,792**
Seining	load	6	$3,850.00	*$23,100*
Hauling	load	6	$2,300.00	*$13,800*
Contractual Labor				**$36,900**
Fuel and oil ($52/acre)	per acre	1	$52.00	*$7,070*
Electrical ($180/acre)	per acre	1	$180.00	*$24,480*
Supplies ($19/acre)	per acre	1	$19.00	*$2,580*
Chemicals ($74/acre)	per acre	1	$74.00	*$10,060*
Feed	ton	463	$300.00	*$138,970*
Farm Operation Costs				**$183,160**
Supplies				*$2,000*
Chemicals				*$1,900*
Hatchery Costs				**$3,900**
Trucks ($30/acre)	per acre	1	$30.00	*$4,080*
Tractors ($11.75/acre)	per acre	1	$11.75	*$1,600*
Aerators ($24/acre)	per acre	1	$24.00	*$3,270*
Repairs and Maintenance (Machinery and Equipment)				**$8,950**
Interest on Operating Capital				**$21,647**
TOTAL VARIABLE COSTS (TVC)				**$323,349**

Appendix Table 1.1 (Continued)

	Unit	Quantity	Price or Cost	Value or cost
FIXED COSTS				
Manager	person year	1	$75,000	*$75,000*
Assistant Manager	person year	1	$25,000	*$25,000*
Payroll Tax Expense (11.5%)				*$11,500*
Workmen's Compensation (4.4%)				*$4,400*
Salaries and Related Expenses				**$115,900**
General ($32/acre)	per acre	1	$32.00	*$4,350*
Vehicle				*$2,000*
Insurance				**$6,350**
Hatchery				*$500*
Ponds				*$2,000*
Repairs and Maintenance (Ponds and Hatchery)				**$2,500**
Interest on Capital Investment				**$120,067**
Depreciation (Building and Equipment)				**$110,176**
Supplies				*$700*
Telephone				*$1,000*
Trash				*$900*
Dues and Subscriptions				*$500*
Travel				*$2,000*
Contributions				*$1,000*
Accounting and Legal				*$7,500*
Taxes and Licences				*$3,520*
Miscellaneous				*$1,000*
Office and Personnel Overhead Costs				**$18,120**
TOTAL FIXED COSTS (TFC)				**$373,113**

Appendix Table 1.2 Variable and fixed costs for 50-acre CB hybrid catfish operation, using carp pituitary extract (CPE) at 2mg/kg priming dose followed by 8 mg/kg resolving dose as ovulating agent

	Unit	Quantity	Price or Cost	Value or cost
VARIABLE COSTS				
Female channel catfish brood fish	lb	30,000	$2.00	*$60,000*
Male blue catfish brood fish	lb	6,250	$3.50	*$21,875*
Brood Fish				**$81,875**
Hatchery Labor	person days	675	$52.00	*$35,100*
Payroll Tax Expense (11.5%)				*$4,037*
Workmen's Compensation (4.4%)				*$1,544*
Hired Labor				**$40,681**
Seining	load	6	$2,875.00	*$17,250*
Hauling	load	6	$2,050.00	*$12,300*
Contractual Labor				**$29,550**
Fuel and oil ($52/acre)	per acre	1	$52.00	*$2,600*
Electrical ($180/acre)	per acre	1	$180.00	*$9,000*
Supplies ($19/acre)	per acre	1	$19.00	*$950*
Chemicals ($74/acre)	per acre	1	$74.00	*$3,700*
Feed	ton	216	$300.00	*$64,690*
Farm Operation Costs				**$80,940**
Supplies				*$450*
Chemicals				*$210*
Hormones				*$29,950*
Hybrid Production Costs				**$30,610**
Trucks ($30/acre)	per acre	1	$30.00	*$1,500*
Tractors ($11.75/acre)	per acre	1	$11.75	*$600*
Aerators ($24/acre)	per acre	1	$24.00	*$1,200*
Repairs and Maintenance (Machinery and Equipment)				**$3,300**
Interest on Operating Capital				**$18,538**
TOTAL VARIABLE COSTS (TVC)				**$285,494**

Appendix Table 1.2 (Continued)

	Unit	Quantity	Price or Cost	Value or cost
FIXED COSTS				
Manager	person year	1	$75,000	*$75,000*
Assistant Manager	person year	1	$25,000	*$25,000*
Payroll Tax Expense (11.5%)				*$11,500*
Workmen's Compensation (4.4%)				*$4,400*
Salaries and Related Expenses				**$115,900**
General ($32/acre)	per acre	1	$32	*$1,600*
Vehicle				*$2,000*
Insurance				**$3,600**
Hatchery				*$500*
Ponds				*$1,000*
Repairs and Maintenance(Ponds and Hatchery)				**$1,500**
Interest on Capital Investment				**$84,764**
Depreciation(Building and Equipment)				**$80,188**
Supplies				*$600*
Telephone				*$1,000*
Trash				*$900*
Dues and Subscriptions				*$500*
Travel				*$2,000*
Contributions				*$1,000*
Accounting and Legal				*$7,500*
Taxes and Licences				*$1,540*
Miscellaneous				*$1,000*
Office and Personnel Overhead Costs				**$16,040**
TOTAL FIXED COSTS (TFC)				**$301,992**

Appendix Table 1.3 Income statement for 136-acre channel catfish operation, over a 20-year planning horizon

	ITEM	Year → 0	1	2	3	4	5	6
1	**Cash Farm Income**							
2	**Sale fingerling**	$0	$0	$214,200	$642,600	$642,600	$642,600	$642,600
3	**Sale brood fish**	$0	$0	$0	$5,000	$5,000	$5,000	$5,000
4	**Total Cash Income** (Line 2 + Line 3)	**$0**	**$0**	**$214,200**	**$647,600**	**$647,600**	**$647,600**	**$647,600**
5								
6	**Cash Farm Expenses**							
7	**Operating Expenses**	$0	$97,225	$414,500	$420,570	$420,570	$420,570	$420,570
8	**Interest on Operating Expenses** (7%)	$0	$0	$10,521	$21,647	$0	$0	$0
9	**Interest on Principal** (7%)	$0	$53,068	$98,420	$120,067	$116,445	$112,254	$104,562
10	**Total Cash Expenses** (Line 7 + Line 8 + Line 9)	**$0**	**$150,293**	**$523,441**	**$562,284**	**$537,015**	**$532,824**	**$525,132**
11								
12	**Net Cash Farm Income** (Line 4 - Line 10)	**$0**	**-$150,293**	**-$309,241**	**$85,316**	**$110,585**	**$114,776**	**$122,468**
13								
14	**Non-cash Adjustments:**							
15	**Depreciation** (straight line with no salvage value)	**$58,658**	**$110,176**	**$110,176**	**$110,176**	**$110,176**	**$110,176**	**$110,176**
16								
17	**Net Farm Income** (Line 12 - Line 15)	**-$58,658**	**-$260,469**	**-$419,417**	**-$24,860**	**$409**	**$4,600**	**$12,292**
18								
19	**Construction and Equipment**							
20	(initial outlay and recurring costs)	$758,120	$497,590	$0	$33,570	$50,710	$4,900	$44,300
21	**Repayment**	$0	-$150,293	-$309,241	$85,316	$110,585	$114,776	$122,468
22								
23	**Cash Value** (income-debt)	-$758,120	-$1,556,296	-$2,024,484	-$1,578,181	-$1,493,037	-$1,378,970	-$1,293,110
24	**Assets** (Lag Line 24 + Line 20 - Line 15)	$699,463	$1,086,877	$976,701	$900,095	$840,629	$735,353	$669,477
25	**Net Value** (Line 23 + Line 24)	-$58,658	-$469,420	-$1,047,784	-$678,087	-$652,409	-$643,618	-$623,634
26								
27	**Taxable Income** (Line 4 - Line 10 - Line 15 - Line 20)	-$816,778	-$758,059	-$419,417	-$58,430	-$50,301	-$300	-$32,008
28	**Income Taxes** (Line 27 * 6.5%)	$0	$0	$0	$0	$0	$0	$0
29								
30	**Total Cash Outflow** (Line 10 + Line 20 + Line 28)	**$758,120**	**$647,883**	**$523,441**	**$595,854**	**$587,725**	**$537,724**	**$569,432**
31								
32	**Net Cash Flow** (Line 4 - Line 30)	**-$758,120**	**-$647,883**	**-$309,241**	**$51,746**	**$59,875**	**$109,876**	**$78,168**

