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Analysis of U.S. aquacultural producer preferences for genetic improvement and cryopreservation

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ANALYSIS OF U.S. AQUACULTURAL PRODUCER PREFERENCES FOR GENETIC IMPROVEMENT AND CRYOPRESERVATION

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ABSTRACT

Aquaculture industries in the U.S. generate $1 billion in farm-level sales. Genetic improvement of fish stocks may be a way to increase the market share of aquaculture within the U.S. seafood market as well as the market share within the world market. This study evaluates the preferences, beliefs, and opinions of aquaculture producers across the U.S. about topics such as cryopreservation, genetic improvement, and the future of the aquaculture industry. Willingness-to-pay values for specific genetic improvements by aquaculture grow-out producers were elicited.

A national survey of aquaculture producers was used to elicit the information used in the analysis. The survey included sections for hatchery producers, foodfish grow-out producers, and demographic information. Hatchery producers were asked questions relating to their production methods and costs as well as their opinions and knowledge about cryopreservation and its benefits. Producer opinions of cryopreservation services were analyzed using an ordered probit model. Choice-based conjoint analysis was used to elicit relative importance and willingness-to-pay estimates for specific genetic attributes from foodfish grow-out producers. The attributes were growth rate, disease resistance, and resistance to 10% lower dissolved oxygen levels. The choice-based responses were analyzed using a conditional logit model. Contingent valuation questions were also asked to grow-out producers so that willingness-to-pay estimates for supply reliability and genetic uniformity could be calculated. The contingent valuation responses were analyzed using a double-hurdle model.

Results showed that the hybrid striped bass hatchery producers were the most interested in cryopreservation services. Growth rate proved to be the most important genetic attribute available to foodfish grow-out producers. Producers were willing to pay a 22% price premium to

acquire a fish stock with a 20% improved growth rate. Trout producers were willing to pay the most for supply reliability. Overall, producers were willing to pay an 18% premium to improve the genetic uniformity and increase the reliability of supply.

This research shows an interest in the genetic improvement of aquaculture foodfish stocks as well as an interest by hatcheries for cryopreservation services. More research is needed to determine the specific costs hatcheries would need to bear to incorporate cryopreservation services.

CHAPTER I: INTRODUCTION

A. Background

Aquaculture is defined as the cultivation of aquatic plants and animals, within a controlled environment, for all or part of their life cycle (Selock 2001). Within the United States, aquaculture primarily consists of the production of foodfish, ornamental fish, baitfish, mollusks, crustaceans, aquatic plants, and reptiles such as alligators and turtles (ERS 2003). From the 1980s through the 90s, rapid growth occurred within many aquaculture industries, resulting in the quadrupling of U.S. aquaculture production. Foodfish production, which includes catfish, trout, salmon, tilapia, hybrid striped bass, sturgeon, yellow perch, and walleye[1], make up approximately two-thirds of total aquaculture sales (NASS 2000; ERS 2003). According to a 2001 report, U.S. aquaculture contributed 200 to 300 million pounds of edible weight to the total U.S. seafood supply (Selock 2001). In recent years, there has been a continued increase in the percentage of American-consumed seafood that comes from aquaculture, as opposed to seafood acquired through wild catch (Harvey 2003). Whether consumers know it or not, approximately 30% of their seafood is being raised through aquaculture production.

According to the 1998 Census of Aquaculture, U.S. farm-level sales were $978 million, with an estimated 4,028 farms (Table I-1) (LASS 2000). The Southern region contains about 68% of the aquaculture farms in the U.S., and is responsible for 65% of total U.S. sales. Mississippi alone accounts for over $290 million in sales (NASS 2004). The food and sport fish sectors dominate the total aquaculture industry, representing over 70% of the total sales. Aquaculture is one of the fastest growing segments in agriculture. Expectations are that aquaculture products will continue to penetrate seafood markets as production systems become

[1] A complete list of scientific names is included in Appendix XII.

more competitive with wild-harvests. Aquaculture provides a means for consumers to consistently enjoy the species of their choice.

Table I-1. Regional Aquaculture Statistics.

State	Total Aquaculture		
	Farms	Sales ($1,000)	Percent of U.S.
Alabama	259	59,694	6.1%
Arkansas	222	84,120	8.6%
Louisiana	683	53,220	5.4%
Mississippi	419	290,382	29.7%
United States	4,028	978,012	100.0%

Source: Louisiana Agricultural Statistics Service 2000.

B. World Aquaculture

The use of aquaculture to reduce risks and improve gains is not restricted to the United States. Seafood industries around the world are increasing their reliance on aquaculture products as a way to increase seafood production (Harvey 2003). The Food and Agriculture Organization (FAO) of the United Nations estimated that, in 1999, aquaculture production reached 33 million metric tons. The FAO estimates the 2001 numbers to be close to 38 million tons. This is an increase of 15% in just 2 years. China, and the rest of Asia, are the dominant suppliers when it comes to aquaculture production. China is responsible for over 70% of the total volume of world aquaculture production, and close to 50% of the total world value. Figure I-1 shows the major producers of aquaculture products in 2000. The figure lists the quantities produced as well as the value of production for each country. India was the second largest producer of aquaculture products in terms of quantity, producing just over 2 million tons, whereas Japan was the second largest in terms of the value of production, with nearly $4.5 billion (WAO 2002).

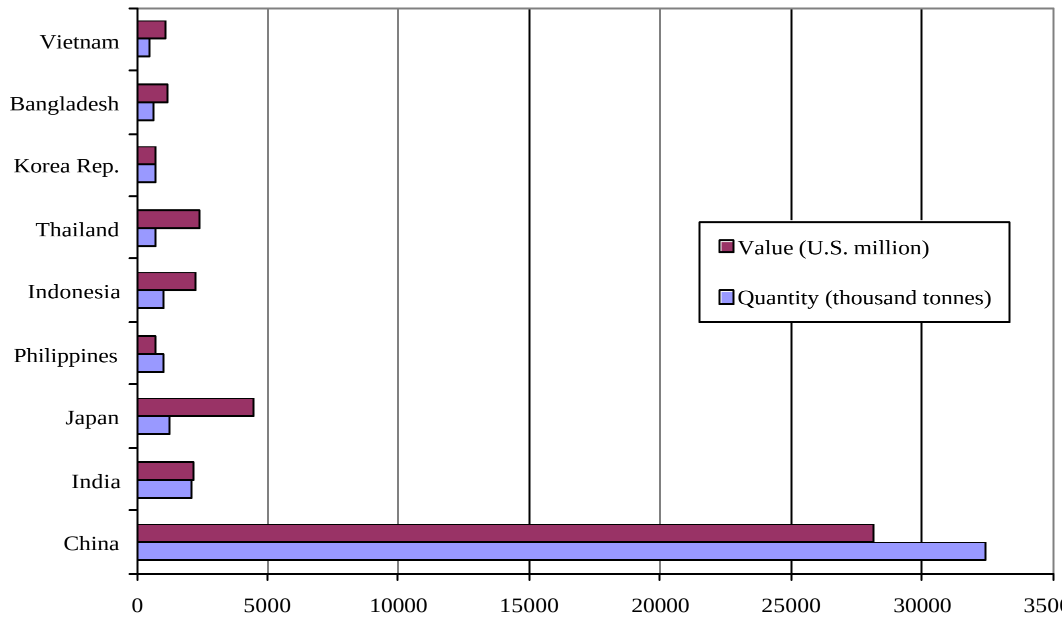
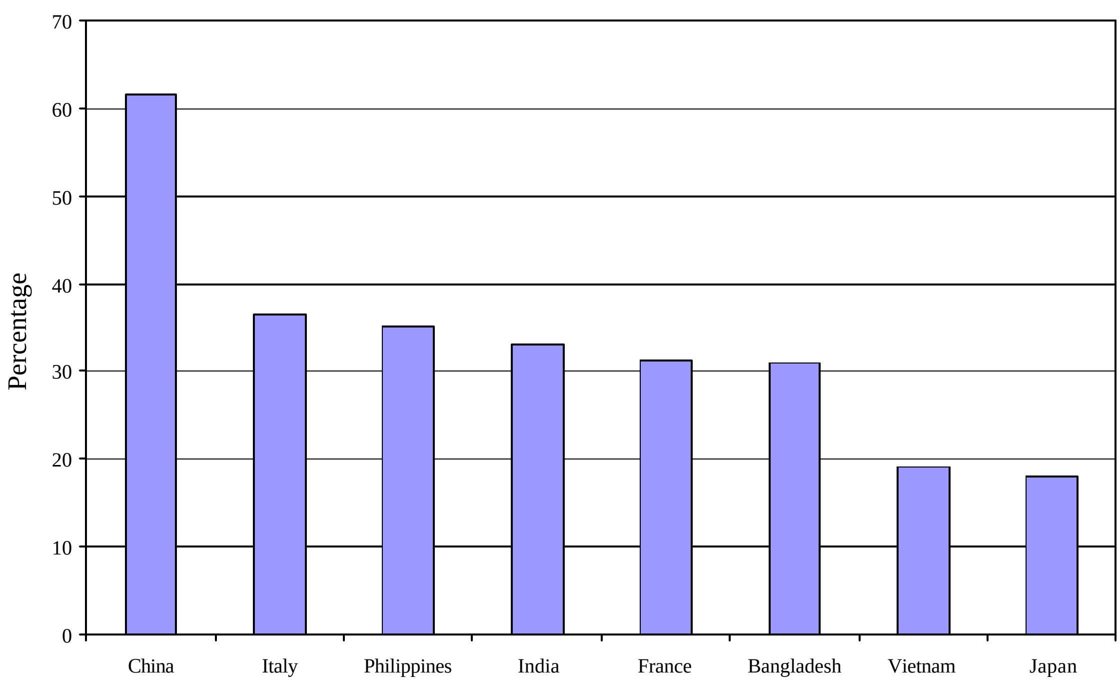