Appendix Table 1.3 (Continued)

	ITEM	Year →	7	8	9	10	11	12	13
1	**Cash Farm Income**								
2	**Sale fingerling**		$642,600	$642,600	$642,600	$642,600	$642,600	$642,600	$642,600
3	**Sale brood fish**		$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000
4	**Total Cash Income** (Line 2 + Line 3)		**$647,600**	**$647,600**	**$647,600**	**$647,600**	**$647,600**	**$647,600**	**$647,600**
5									
6	**Cash Farm Expenses**								
7	**Operating Expenses**		$420,570	$420,570	$420,570	$420,570	$420,570	$420,570	$420,570
8	**Interest on Operating Expenses** (7%)		$0	$0	$0	$0	$0	$0	$0
9	**Interest on Principal** (7%)		$99,090	$91,934	$84,228	$76,581	$86,043	$101,768	$97,099
10	**Total Cash Expenses** (Line 7 + Line 8 + Line 9)		**$519,660**	**$512,504**	**$504,798**	**$497,151**	**$506,613**	**$522,338**	**$517,669**
11									
12	**Net Cash Farm Income** (Line 4 - Line 10)		**$127,940**	**$135,096**	**$142,802**	**$150,449**	**$140,987**	**$125,262**	**$129,931**
13									
14	**Non-cash Adjustments:**								
15	**Depreciation** (straight line with no salvage value)		**$110,176**	**$110,176**	**$110,176**	**$110,176**	**$110,176**	**$110,176**	**$110,176**
16									
17	**Net Farm Income** (Line 12 - Line 15)		**$17,764**	**$24,920**	**$32,626**	**$40,273**	**$30,811**	**$15,086**	**$19,755**
18									
19	**Construction and Equipment**								
20	(initial outlay and recurring costs)		$25,710	$25,000	$33,570	$285,610	$365,630	$58,570	$25,710
21	**Repayment**		$127,940	$135,096	$142,802	$150,449	$140,987	$125,262	$129,931
22									
23	**Cash Value** (income-debt)		-$1,185,408	-$1,068,156	-$951,218	-$1,078,732	-$1,312,837	-$1,261,870	-$1,152,980
24	**Assets** (Lag Line 24 + Line 20 - Line 15)		$585,011	$499,835	$423,229	$598,663	$854,117	$802,511	$718,045
25	**Net Value** (Line 23 + Line 24)		-$600,398	-$568,322	-$527,990	-$480,070	-$458,721	-$459,360	-$434,936
26									
27	**Taxable Income** (Line 4 - Line 10 - Line 15 - Line 20)		-$7,946	-$80	-$944	-$245,337	-$334,819	-$43,484	-$5,955
28	**Income Taxes** (Line 27 * 6.5%)		$0	$0	$0	$0	$0	$0	$0
29									
30	**Total Cash Outflow** (Line 10 + Line 20 + Line 28)		**$545,370**	**$537,504**	**$538,368**	**$782,761**	**$872,243**	**$580,908**	**$543,379**
31									
32	**Net Cash Flow** (Line 4 - Line 30)		**$102,230**	**$110,096**	**$109,232**	**-$135,161**	**-$224,643**	**$66,692**	**$104,221**

Appendix Table 1.3 (Continued)

	ITEM	Year → 14	15	16	17	18	19	20
1	**Cash Farm Income**							
2	**Sale fingerling**	$642,600	$642,600	$642,600	$642,600	$642,600	$642,600	$642,600
3	**Sale brood fish**	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000
4	**Total Cash Income** (Line 2 + Line 3)	**$647,600**	**$647,600**	**$647,600**	**$647,600**	**$647,600**	**$647,600**	**$647,600**
5								
6	**Cash Farm Expenses**							
7	**Operating Expenses**	$420,570	$420,570	$420,570	$420,570	$420,570	$420,570	$420,570
8	**Interest on Operating Expenses** (7%)	$0	$0	$0	$0	$0	$0	$0
9	**Interest on Principal** (7%)	$89,804	$80,198	$72,613	$66,104	$54,839	$45,136	$34,203
10	**Total Cash Expenses** (Line 7 + Line 8 + Line 9)	**$510,374**	**$500,768**	**$493,183**	**$486,674**	**$475,409**	**$465,706**	**$454,773**
11								
12	**Net Cash Farm Income** (Line 4 - Line 10)	**$137,226**	**$146,832**	**$154,417**	**$160,926**	**$172,191**	**$181,894**	**$192,827**
13								
14	**Non-cash Adjustments:**							
15	**Depreciation** (straight line with no salvage value)	**$110,176**	**$110,176**	**$110,176**	**$110,176**	**$110,176**	**$110,176**	**$62,259**
16								
17	**Net Farm Income** (Line 12 - Line 15)	**$27,050**	**$36,656**	**$44,241**	**$50,750**	**$62,015**	**$71,718**	**$130,569**
18								
19	**Construction and Equipment**							
20	(initial outlay and recurring costs)	$0	$38,470	$61,440	$0	$33,570	$25,710	$4,900
21	**Repayment**	$137,226	$146,832	$154,417	$160,926	$172,191	$181,894	$192,827
22								
23	**Cash Value** (income-debt)	-$1,008,459	-$890,491	-$789,929	-$622,494	-$472,608	-$306,721	-$107,861
24	**Assets** (Lag Line 24 + Line 20 - Line 15)	$607,869	$536,163	$487,427	$377,251	$300,645	$216,179	$158,820
25	**Net Value** (Line 23 + Line 24)	-$400,591	-$354,329	-$302,503	-$245,244	-$171,964	-$90,543	$50,959
26								
27	**Taxable Income** (Line 4 - Line 10 - Line 15 - Line 20)	$27,050	-$1,814	-$17,199	$50,750	$28,445	$46,008	$125,669
28	**Income Taxes** (Line 27 * 6.5%)	$1,758	$0	$0	$3,299	$1,849	$2,991	$8,168
29								
30	**Total Cash Outflow** (Line 10 + Line 20 + Line 28)	**$512,132**	**$539,238**	**$554,623**	**$489,973**	**$510,828**	**$494,407**	**$467,841**
31								
32	**Net Cash Flow** (Line 4 - Line 30)	**$135,468**	**$108,362**	**$92,977**	**$157,627**	**$136,772**	**$153,193**	**$179,759**

Appendix Table 1.4 Income statement for 50-acre CB hybrid catfish operation using carp pituitary extract (CPE) at 2mg/kg priming dose followed by 8 mg/kg resolving dose as ovulating agent, over a 20-year planning horizon