Figure I-1. Aquaculture Production: Major Producer Countries In 2000.
Source: Food Agricultural Organization 2004.

One of the fastest growing aquaculture producing regions has been South America, led by Chile (WAO 2004). Although South American countries are not yet competitive with the leading countries represented in Figure I-1, they may be in the future. Many countries around the world see the introduction of aquaculture as a way to promote international trade as well as a means to increase their revenues. This trend is especially evident in developing countries, which may be the reason why South America is incorporating more aquaculture into their production activities. Nineteen ninety-six data from the FAO (Figure I-2) shows how important aquaculture systems are to the total aquatic production of specific countries. Over half of China's seafood production comes from aquaculture. India, which produces about one-third of its total aquatic sales through aquaculture, generates over $1 billion per year from aquaculture farms.

C. Louisiana Aquaculture

The Southern region of the United States, of which Louisiana is a part, includes 6 of the top 10 states in terms of the value of aquacultural products (NASS 2004). Aquaculture is a major part of Louisiana's heritage and culture. Louisiana is famous for its seafood commerce, most notably in crawfish. Farming of crawfish (*Procambarus clarkii*) in Louisiana began in the 1960s, and now produces about 90% of the total domestic crop, yielding up to 60 million pounds per year. The industry's impact on the state's economy typically exceeds $50 million a year. Another valuable product to Louisiana aquaculture is channel catfish (*Ictalurus punctatus*). As of 2003, the Louisiana catfish industry had a farm value of over $19 million while producing almost 34 million pounds. In 2003, the total farm value of Louisiana aquaculture was $120.19 million and the total value including processing and marketing was $198.31 million (Lutz and Romaire 2004). The impact that aquaculture has on Louisiana goes beyond monetary sale values associated with production. Some examples of this include the people in the state who depend on aquaculture to make a living, as well as the money that is generated through tourism related to an attraction to commodities such as crawfish.



<u>Figure I-2. Percentage Of Seafood Production Coming From Aquaculture Systems.</u>
Source: FAO Fisheries Department 1996.

D. Seafood Prices

As a result of the continued global increase in the production of some seafood products, producers and consumers are experiencing a steady decline in the price per pound of these products (Selock 2001). The catfish industry provides a good example. In 2000, catfish processors were receiving an average of $2.38 per pound. By 2003, they were averaging $2.05 per pound (Harvey 2004). Over the past 6 years, however, the U.S. trout industry has been more stable. The average price per pound in 1998 was $1.04 and the 2003 price was $1.09. The highest price during this timeframe was $1.13, which was received in 2001, and the lowest price was the 1998 price of $1.04 (NASS 2004).

E. Production Techniques

A variety of production systems are used in aquaculture industries. The type of species farmed, the way in which spawning takes place, and the method in which the fish are raised are factors that affect how animals are farmed. For example, baitfish, ornamental fish, crustaceans, and algae may be profitably raised using a variety of aquacultural systems. The most prominent products, however, are foodfish. This sector is responsible for nearly 70% of the total sales of aquacultural products (NASS 2004). The foodfish sector encompasses catfish (*Ictalurus* species), hybrid striped bass (*Morone* species), rainbow trout (*Oncorhynchus mykiss*), tilapia (*Tilapia* and *Oreochromis* species), salmon (*Salmo* and *Oncorhynchu* species) sand other fish species that are sold to consumers.

Methods for aquacultural production are presented in Figure I-3. Pond production is by far the most prevalent, accounting for over 60% of the production methods used in the U.S. (NASS 2004). On a global scale, pond production accounts for over 90% of total aquacultural production (NATFISH 2004). Catfish are the most prevalent species to be farmed in ponds in the United States. However, other species such as bass, crawfish, and baitfish are also commonly produced in pond systems. This form of production refers to fingerlings (seed stock) being placed into ponds where they are fed a formula feed until they reach a desired market size. This size varies among species. For example, catfish producers tend to sell fish when they reach an average of 0.75 to 2 pounds in weight (Jensen 1995).