	ITEM	Year → 0	1	2	3	4	5	6
1	**Cash Farm Income**							
2	**Sale fingerling**	$0	$0	$191,250	$573,750	$573,750	$573,750	$573,750
3	**Sale brood fish**	$0	$0	$0	$5,000	$5,000	$5,000	$5,000
4	**Total Cash Income** (Line 2 + Line 3)	**$0**	**$0**	**$191,250**	**$578,750**	**$578,750**	**$578,750**	**$578,750**
5								
6	**Cash Farm Expenses**							
7	**Operating Expenses**	$0	$97,225	$380,575	$355,870	$355,870	$355,870	$355,870
8	**Interest on Operating Expenses** (7%)	$0	$0	$9,278	$18,538	$0	$0	$0
9	**Interest on Principal** (7%)	$0	$35,317	$66,226	$84,764	$77,569	$70,947	$60,740
10	**Total Cash Expenses** (Line 7 + Line 8 + Line 9)	**$0**	**$132,542**	**$456,079**	**$459,172**	**$433,439**	**$426,817**	**$416,610**
11								
12	**Net Cash Farm Income** (Line 4 - Line 10)	**$0**	**-$132,542**	**-$264,829**	**$119,578**	**$145,311**	**$151,933**	**$162,140**
13								
14	**Non-cash Adjustments:**							
15	**Depreciation** (straight line with no salvage value)	**$38,943**	**$80,188**	**$80,188**	**$80,188**	**$80,188**	**$80,188**	**$80,188**
16								
17	**Net Farm Income** (Line 12 - Line 15)	**-$38,943**	**-$212,730**	**-$345,016**	**$39,390**	**$65,124**	**$71,746**	**$81,953**
18								
19	**Construction and Equipment**							
20	(initial outlay and recurring costs)	$504,530	$309,020	$0	$16,790	$50,710	$6,120	$84,010
21	**Repayment**	$0	-$132,542	-$264,829	$119,578	$145,311	$151,933	$162,140
22								
23	**Cash Value** (income-debt)	-$504,530	-$1,078,634	-$1,475,750	-$988,555	-$868,221	-$715,786	-$627,449
24	**Assets** (Lag Line 24 + Line 20 - Line 15)	$465,587	$694,420	$614,232	$550,835	$521,357	$447,290	$451,112
25	**Net Value** (Line 23 + Line 24)	-$38,943	-$384,215	-$861,518	-$437,720	-$346,864	-$268,496	-$176,337
26								
27	**Taxable Income** (Line 4 - Line 10 - Line 15 - Line 20)	-$543,473	-$521,750	-$345,016	$22,600	$14,414	$65,626	-$2,058
28	**Income Taxes** (Line 27 * 6.5%)				$1,469	$937	$4,266	-$134
29								
30	**Total Cash Outflow** (Line 10 + Line 20 + Line 28)	**$504,530**	**$441,562**	**$456,079**	**$477,431**	**$485,086**	**$437,203**	**$500,486**
31								
32	**Net Cash Flow** (Line 4 - Line 30)	**-$504,530**	**-$441,562**	**-$264,829**	**$101,319**	**$93,664**	**$141,547**	**$78,264**

Appendix Table 1.4 (Continued)

	ITEM Year →	7	8	9	10	11	12	13
1	**Cash Farm Income**							
2	**Sale fingerling**	$573,750	$573,750	$573,750	$573,750	$573,750	$573,750	$573,750
3	**Sale brood fish**	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000
4	**Total Cash Income** (Line 2 + Line 3)	**$578,750**	**$578,750**	**$578,750**	**$578,750**	**$578,750**	**$578,750**	**$578,750**
5								
6	**Cash Farm Expenses**							
7	**Operating Expenses**	$355,870	$355,870	$355,870	$355,870	$355,870	$355,870	$355,870
8	**Interest on Operating Expenses** (7%)	$0	$0	$0	$0	$0	$0	$0
9	**Interest on Principal** (7%)	$55,271	$45,424	$34,752	$22,758	$20,174	$21,633	$10,385
10	**Total Cash Expenses** (Line 7 + Line 8 + Line 9)	**$411,141**	**$401,294**	**$390,622**	**$378,628**	**$376,044**	**$377,503**	**$366,255**
11								
12	**Net Cash Farm Income** (Line 4 - Line 10)	**$167,609**	**$177,456**	**$188,128**	**$200,122**	**$202,706**	**$201,247**	**$212,495**
13								
14	**Non-cash Adjustments:**							
15	**Depreciation** (straight line with no salvage value)	**$80,188**	**$80,188**	**$80,188**	**$80,188**	**$80,188**	**$80,188**	**$80,188**
16								
17	**Net Farm Income** (Line 12 - Line 15)	**$87,422**	**$97,269**	**$107,941**	**$119,935**	**$122,519**	**$121,060**	**$132,308**
18								
19	**Construction and Equipment**							
20	(initial outlay and recurring costs)	$26,930	$25,000	$16,790	$163,210	$223,540	$40,570	$26,930
21	**Repayment**	$167,609	$177,456	$188,128	$200,122	$202,706	$201,247	$148,361
22								
23	**Cash Value** (income-debt)	-$481,301	-$318,998	-$136,988	-$88,082	-$106,332	$52,886	$212,495
24	**Assets** (Lag Line 24 + Line 20 - Line 15)	$397,855	$342,667	$279,270	$362,292	$505,645	$466,027	$412,770
25	**Net Value** (Line 23 + Line 24)	-$83,446	$23,669	$142,282	$274,210	$399,313	$518,913	$625,265
26								
27	**Taxable Income** (Line 4 - Line 10 - Line 15 - Line 20)	$60,492	$72,269	$91,151	-$43,276	-$101,022	$80,490	$105,378
28	**Income Taxes** (Line 27 * 6.5%)	$3,932	$4,697	$5,925	-$2,813	-$6,566	$5,232	$6,850
29								
30	**Total Cash Outflow** (Line 10 + Line 20 + Line 28)	**$442,003**	**$430,991**	**$413,337**	**$539,025**	**$593,018**	**$423,305**	**$400,035**
31								
32	**Net Cash Flow** (Line 4 - Line 30)	**$136,747**	**$147,759**	**$165,413**	**$39,725**	**-$14,268**	**$155,445**	**$178,715**

Appendix Table 1.4 (Continued)

	ITEM	Year → 14	15	16	17	18	19	20
1	**Cash Farm Income**							
2	**Sale fingerling**	$573,750	$573,750	$573,750	$573,750	$573,750	$573,750	$573,750
3	**Sale brood fish**	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000
4	**Total Cash Income** (Line 2 + Line 3)	**$578,750**	**$578,750**	**$578,750**	**$578,750**	**$578,750**	**$578,750**	**$578,750**
5								
6	**Cash Farm Expenses**							
7	**Operating Expenses**	$355,870	$355,870	$355,870	$355,870	$355,870	$355,870	$355,870
8	**Interest on Operating Expenses** (7%)	$0	$0	$0	$0	$0	$0	$0
9	**Interest on Principal** (7%)	$0	$0	$0	$0	$0	$0	$0
10	**Total Cash Expenses** (Line 7 + Line 8 + Line 9)	**$355,870**	**$355,870**	**$355,870**	**$355,870**	**$355,870**	**$355,870**	**$355,870**
11								
12	**Net Cash Farm Income** (Line 4 - Line 10)	**$222,880**	**$222,880**	**$222,880**	**$222,880**	**$222,880**	**$222,880**	**$222,880**
13								
14	**Non-cash Adjustments:**							
15	**Depreciation** (straight line with no salvage value)	**$80,188**	**$80,188**	**$80,188**	**$80,188**	**$80,188**	**$80,188**	**$46,435**
16								
17	**Net Farm Income** (Line 12 - Line 15)	**$142,693**	**$142,693**	**$142,693**	**$142,693**	**$142,693**	**$142,693**	**$176,446**
18								
19	**Construction and Equipment**							
20	(initial outlay and recurring costs)	$0	$21,690	$119,150	$1,220	$15,570	$26,930	$0
21	**Repayment**	$0	$0	$0	$0	$0	$0	$0
22								
23	**Cash Value** (income-debt)	$222,880	$222,880	$222,880	$222,880	$222,880	$222,880	$222,880
24	**Assets** (Lag Line 24 + Line 20 - Line 15)	$332,582	$274,085	$313,047	$234,080	$169,462	$116,205	$69,770
25	**Net Value** (Line 23 + Line 24)	$555,462	$496,965	$535,927	$456,960	$392,342	$339,085	$292,650
26								
27	**Taxable Income** (Line 4 - Line 10 - Line 15 - Line 20)	$142,693	$121,003	$23,543	$141,473	$127,123	$115,763	$176,446
28	**Income Taxes** (Line 27 * 6.5%)	$9,275	$7,865	$1,530	$9,196	$8,263	$7,525	$11,469
29								
30	**Total Cash Outflow** (Line 10 + Line 20 + Line 28)	**$365,145**	**$385,425**	**$476,550**	**$366,286**	**$379,703**	**$390,325**	**$367,339**
31								
32	**Net Cash Flow** (Line 4 - Line 30)	**$213,605**	**$193,325**	**$102,200**	**$212,464**	**$199,047**	**$188,425**	**$211,411**

Appendix Table 1.5 Computation[9] of indicators of financial desirability for 136-acre channel catfish operation