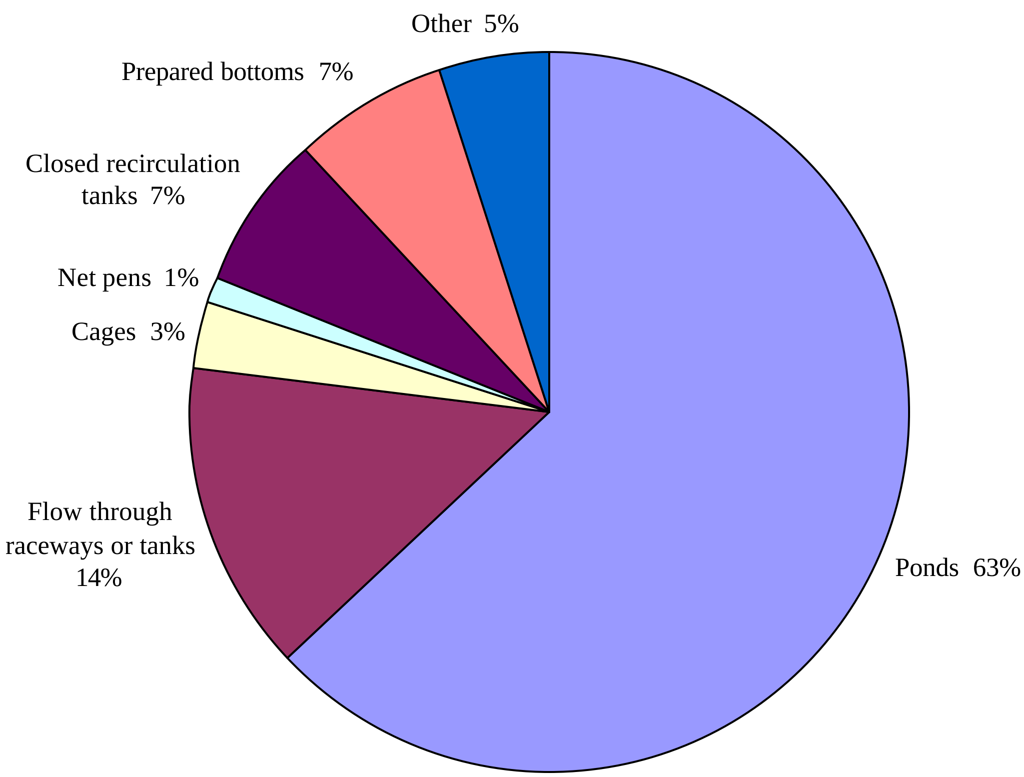


Figure I-3. Production Methods Used In Aquaculture Production.
Source: NASS 1997 census.

The second most prevalent method of aquaculture production (Figure I-3) is the flow-through method at 14%. This method can be used in raceways or tanks. The distinguishing feature of the flow-through method is that water is used only once in the production cycle. Flow-through systems are typically land-based systems in which there is a water inlet at one end and an outlet at the other. The water flow is strictly controlled. Raceways are concrete structures with an average depth of three to four feet and an approximate length to width ratio of 6:1. Some of the advantages of raceways are the utilization of higher stocking rates, the ease of maintaining water quality, and decreased aeration requirements relative to ponds. The use of raceways or tanks provides the ability to keep an accurate inventory of the crop, as well as making harvesting relatively easy, compared to ponds. Raceway production is also more intensive and allows for more control by managers. A disadvantage is that the stock is vulnerable to quality problems of the local water supply. Another disadvantage may be the cost of pumping the 400 to 4,000 gallons of water per minute that are needed to run these types of operations. The most common fish produced in flow-through systems are rainbow trout, although channel catfish, largemouth bass, hybrid striped bass, and exotic species are also produced in this system efficiently (NATFISH 2004; KSU 2004).

Closed recirculation systems utilize the same general concepts as flow-through systems, except for water use. Seven percent of U.S. producers utilize a closed recirculation system (Figure I-3). The species farmed using this system are the same as those farmed with the flow-through system. However, closed systems are typically the preferred method for the production of shellfish and crustaceans. The difference between the two methods is that the water is treated to maintain its quality, and then re-used within a closed recirculation tank, as opposed to being used only once with the flow-through systems. Specific water flow is still important, and pumps are used to maintain optimal water quality. The tanks may be constructed of steel, fiberglass, or concrete, and typically have a cylindrical shape. One advantage of the recirculating tanks is the ease of fish removal. Individual fish, or the entire stock, can be extracted with greater ease relative to pond production. Some other advantages include a reduction in water costs, site flexibility, waste management control, increased stocking density, and fish health control.

Another important quality of a closed system is the ability to safely farm exotic or genetically modified organisms. Although these systems allow for a more efficient use of water, they are expensive to set up and operate (NATFISH 2004; AWI 2004; Dunning, Losordo, and Hobbs 1998; Rawlinson and Forster 2000).

Even though cages and net pens account for only about 4% of U.S. production, they are an efficient use of space. The difference between cages and net pens is simply the material used to enclose the fish. For each method, the enclosure is within an existing resource of water, such as a lake. The water flows freely through the net or cage. These are typically used when it is not practical to operate an open pond culture, and it is often a more labor-intensive production method. Some advantages include the many types of water resources that can be used, a relatively small initial investment, and ease of harvesting. Disadvantages include the potential for low dissolved oxygen levels, rapid spread of diseases, vandalism, and theft. Catfish, striped bass, trout, tilapia, and carp are just a few of the many species that are capable of being raised in cages or pens (Masser 1997; Masser 1988).

Prepared bottom methods, which represent about 7% of the production methods used, are principally utilized in shellfish production. The bottoms of tidal waters are prepared with materials that enable the shellfish to grow and survive. For example, pieces of clam or oyster shells may be added to the waters so that the oyster larvae (spat) will have objects to attach themselves to. There is also off-bottom production which is commonly used in shellfish production. These include rafts or racks that are attached to sacks of oysters and float in the water, with the shellfish remaining below the surface. It is believed that the off-bottom methods allow oysters to grow to market size faster than the prepared bottom methods (NATFISH 2004; Louisiana Sea Grant College Program 2004).

F. Spawning Techniques

Spawning of aquatic species may be done naturally or artificially. Natural spawning occurs when producers allow fish to spawn and fertilize the eggs on their own. Natural spawning is done by keeping males and females of a particular species in the same pond, and harvesting the fertilized eggs. Artificial spawning typically consists of fertilizing the eggs in a hatchery. Artificial spawning begins with the taking of males and females from a broodstock pond, or capturing them from the wild. Once captured, eggs are collected from females and sperm is collected from the males. In the hatchery, the sperm of the males is mixed with the eggs of the females so that fertilization can occur. With this mixture, water typically is added to activate the gametes. The eggs are fertilized and begin to develop and hatch. The newly hatched fry are typically allowed to develop in the hatchery, perhaps through the use of an indoor trough system (McCraren 1989; Leitritz and Lewis 1980). When the fry develop into fingerlings, the aquaculture firm proceeds with the production method that best fits its operation.

Figure I-4 shows the typical production sequence for producing hybrids of channel catfish females (*Ictalurus punctatus*) and blue catfish males (*Ictalurus furcatus*). The first step of production is the collection of the broodstock. Several hatcheries keep their broodstock in separate ponds, while others catch the blue catfish from the wild each year. The next, and most important, step in the production cycle is the spawning method. For the production of channel catfish, the prevailing method is natural spawning within spawning containers inside the ponds (Jensen 1995). After eggs are fertilized, they are brought into the hatchery. However, in the production of hybrids (Figure I-4), the most reliable way to spawn is artificially, which requires the stripping of eggs and the collection of sperm from the broodstock. Regardless of the method used, fertilized eggs develop into fry within a trough system in the hatchery (Masser and

Dunham 1998). At this point in the production cycle, the fry may be sold to producers or other grow-out facilities. If fry are not sold, they are placed in a nursery pond until they reach