		With capital renewal at different times		Useful life is doubled		Initial investment lasts 20 years	
Period		Net Cash Flow	Payback Period	Net Cash Flow	Payback Period	Net Cash Flow	Payback Period
0		-$1,255,710	-$1,255,710	-$1,255,710	-$1,255,710	-$1,255,710	-$1,255,710
1		-$150,293	-$1,406,003	-$150,293	-$1,406,003	-$150,293	-$1,406,003
2		-$309,241	-$1,715,244	-$309,241	-$1,715,244	-$309,241	-$1,715,244
3		$51,746	-$1,663,497	$83,765	-$1,631,479	$83,381	-$1,631,863
4		$59,875	-$1,603,622	$109,588	-$1,521,891	$109,204	-$1,522,658
5		$109,876	-$1,493,746	$116,980	-$1,404,910	$116,596	-$1,406,062
6		$78,168	-$1,415,578	$124,889	-$1,280,022	$124,505	-$1,281,557
7		$102,230	-$1,313,348	$109,312	-$1,170,709	$132,967	-$1,148,590
8		$110,096	-$1,203,252	$117,349	-$1,053,361	$142,023	-$1,006,567
9		$109,232	-$1,094,020	$148,659	-$904,701	$151,711	-$854,856
10		-$135,161	-$1,229,181	$154,204	-$750,498	$162,079	-$692,777
11		-$224,643	-$1,453,824	$154,593	-$595,905	$173,171	-$519,606
12		$66,692	-$1,387,132	$179,842	-$416,063	$185,040	-$334,565
13		$104,221	-$1,282,911	$168,113	-$247,950	$197,740	-$136,825
14		$135,468	-$1,147,444	$203,640	-$44,310	$211,330	$74,505
15		$108,362	-$1,039,082	$216,267	$171,957	$215,883	
16		$92,977	-$946,105	$192,892		$215,883	
17		$157,627	-$788,477	$216,267		$215,883	
18		$136,772	-$651,705	$216,267		$215,883	
19		$153,193	-$498,512	$192,228		$215,883	
20		$179,788	-$318,753	$214,216		$213,867	
NPV	13%	-$1,133,749		-$790,586		-$754,614	
PI	13%	-0.02		0.29		0.32	
NPV	10%	-$1,086,949		-$619,219		-$569,826	
PI	10%	0.05		0.46		0.50	
NPV	7%	-$991,453		-$341,427		-$272,367	
PI	7%	0.16		0.71		0.77	
NPV	4%	-$811,278		$111,023		$209,556	
PI	4%	0.33		1.09		1.17	
NPV	1%	-$480,891		$857,096		$1,000,874	
PI	1%	0.61		1.69		1.81	
IRR		-2%		5%		5%	
Payback Period			unable to recover initial investments over the 20-year period		14 years and 2.5 months		13 years and 8 months

[9] NPV and IRR were computed using functions in Microsoft Excel 2003 using the following syntax:

- NPV(rate, value1, value2, …, value*n*) where rate is the rate of discount, value1 is the initial investment, and value2, …, value*n* are the net cash flows over the life of the project
- IRR(value1, value2, …, value*n*) where value1 is the initial investment, and value2, …, value*n* are the net cash flows over the life of the project

PI was computed by taking the NPV of net cash flows excluding initial investment and dividing the resultant NPV by the amount of initial investment

Payback period is simply the number of years it takes to recover initial investment, i.e., when amount corresponding to period becomes zero.

Appendix Table 1.6 Computation[9] of indicators of financial desirability for 50-acre CB hybrid catfish operation using carp pituitary extract (CPE) at 2mg/kg priming dose followed by 8 mg/kg resolving dose as ovulating agent

		With capital renewal at different times		Useful life is doubled		Initial investment lasts 20 years	
Period		Net Cash Flow	Payback Period	Net Cash Flow	Payback Period	Net Cash Flow	Payback Period
0		-$813,550	-$813,550	-$813,550	-$813,550	-$813,550	-$813,550
1		**-$132,542**	-$946,092	**-$132,542**	**-$946,092**	**-$132,542**	**-$946,092**
2		**-$264,829**	-$1,210,921	-$264,829	**-$1,210,921**	-$264,829	**-$1,210,921**
3		**$101,319**	-$1,109,602	$114,176	**-$1,096,745**	$114,251	**-$1,096,670**
4		**$93,664**	-$1,015,938	$139,962	**-$956,783**	$139,410	**-$957,261**
5		**$141,547**	-$874,391	$148,405	**-$808,378**	$148,997	**-$808,264**
6		**$78,264**	-$796,127	$159,721	**-$648,657**	$159,256	**-$649,008**
7		**$136,747**	-$659,380	$145,977	**-$502,680**	$170,233	**-$478,775**
8		**$147,759**	-$511,621	$157,318	**-$345,362**	$181,977	**-$296,798**
9		**$165,413**	-$346,208	$190,352	**-$155,010**	$194,545	**-$102,253**
10		**$39,725**	-$306,483	$200,022	**$45,012**	$207,992	**$105,739**
11		**-$14,268**	-$320,751	$142,097		$210,838	
12		**$155,445**	-$165,305	$211,437		$210,838	
13		**$178,715**	$13,410	$186,257		$210,838	
14		**$213,605**		$211,437		$210,838	
15		**$193,325**		$210,764		$210,838	
16		**$102,200**		$188,062		$210,838	
17		**$212,464**		$210,296		$210,838	
18		**$199,047**		$211,437		$210,838	
19		**$188,425**		$186,725		$210,838	
20		**$211,411**		$209,858		$209,397	
NPV	13%	**-$422,661**		**-$233,490**		**-$188,010**	
PI	13%	0.41		0.68		0.74	
NPV	10%	**-$268,217**		**-$21,394**		**$40,695**	
PI	10%	0.64		0.97		1.06	
NPV	7%	**-$21,831**		**$305,550**		**$391,704**	
PI	7%	0.97		1.40		1.52	
NPV	4%	$376,048		$818,034		$939,771	
PI	4%	1.48		2.05		2.20	
NPV	1%	$1,030,002		$1,638,184		$1,813,725	
PI	1%	2.28		3.03		3.25	
IRR		7%		10%		10%	
Payback Period			12 years and 11 months		9 years and 9 months		9 years and 6 months

APPENDIX TO CHAPTER 2

Appendix Table 2.1 Variable and fixed costs for 136-acre CB hybrid catfish operation, using CPE at 2mg/kg priming dose followed by 8 mg/kg resolving dose as ovulating agent

	Unit	Quantity	Price or Cost	Value or cost
VARIABLE COSTS				
Female channel catfish brood fish	lb	80,930	$2.00	*$161,860*
Male blue catfish brood fish	lb	16,860	$3.50	*$59,011*
Brood Fish				**$220,871**
Hatchery Labor	person days	1821	$52.00	*$94,688*
Payroll Tax Expense (11.5%)				*$10,889*
Workmen's Compensation (4.4%)				*$4,166*
Hired Labor				**$109,744**
Seining	load	15	$2,875.00	*$42,291*
Hauling	load	15	$2,050.00	*$30,155*
Contractual Labor				**$72,446**
Fuel and oil ($52/acre)	per acre	1	$52.00	*$7,070*
Electrical ($180/acre)	per acre	1	$180.00	*$24,480*
Supplies ($19/acre)	per acre	1	$19.00	*$2,580*
Chemicals ($74/acre)	per acre	1	$74.00	*$10,060*
Feed	ton	541	$300.00	*$162,240*
Farm Operation Costs				**$206,430**
Supplies				*$1,590*
Chemicals				*$3,750*
Hormones				*$79,430*
Hybrid Production Costs				**$84,770**
Trucks ($30/acre)	per acre	1	$30.00	*$4,080*
Tractors ($11.75/acre)	per acre	1	$11.75	*$1,600*
Aerators ($24/acre)	per acre	1	$24.00	*$3,270*
Repairs and Maintenance (Machinery and Equipment)				**$8,950**
Interest on Operating Capital				**$27,750**
TOTAL VARIABLE COSTS (TVC)				**$730,961**

Appendix Table 2.1 (Continued)