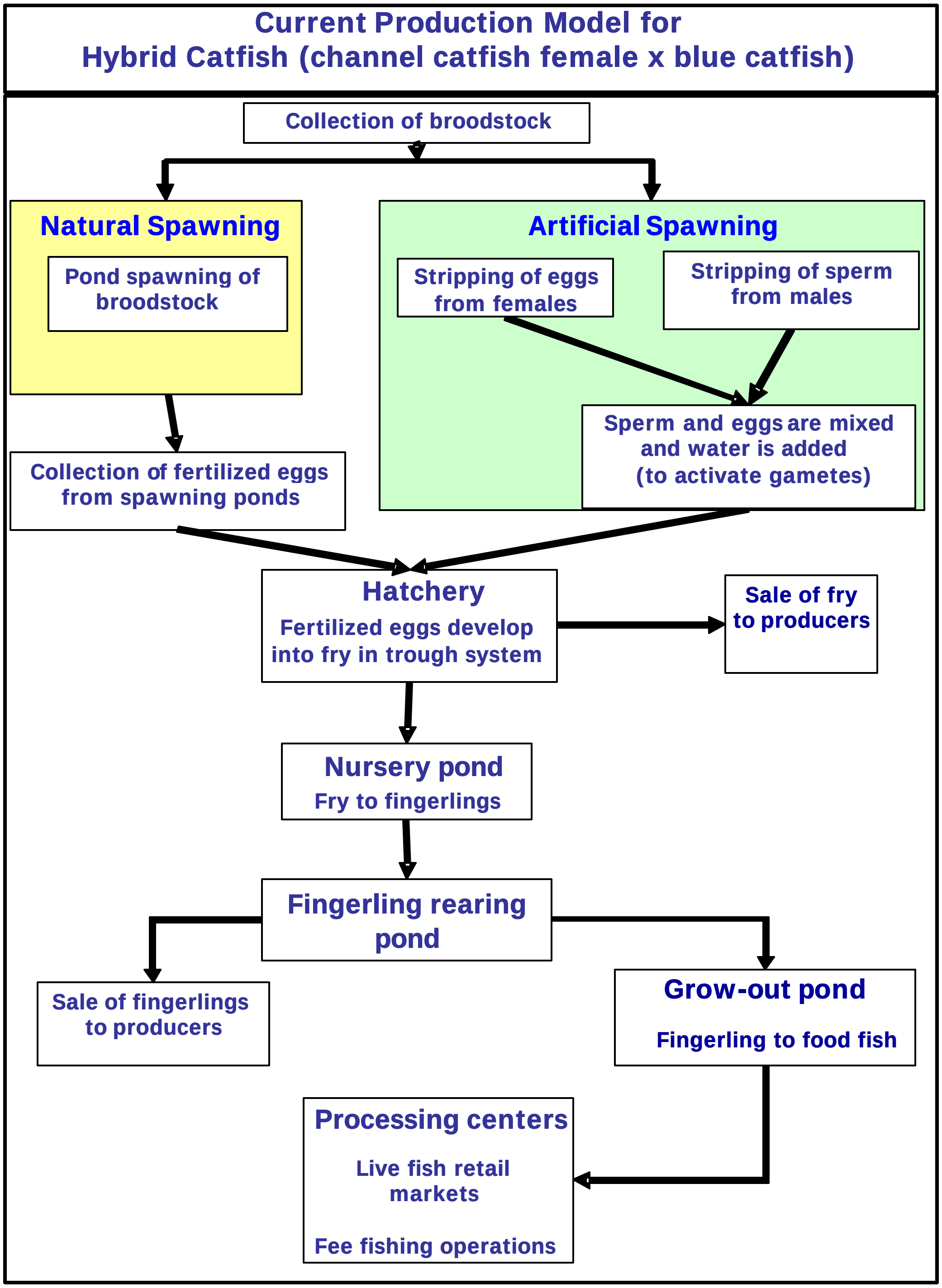


Figure I-4. Diagram Of The Current Production Cycle And Artificial Spawning Methods For Hybrid Catfish.

fingerling size. Fingerlings may also be sold to outside buyers. If they are intended to be used as foodfish, the fingerlings may be graded and moved to a larger grow-out pond until they reach approximately 0.75 to 2 pounds. The fish are then sold to processing plants or other catfish markets.

The process of producing hybrid striped bass is similar to that of hybrid catfish. The original cross for a hybrid bass was the striped bass female (*Morone saxatilis*) with the white bass male (*Morone chrysops*). However, the reverse cross has proven effective as well. White bass and striped bass broodstock are collected from the wild each year, typically with the use of a hook and line, gill net, or by electrofishing (McCraren 1989). Artificial spawning is the only technique that is used, because the females, typically, will not ovulate in the presence of the males while in captivity. The fertilized eggs are placed into a hatching jar until they are ready to be moved into an aquarium. The developed fry are placed into ponds to continue the grow-out process. One major problem with the hybridization of *Morone* bass is that the spawning seasons for the white bass and striped bass are asynchronous. This means that the spawning seasons do not directly overlap, leaving a small window for fertilization between the two species (Hodson and Hayes 1989). This makes for a precarious situation for the hybrid striped bass industry, particularly the grow-out producers. There is a risk that there may not be adequate time to spawn enough hybrid bass to satisfy industry demand. Producers are looking for a way to reduce or eliminate that risk.