	Unit	Quantity	Price or Cost	Value or cost
FIXED COSTS				
Manager	person year	1	$75,000	*$75,000*
Assistant Manager	person year	1	$25,000	*$25,000*
Payroll Tax Expense (11.5%)				*$11,500*
Workmen's Compensation (4.4%)				*$4,400*
Salaries and Related Expenses				**$115,900**
General ($32/acre)	per acre	1	$32	*$4,350*
Vehicle				*$2,000*
Insurance				**$6,350**
Hatchery				*$500*
Ponds				*$2,000*
Repairs and Maintenance (Ponds and Hatchery)				**$2,500**
Interest on Capital Investment				**$141,623**
Depreciation (Building and Equipment)				**$138,979**
Supplies				*$700*
Telephone				*$1,000*
Trash				*$900*
Dues and Subscriptions				*$500*
Travel				*$2,000*
Contributions				*$1,000*
Accounting and Legal				*$7,500*
Taxes and Licences				*$3,520*
Miscellaneous				*$1,000*
Office and Personnel Overhead Costs				**$18,120**
TOTAL FIXED COSTS (TFC)				**$423,472**

Appendix Table 2.2 Income statement for 136-acre CB hybrid catfish operation using CPE at 2mg/kg priming dose followed by 8 mg/kg resolving dose as ovulating agent, over a 20-year planning horizon

	ITEM	Year → 0	1	2	3	4	5	6
1	**Cash Farm Income**							
2	**Sale fingerling**	$0	$0	$513,315	$1,539,945	$1,539,945	$1,539,945	$1,539,945
3	**Sale brood fish**	$0	$0	$0	$13,488	$13,488	$13,488	$13,488
4	**Total Cash Income** (Line 2 + Line 3)	**$0**	**$0**	**$513,315**	**$1,553,433**	**$1,553,433**	**$1,553,433**	**$1,553,433**
5								
6	**Cash Farm Expenses**							
7	**Operating Expenses**	$0	$97,225	$784,698	$713,189	$713,189	$713,189	$713,189
8	**Interest on Operating Expenses** (7%)	$0	$0	$11,167	$27,750	$0	$0	$0
9	**Interest on Principal** (7%)	$0	$62,308	$113,873	$141,623	$97,198	$48,758	$0
10	**Total Cash Expenses** (Line 7 + Line 8 + Line 9)	**$0**	**$159,533**	**$909,739**	**$882,562**	**$810,387**	**$761,947**	**$713,189**
11								
12	**Net Cash Farm Income** (Line 4 - Line 10)	**$0**	**-$159,533**	**-$396,424**	**$670,871**	**$743,046**	**$791,486**	**$840,244**
13								
14	**Non-cash Adjustments:**							
15	**Depreciation** (straight line with no salvage value)	**$65,258**	**$138,979**	**$138,979**	**$138,979**	**$138,979**	**$138,979**	**$138,979**
16								
17	**Net Farm Income** (Line 12 - Line 15)	**-$65,258**	**-$298,512**	**-$535,402**	**$531,893**	**$604,067**	**$652,507**	**$701,265**
18								
19	**Construction and Equipment**							
20	(initial outlay and recurring costs)	$890,120	$577,110	$0	$36,230	$51,040	$7,560	$199,140
21	**Repayment**	$0	-$159,533	-$396,424	$670,871	$743,046	$696,540	$0
22								
23	**Cash Value** (income-debt)	-$890,120	-$1,786,296	-$2,419,610	-$717,674	$46,506	$791,486	$840,244
24	**Assets** (Lag Line 24 + Line 20 - Line 15)	$824,863	$1,262,994	$1,124,016	$1,021,267	$933,329	$801,910	$862,072
25	**Net Value** (Line 23 + Line 24)	-$65,258	-$523,302	-$1,295,595	$303,593	$979,835	$1,593,396	$1,702,315
26								
27	**Taxable Income** (Line 4 - Line 10 - Line 15 - Line 20)	-$955,378	-$875,622	-$535,402	$495,663	$553,027	$644,947	$502,125
28	**Income Taxes** (Line 27 * 6.5%)				$32,218	$35,947	$41,922	$32,638
29								
30	**Total Cash Outflow** (Line 10 + Line 20 + Line 28)	**$890,120**	**$736,643**	**$909,739**	**$951,010**	**$897,374**	**$811,429**	**$944,968**
31								
32	**Net Cash Flow** (Line 4 - Line 30)	**-$890,120**	**-$736,643**	**-$396,424**	**$602,423**	**$656,059**	**$742,004**	**$608,466**

Appendix Table 2.2 (Continued)

	ITEM Year →	7	8	9	10	11	12	13
1	**Cash Farm Income**							
2	**Sale fingerling**	$1,539,945	$1,539,945	$1,539,945	$1,539,945	$1,539,945	$1,539,945	$1,539,945
3	**Sale brood fish**	$13,488	$13,488	$13,488	$13,488	$13,488	$13,488	$13,488
4	**Total Cash Income** (Line 2 + Line 3)	**$1,553,433**	**$1,553,433**	**$1,553,433**	**$1,553,433**	**$1,553,433**	**$1,553,433**	**$1,553,433**
5								
6	**Cash Farm Expenses**							
7	**Operating Expenses**	$713,189	$713,189	$713,189	$713,189	$713,189	$713,189	$713,189
8	**Interest on Operating Expenses** (7%)	$0	$0	$0	$0	$0	$0	$0
9	**Interest on Principal** (7%)	$0	$0	$0	$0	$0	$0	$0
10	**Total Cash Expenses** (Line 7 + Line 8 + Line 9)	**$713,189**	**$713,189**	**$713,189**	**$713,189**	**$713,189**	**$713,189**	**$713,189**
11								
12	**Net Cash Farm Income** (Line 4 - Line 10)	**$840,244**	**$840,244**	**$840,244**	**$840,244**	**$840,244**	**$840,244**	**$840,244**
13								
14	**Non-cash Adjustments:**							
15	**Depreciation** (straight line with no salvage value)	**$138,979**	**$138,979**	**$138,979**	**$138,979**	**$138,979**	**$138,979**	**$138,979**
16								
17	**Net Farm Income** (Line 12 - Line 15)	**$701,265**	**$701,265**	**$701,265**	**$701,265**	**$701,265**	**$701,265**	**$701,265**
18								
19	**Construction and Equipment**							
20	(initial outlay and recurring costs)	$28,700	$25,000	$36,230	$285,940	$397,330	$58,570	$28,700
21	**Repayment**	$0	$0	$0	$0	$0	$0	$0
22								
23	**Cash Value** (income-debt)	$840,244	$840,244	$840,244	$840,244	$840,244	$840,244	$840,244
24	**Assets** (Lag Line 24 + Line 20 - Line 15)	$751,793	$637,815	$535,066	$682,028	$940,379	$859,971	$749,692
25	**Net Value** (Line 23 + Line 24)	$1,592,037	$1,478,058	$1,375,310	$1,522,271	$1,780,623	$1,700,214	$1,589,936
26								
27	**Taxable Income** (Line 4 - Line 10 - Line 15 - Line 20)	$672,565	$676,265	$665,035	$415,325	$303,935	$642,695	$672,565
28	**Income Taxes** (Line 27 * 6.5%)	$43,717	$43,957	$43,227	$26,996	$19,756	$41,775	$43,717
29								
30	**Total Cash Outflow** (Line 10 + Line 20 + Line 28)	**$785,606**	**$782,147**	**$792,647**	**$1,026,126**	**$1,130,275**	**$813,535**	**$785,606**
31								
32	**Net Cash Flow** (Line 4 - Line 30)	**$767,827**	**$771,287**	**$760,787**	**$527,308**	**$423,158**	**$739,899**	**$767,827**

Appendix Table 2.2 (Continued)

	ITEM	Year → 14	15	16	17	18	19	20
1	**Cash Farm Income**							
2	**Sale fingerling**	$1,539,945	$1,539,945	$1,539,945	$1,539,945	$1,539,945	$1,539,945	$1,539,945
3	**Sale brood fish**	$13,488	$13,488	$13,488	$13,488	$13,488	$13,488	$13,488
4	**Total Cash Income** (Line 2 + Line 3)	**$1,553,433**	**$1,553,433**	**$1,553,433**	**$1,553,433**	**$1,553,433**	**$1,553,433**	**$1,553,433**
5								
6	**Cash Farm Expenses**							
7	**Operating Expenses**	$713,189	$713,189	$713,189	$713,189	$713,189	$713,189	$713,189
8	**Interest on Operating Expenses** (7%)	$0	$0	$0	$0	$0	$0	$0
9	**Interest on Principal** (7%)	$0	$0	$0	$0	$0	$0	$0
10	**Total Cash Expenses** (Line 7 + Line 8 + Line 9)	**$713,189**	**$713,189**	**$713,189**	**$713,189**	**$713,189**	**$713,189**	**$713,189**
11								
12	**Net Cash Farm Income** (Line 4 - Line 10)	**$840,244**	**$840,244**	**$840,244**	**$840,244**	**$840,244**	**$840,244**	**$840,244**
13								
14	**Non-cash Adjustments:**							
15	**Depreciation** (straight line with no salvage value)	**$138,979**	**$138,979**	**$138,979**	**$138,979**	**$138,979**	**$138,979**	**$84,911**
16								
17	**Net Farm Income** (Line 12 - Line 15)	**$701,265**	**$701,265**	**$701,265**	**$701,265**	**$701,265**	**$701,265**	**$755,333**
18								
19	**Construction and Equipment**							
20	(initial outlay and recurring costs)	$0	$41,130	$216,610	$2,660	$33,570	$28,700	$4,900
21	**Repayment**	$0	$0	$0	$0	$0	$0	$0
22								
23	**Cash Value** (income-debt)	$840,244	$840,244	$840,244	$840,244	$840,244	$840,244	$840,244
24	**Assets** (Lag Line 24 + Line 20 - Line 15)	$610,714	$512,865	$590,497	$454,178	$348,770	$238,491	$158,480
25	**Net Value** (Line 23 + Line 24)	$1,450,957	$1,353,109	$1,430,740	$1,294,422	$1,189,013	$1,078,735	$998,724
26								
27	**Taxable Income** (Line 4 - Line 10 - Line 15 - Line 20)	$701,265	$660,135	$484,655	$698,605	$667,695	$672,565	$750,433
28	**Income Taxes** (Line 27 * 6.5%)	$45,582	$42,909	$31,503	$45,409	$43,400	$43,717	$48,778
29								
30	**Total Cash Outflow** (Line 10 + Line 20 + Line 28)	**$758,772**	**$797,228**	**$961,302**	**$761,259**	**$790,160**	**$785,606**	**$766,868**
31								
32	**Net Cash Flow** (Line 4 - Line 30)	**$794,662**	**$756,205**	**$592,131**	**$792,175**	**$763,274**	**$767,827**	**$786,566**

Appendix Table 2.3 Enterprise budget for a commercial channel catfish (*Ictalurus punctatus*) operation

Size of Operation	**136 acres**	
GROSS RECEIPTS	**Total**	**Per acre**
Sale of Fingerling (7.65 million @ $0.084 each)	*$642,600*	*$4,725*
Sale of Culled Female Brood Fish (10,000 lbs @ $0.50 each)	*$5,000*	*$37*
Total Gross Receipts	**$647,600**	**$4,762**
VARIABLE COSTS		
Brood Fish	*$48,000*	*$353*
Hatchery Labor	*$20,792*	*$153*
Contractual Labor	*$36,900*	*$271*
Farm Operation Costs	*$183,160*	*$1,347*
Hatchery Costs	*$3,900*	*$29*
Repairs and Maintenance (Machinery and Equipment)	*$8,950*	*$66*
Interest on Operating Expenses	*$21,647*	*$159*
Total Variable Costs (TVC)	**$323,349**	**$2,378**
Income above variable costs	**$324,251**	**$2,384**
FIXED COSTS		
Salaries and Related Expenses	*$115,900*	*$852*
Insurance	*$6,350*	*$47*
Repairs and Maintenance (Ponds and Hatchery)	*$2,500*	*$18*
Interest on Capital Investment	*$120,067*	*$883*
Depreciation (Building and Equipment)	*$110,176*	*$810*
Office and Personnel Overhead Costs	*$18,120*	*$133*
Total fixed Costs (TFC)	**$373,113**	**$2,743**
TOTAL EXPENSES (TVC + TFC)	**$696,462**	**$5,121**
Net returns above total expenses	**-$48,862**	**-$359**
Breakeven price to cover variable costs (per fingerling sold)	**$0.042**	
Breakeven price to cover total costs (per fingerling sold)	**$0.091**	

APPENDIX TO CHAPTER 3

Appendix Table 3.1 Enterprise budget for commercial channel catfish (*Ictalurus punctatus*) operation

Size of operation	**136 acres**	
GROSS RECEIPTS	**Total**	**Per acre**
Sale of Fingerling (7.65 million @ $0.084 each)	*$642,600*	*$4,725*
Sale of Culled Female Brood Fish (10,000 lbs @ $0.50 each)	*$5,000*	*$37*
Total Gross Receipts	**$647,600**	**$4,762**
VARIABLE COSTS		
Brood Fish	*$48,000*	*$353*
Hatchery Labor	*$20,792*	*$153*
Contractual Labor	*$36,900*	*$271*
Farm Operation Costs	*$183,160*	*$1,347*
Hatchery Costs	*$3,900*	*$29*
Repairs and Maintenance (Machinery and Equipment)	*$8,950*	*$66*
Interest on Operating Expenses	*$21,647*	*$159*
Total Variable Costs (TVC)	**$323,349**	**$2,378**
Income above variable costs	**$324,251**	**$2,384**
FIXED COSTS		
Salaries and Related Expenses	*$115,900*	*$852*
Insurance	*$6,350*	*$47*
Repairs and Maintenance (Ponds and Hatchery)	*$2,500*	*$18*
Interest on Capital Investment	*$120,067*	*$883*
Depreciation (Building and Equipment)	*$110,176*	*$810*
Office and Personnel Overhead Costs	*$18,120*	*$133*
Total fixed Costs (TFC)	**$373,113**	**$2,743**
TOTAL EXPENSES (TVC + TFC)	**$696,462**	**$5,121**
Net returns above total expenses	**-$48,862**	**-$359**
Breakeven price to cover variable costs (per fingerling sold)	**$0.042**	
Breakeven price to cover total costs (per fingerling sold)	**$0.091**	

APPENDIX TO CHAPTER 4

Appendix Table 4.1 Variable and fixed costs for 136-acre CB hybrid catfish operation, using normal[7] channel catfish female injected with 20 μg/kg priming dose followed by 100 μg/kg resolving dose LHRHa as ovulating agent

	Unit	Quantity	Price or Cost	Value or cost
VARIABLE COSTS				
Female channel catfish brood fish	lb	22,804	$2.00	*$45,608*
Male blue catfish broodfish	lb	4,751	$3.50	*$16,628*
Brood Fish				**$62,236**
Hatchery Labor	person days	1644	$52.00	*$85,472*
Payroll Tax Expense (11.5%)				*$9,829*
Workmen's Compensation (4.4%)				*$3,761*
Hired Labor				**$99,062**
Seining	load	7	$2,875.00	*$21,114*
Hauling	load	7	$2,050.00	*$15,055*
Contractual Labor				**$36,169**
Fuel and oil ($52/acre)	per acre	1	$52.00	*$7,070*
Electrical ($180/acre)	per acre	1	$180.00	*$24,480*
Supplies ($19/acre)	per acre	1	$19.00	*$2,580*
Chemicals ($74/acre)	per acre	1	$74.00	*$10,060*
Feed	ton	241	$300.00	*$72,280*
Farm Operation Costs				**$116,470**
Supplies				*$1,590*
Chemicals				*$830*
Hormones				*$18,710*
Hybrid Production Costs				**$21,130**
Trucks ($30/acre)	per acre	1	$30.00	*$4,080*
Tractors ($11.75/acre)	per acre	1	$11.75	*$1,600*
Aerators ($24/acre)	per acre	1	$24.00	*$3,270*
Repairs and Maintenance (Machinery and Equipment)				**$8,950**
Interest on Operating Capital				**$23,010**
TOTAL VARIABLE COSTS (TVC)				**$367,027**