G. The Role of Cryopreservation

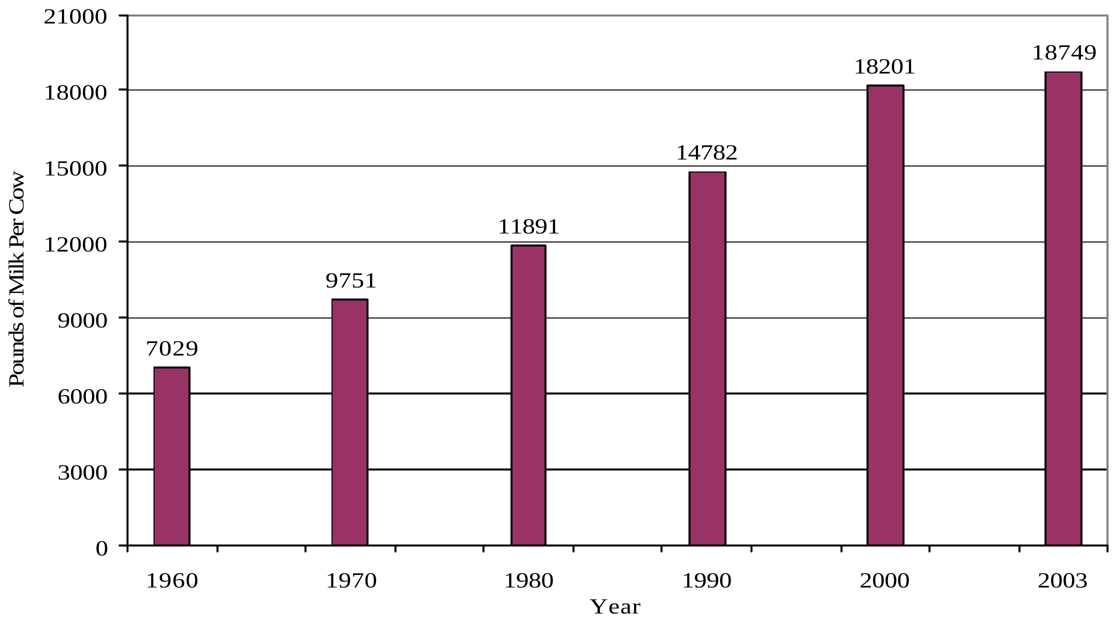
Cryopreservation of sperm is a process in which the gametes from particular males are frozen in a viable state, and stored for fertilization at a later date. The steps involved in this process include: 1) collection of sperm from the male; 2) addition of an extender to the sperm (dilution); 3) observation of sperm motility; 4) addition of a cryoprotectant (e.g., methanol, dimethyl sulfoxide); 5) packaging and labeling of the cryopreserved sperm into the desired container (e.g., 0.5-mL straws); 6) freezing of the sperm; and 7) storage of the frozen sperm. To utilize the preserved sperm, hatchery operators must thaw the straws, extract the sperm, observe the motility (if possible), and continue with established artificial insemination techniques.

The use of cryopreservation techniques has many benefits, not the least of which is the ability to improve the genetic characteristics of species. Other benefits include ensuring the long-term sustainability of improved lines, reducing risks involved with the natural reproductive methods of animals, and improved efficiency in production practices. The U.S. Dairy industry is perhaps the best example of the benefits of commercialized cryopreservation.

H. Existing Livestock Cryopreservation

The dairy and swine industries have experienced tremendous benefits due to cryopreservation techniques and the availability of stored sperm (Avault 2002). This can be attributed to research associated with the freezing of livestock semen over the last 50 years. Cryopreservation allows for the preservation of desirable genes for selective breeding, crossbreeding, and hybridization, as well as the consistency of broodstock quality (Avault 2002). By having the capability to freeze sperm from a selected bull, farmers can take advantage of the genetic makeup of that particular bull. Manipulation of the genetic makeup of dairy cows is the most important and far-reaching aspect of improvement that cryopreservation brings to the dairy industry. The ability of farmers to select bulls that exhibit the most desirable traits is what has made cryopreservation in the dairy industry so successful.

With selective breeding, U.S. dairy farms yielded an average of 18,571 pounds of milk per cow from 9.14 million dairy cows in 2002 (Figure I-5). The cash receipts from the marketing of milk for 2002 reached $20.5 billion at an average of $12.19 per hundredweight (CWT) (NASS 2003). In 2002, there were 15,526,552 units of dairy semen sold domestically. Although the number of dairy cows has continually decreased, semen sales have been stable since 1980, hovering around 12.5 million units, and actually increasing significantly since 1998 (NAAB 2003b; NASS 2003).