Appendix Table 4.1 (Continued)

	Unit	Quantity	Price or Cost	Value or cost
FIXED COSTS				
Manager	person year	1	$75,000	*$75,000*
Assistant Manager	person year	1	$25,000	*$25,000*
Payroll Tax Expense (11.5%)				*$11,500*
Workmen's Compensation (4.4%)				*$4,400*
Salaries and Related Expenses				**$115,900**
General ($32/acre)	per acre	1	$32	*$4,350*
Vehicle				*$2,000*
Insurance				**$6,350**
Hatchery				*$500*
Ponds				*$2,000*
Repairs and Maintenance (Ponds and Hatchery)				**$2,500**
Interest on Capital Investment				**$136,884**
Depreciation (Building and Equipment)				**$138,979**
Supplies				*$700*
Telephone				*$1,000*
Trash				*$900*
Dues and Subscriptions				*$500*
Travel				*$2,000*
Contributions				*$1,000*
Accounting and Legal				*$7,500*
Taxes and Licences				*$3,520*
Miscellaneous				*$1,000*
Office and Personnel Overhead Costs				**$18,120**
TOTAL FIXED COSTS (TFC)				**$418,733**
TOTAL EXPENSES (TVC + TFC)				**$785,760**

Appendix Table 4.2 Income statement for 136-acre CB hybrid catfish operation, using normal[7] channel catfish female injected with 20 µg/kg priming dose followed by 100 µg/kg resolving dose LHRHa as ovulating agent, over a 20-year planning horizon

	ITEM	Year → 0	1	2	3	4	5	6
1	**Cash Farm Income**							
2	**Sale fingerling**	$0	$0	$256,275	$768,825	$768,825	$768,825	$768,825
3	**Sale brood fish**	$0	$0	$0	$3,801	$3,801	$3,801	$3,801
4	**Total Cash Income** (Line 2 + Line 3)	**$0**	**$0**	**$256,275**	**$772,626**	**$772,626**	**$772,626**	**$772,626**
5								
6	**Cash Farm Expenses**							
7	**Operating Expenses**	$0	$97,225	$459,954	$450,303	$450,303	$450,303	$450,303
8	**Interest on Operating Expenses** (7%)	**$0**	**$0**	**$11,167**	**$23,010**	**$0**	**$0**	**$0**
9	**Interest on Principal** (7%)	**$0**	**$62,308**	**$113,873**	**$136,884**	**$128,050**	**$118,024**	**$104,252**
10	**Total Cash Expenses** (Line 7 + Line 8 + Line 9)	**$0**	**$159,533**	**$584,994**	**$610,197**	**$578,353**	**$568,327**	**$554,555**
11								
12	**Net Cash Farm Income** (Line 4 - Line 10)	**$0**	**-$159,533**	**-$328,719**	**$162,428**	**$194,273**	**$204,299**	**$218,071**
13								
14	**Non-cash Adjustments:**							
15	**Depreciation** (straight line with no salvage value)	**$65,258**	**$138,979**	**$138,979**	**$138,979**	**$138,979**	**$138,979**	**$138,979**
16								
17	**Net Farm Income** (Line 12 - Line 15)	**-$65,258**	**-$298,512**	**-$467,698**	**$23,450**	**$55,294**	**$65,320**	**$79,092**
18								
19	**Construction and Equipment**							
20	(initial outlay and recurring costs)	$890,120	$577,110	$0	$36,230	$51,040	$7,560	$199,140
21	**Repayment**	**$0**	**-$159,533**	**-$328,719**	**$162,428**	**$194,273**	**$204,299**	**$218,071**
22								
23	**Cash Value** (income-debt)	**-$890,120**	**-$1,786,296**	**-$2,284,202**	**-$1,666,856**	**-$1,491,779**	**-$1,285,014**	**-$1,252,311**
24	**Assets** (Lag Line 24 + Line 20 - Line 15)	$824,863	$1,262,994	$1,124,016	$1,021,267	$933,329	$801,910	$862,072
25	**Net Value** (Line 23 + Line 24)	**-$65,258**	**-$523,302**	**-$1,160,186**	**-$645,589**	**-$558,450**	**-$483,104**	**-$390,240**
26								
27	**Taxable Income** (Line 4 - Line 10 - Line 15 - Line 20)	-$955,378	-$875,622	-$467,698	-$12,780	$4,254	$57,760	-$120,048
28	**Income Taxes** (Line 27 * 6.5%)				-$831	$277	$3,754	-$7,803
29								
30	**Total Cash Outflow** (Line 10 + Line 20 + Line 28)	$890,120	$736,643	$584,994	$645,597	$629,670	$579,641	$745,892
31								
32	**Net Cash Flow** (Line 4 - Line 30)	-$890,120	-$736,643	-$328,719	$127,029	$142,956	$192,984	$26,734

Appendix Table 4.2 (Continued)

	ITEM	Year → 7	8	9	10	11	12	13
1	**Cash Farm Income**							
2	**Sale fingerling**	$768,825	$768,825	$768,825	$768,825	$768,825	$768,825	$768,825
3	**Sale brood fish**	$3,801	$3,801	$3,801	$3,801	$3,801	$3,801	$3,801
4	**Total Cash Income** (Line 2 + Line 3)	**$772,626**	**$772,626**	**$772,626**	**$772,626**	**$772,626**	**$772,626**	**$772,626**
5								
6	**Cash Farm Expenses**							
7	**Operating Expenses**	$450,303	$450,303	$450,303	$450,303	$450,303	$450,303	$450,303
8	**Interest on Operating Expenses** (7%)	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**
9	**Interest on Principal** (7%)	**$102,927**	**$89,578**	**$75,036**	**$60,262**	**$61,934**	**$71,519**	**$58,063**
10	**Total Cash Expenses** (Line 7 + Line 8 + Line 9)	**$553,230**	**$539,881**	**$525,339**	**$510,565**	**$512,237**	**$521,822**	**$508,366**
11								
12	**Net Cash Farm Income** (Line 4 - Line 10)	**$219,396**	**$232,745**	**$247,287**	**$262,061**	**$260,389**	**$250,804**	**$264,260**
13								
14	**Non-cash Adjustments:**							
15	**Depreciation** (straight line with no salvage value)	**$138,979**	**$138,979**	**$138,979**	**$138,979**	**$138,979**	**$138,979**	**$138,979**
16								
17	**Net Farm Income** (Line 12 - Line 15)	**$80,417**	**$93,766**	**$108,308**	**$123,082**	**$121,410**	**$111,825**	**$125,281**
18								
19	**Construction and Equipment**							
20	(initial outlay and recurring costs)	$28,700	$25,000	$36,230	$285,940	$397,330	$58,570	$28,700
21	**Repayment**	**$219,396**	**$232,745**	**$247,287**	**$262,061**	**$260,389**	**$250,804**	**$264,260**
22								
23	**Cash Value** (income-debt)	**-$1,060,291**	**-$839,197**	**-$613,598**	**-$622,704**	**-$761,317**	**-$578,668**	**-$329,653**
24	**Assets** (Lag Line 24 + Line 20 - Line 15)	$751,793	$637,815	$535,066	$682,028	$940,379	$859,971	$749,692
25	**Net Value** (Line 23 + Line 24)	**-$308,498**	**-$201,383**	**-$78,532**	**$59,324**	**$179,062**	**$281,302**	**$420,039**
26								
27	**Taxable Income** (Line 4 - Line 10 - Line 15 - Line 20)	$51,717	$68,766	$72,078	-$162,858	-$275,920	$53,255	$96,581
28	**Income Taxes** (Line 27 * 6.5%)	$3,362	$4,470	$4,685	-$10,586	-$17,935	$3,462	$6,278
29								
30	**Total Cash Outflow** (Line 10 + Line 20 + Line 28)	$585,292	$569,351	$566,254	$785,919	$891,632	$583,854	$543,344
31								
32	**Net Cash Flow** (Line 4 - Line 30)	$187,334	$203,275	$206,372	-$13,294	-$119,007	$188,772	$229,282

Appendix Table 4.2 (Continued)

	ITEM	Year → 14	15	16	17	18	19	20
1	**Cash Farm Income**							
2	**Sale fingerling**	$768,825	$768,825	$768,825	$768,825	$768,825	$768,825	$768,825
3	**Sale brood fish**	$3,801	$3,801	$3,801	$3,801	$3,801	$3,801	$3,801
4	**Total Cash Income** (Line 2 + Line 3)	**$772,626**	**$772,626**	**$772,626**	**$772,626**	**$772,626**	**$772,626**	**$772,626**
5								
6	**Cash Farm Expenses**							
7	**Operating Expenses**	$450,303	$450,303	$450,303	$450,303	$450,303	$450,303	$450,303
8	**Interest on Operating Expenses** (7%)	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**
9	**Interest on Principal** (7%)	**$41,574**	**$21,921**	**$3,772**	**$0**	**$0**	**$0**	**$0**
10	**Total Cash Expenses** (Line 7 + Line 8 + Line 9)	**$491,877**	**$472,224**	**$454,075**	**$450,303**	**$450,303**	**$450,303**	**$450,303**
11								
12	**Net Cash Farm Income** (Line 4 - Line 10)	**$280,749**	**$300,402**	**$318,551**	**$322,323**	**$322,323**	**$322,323**	**$322,323**
13								
14	**Non-cash Adjustments:**							
15	**Depreciation** (straight line with no salvage value)	**$138,979**	**$138,979**	**$138,979**	**$138,979**	**$138,979**	**$138,979**	**$84,911**
16								
17	**Net Farm Income** (Line 12 - Line 15)	**$141,770**	**$161,423**	**$179,572**	**$183,344**	**$183,344**	**$183,344**	**$237,412**
18								
19	**Construction and Equipment**							
20	(initial outlay and recurring costs)	$0	$41,130	$216,610	$2,660	$33,570	$28,700	$4,900
21	**Repayment**	**$280,749**	**$300,402**	**$53,892**	**$0**	**$0**	**$0**	**$0**
22								
23	**Cash Value** (income-debt)	**-$32,415**	**$246,510**	**$318,551**	**$322,323**	**$322,323**	**$322,323**	**$322,323**
24	**Assets** (Lag Line 24 + Line 20 - Line 15)	$610,714	$512,865	$590,497	$454,178	$348,770	$238,491	$158,480
25	**Net Value** (Line 23 + Line 24)	**$578,298**	**$759,375**	**$909,047**	**$776,501**	**$671,092**	**$560,814**	**$480,803**
26								
27	**Taxable Income** (Line 4 - Line 10 - Line 15 - Line 20)	$141,770	$120,293	-$37,038	$180,684	$149,774	$154,644	$232,512
28	**Income Taxes** (Line 27 * 6.5%)	$9,215	$7,819	-$2,407	$11,744	$9,735	$10,052	$15,113
29								
30	**Total Cash Outflow** (Line 10 + Line 20 + Line 28)	$501,092	$521,173	$668,278	$464,707	$493,608	$489,055	$470,316
31								
32	**Net Cash Flow** (Line 4 - Line 30)	$271,534	$251,453	$104,348	$307,918	$279,017	$283,571	$302,309

Appendix Table 4.3 Enterprise budget for a commercial channel catfish (*Ictalurus punctatus*) operation

	Total	Per acre
GROSS RECEIPTS	**Total**	**Per acre**
Sale of Fingerling (7.65 million @ $0.084 each)	*$642,600*	*$4,725*
Sale of Culled Female Brood Fish (10,000 lbs @ $0.50 each)	*$5,000*	*$37*
Total Gross Receipts	**$647,600**	**$4,762**
VARIABLE COSTS		
Brood Fish	*$48,000*	*$353*
Hatchery Labor	*$20,792*	*$153*
Contractual Labor	*$36,900*	*$271*
Farm Operation Costs	*$183,160*	*$1,347*
Hatchery Costs	*$3,900*	*$29*
Repairs and Maintenance (Machinery and Equipment)	*$8,950*	*$66*
Interest on Operating Expenses	*$21,647*	*$159*
Total Variable Costs (TVC)	**$323,349**	**$2,378**
Income above variable costs	**$324,251**	**$2,384**
FIXED COSTS		
Salaries and Related Expenses	*$115,900*	*$852*
Insurance	*$6,350*	*$47*
Repairs and Maintenance (Ponds and Hatchery)	*$2,500*	*$18*
Interest on Capital Investment	*$120,067*	*$883*
Depreciation (Building and Equipment)	*$110,176*	*$810*
Office and Personnel Overhead Costs	*$18,120*	*$133*
Total fixed Costs (TFC)	**$373,113**	**$2,743**
TOTAL EXPENSES (TVC + TFC)	**$696,462**	**$5,121**
Net returns above total expenses	**-$48,862**	**-$359**
Breakeven price to cover variable costs (per fingerling sold)	**$0.042**	
Breakeven price to cover total costs (per fingerling sold)	**$0.091**	

Appendix Table 4.4 Enterprise budget for using carp pituitary extract (CPE) at 2mg/kg priming dose followed by 8 mg/kg resolving dose for the ovulation of channel catfish, *Ictalurus punctatus*, females and fertilization with blue catfish, *I. furcatus*, sperm to produce hybrid catfish embryos in a commercial CB hybrid catfish operation

Size of Operation	**136 acres**	
GROSS RECEIPTS		
Sale of Fingerling (11.41 million @ $0.1350 each)	*$1,539,945*	*$11,323*
Sale of Culled Female Brood Fish (26,977 lbs @ $0.50 each)	*$13,488*	*$99*
Total Gross Receipts	**$1,553,433**	**$11,422**
VARIABLE COSTS		
Brood Fish	*$220,871*	*$1,624*
Hatchery Labor	*$109,744*	*$807*
Contractual Labor	*$72,446*	*$533*
Farm Operation Costs	*$206,430*	*$1,518*
Hybrid Production Costs	*$81,700*	*$601*
Repairs and Maintenance (Machinery and Equipment)	*$8,950*	*$66*
Interest on Operating Capital	*$27,750*	*$204*
Total Variable Costs (TVC)	**$727,891**	**$5,352**
Income above variable costs	**$825,542**	**$6,070**
FIXED COSTS		
Salaries and Related Expenses	*$115,900*	*$852*
Insurance	*$6,350*	*$47*
Repairs and Maintenance (Ponds and Hatchery)	*$2,500*	*$18*
Interest on Capital Investment	*$141,623*	*$1,041*
Depreciation (building and equipment)	*$138,979*	*$1,022*
Office and Personnel Overhead Costs	*$18,120*	*$133*
Total fixed Costs (TFC)	**$423,472**	**$3,114**
TOTAL EXPENSES (TVC + TFC)	**$1,151,362**	**$8,466**
Net returns above total expenses	**$402,071**	**$2,956**
Breakeven price to cover variable costs (per fingerling sold)	**$0.064**	
Breakeven price to cover total costs (per fingerling sold)	**$0.101**	

Appendix Table 4.5 Fry and fingerling cost of production for channel catfish commercial operation, and for using channel catfish female injected with CPE at 2 mg/kg priming dose followed by 8 mg/kg resolving dose under commercial settings and using select channel catfish female injected with LHRHa at 20 μg/kg priming dose followed by 100 μg/kg resolving dose under research settings, in the production of eggs for fertilization with blue catfish sperm to produce hybrid catfish embryos

	Channel Catfish		**Normal CPE**		**Select LHRHa**	
Quantity and Cost of Production	*Fry*	*Fingerling*	*Fry*	*Fingerling*	*Fry*	*Fingerling*
Number (million)	12.75	7.65	13.42	11.41	13.9	11.815
Average weight (g)		30		30		30
Total weight (kg)		229,500		342,210		354,450
Cost of production						
each	**$0.008**	**$0.029**	**$0.034**	**$0.024**	**$0.014**	**$0.021**
per inch		**$0.0048**		**$0.0040**		**$0.0035**
per kg		**$0.952**		**$0.804**		**$0.696**