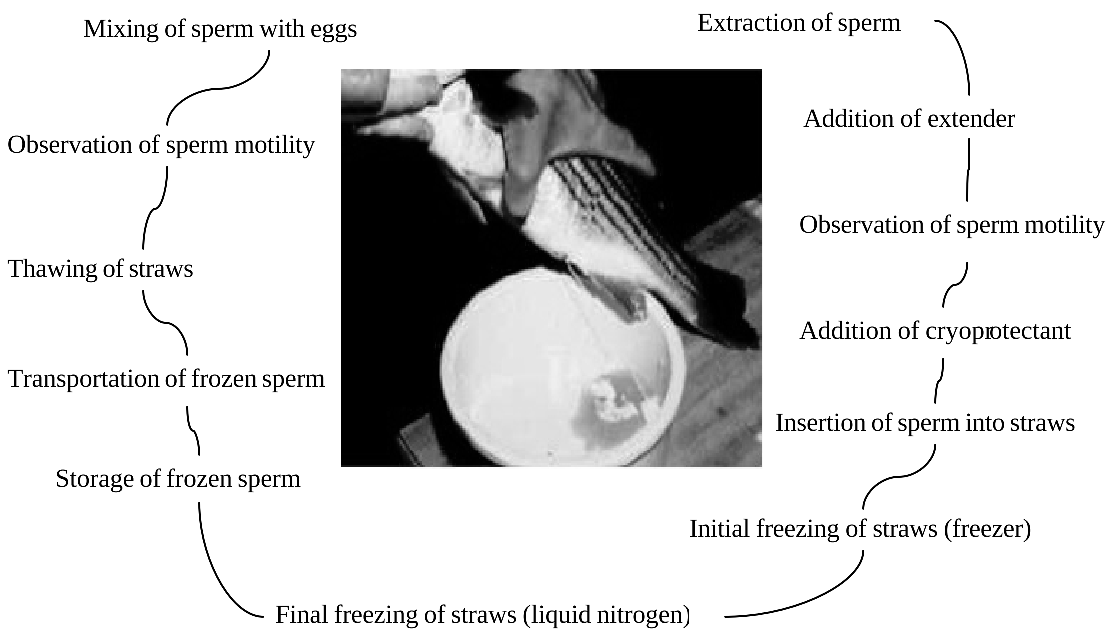
<u>Figure I-5. Annual Milk Produced Per Cow (lbs.).</u>
Source: National Agricultural Statistics Service 2003.

The most important aspect of the integration of cryopreservation and the dairy industry to this research is the efficiency in which the cryopreservation and dairy markets work together. Years of research and refinement have resulted in a dairy industry that efficiently processes, stores, and tracks semen, making improved germplasm available for breeders (Lang et al. 2003). One reason for the market efficiency is because of companies such as Certified Semen Services Inc. (CSS), which is a subsidiary of the National Association of Animal Breeders. This organization allows the breeding industry to regulate itself without government intervention. In essence, CSS provides minimum standards for companies that process cattle semen, establishes and regulates standards to maintain the authenticity of the semen, and regulates the handling, processing, labeling, and identification of the frozen sperm (NAAB 2003a).

I. Aquatic Species Cryopreservation

Over the past 20 years, there have been many significant advancements in the science of cryopreservation of sperm for aquatic species. The processing steps for the cryopreservation of aquatic species can be similar to those of the dairy industry. Figure I-6 illustrates the processing steps that are necessary to utilize cryopreserved aquatic sperm. The method by which the sperm is extracted is species-specific. For example, with species such as channel catfish, the sperm must be surgically removed. In most cases the catfish is killed in order to extract the sperm (Tiersch, Goudie, and Carmichael 1994). Other species, like tilapia (*Oreochromis nilotica*), can produce sperm at the desired time without needing to be killed. The observation of sperm motility is typically accomplished using a microscope. An extender that is often used is Hanks' balanced salt solution (HBSS), which is added at various ratios depending on the species (Gwo 2000; Kwantong and Bart 2003; Tiersch, Goudie, and Carmichael 1994; Thirumala et al. 2006). There are other extenders, such as sodium chloride (NaCl) or potassium chloride (KCL), which are used with certain species like sturgeon (Billard et al. 2004). The use of an extender is important because it dilutes the milt to a larger volume, temporarily reduces motility, and facilitates work with the samples. The amount and type of cryoprotectant will also vary with the species of fish. The purpose of the cryoprotectant is to protect the cells during the cooling and freezing process. Some examples of cryoprotectants include dimethyl sulfoxide (DMSO), methanol (MeOH), glycerol, and dimethyl acetamide (DMA) (Cloud 2000a). Aquatic sperm are sometimes frozen in 0.5-mL french straws (Tiersch, Goudie, and Carmichael 1994) that can be labeled with the owner of fish, date of freezing, species name, an I.D. number, and the name of the company doing the freezing (Cloud 2000b; Wayman and Tiersch 2000).

The process of freezing the sperm starts with a cooling sequence. The sperm is cooled in a freezing chamber by carefully decreasing the temperature until the sperm is well below the freezing point. After freezing is complete, the straws are immediately placed into liquid nitrogen for storage at -196° C. When it is time to utilize the preserved sperm for production purposes, the straws are thawed in a water bath at temperatures around 40° C for seven to ten seconds (Lang et al. 2003).



<u>Figure I-6. Cryopreservation Procedures For Aquatic Species.</u>

J. Cryopreservation and Genetics

The benefits that cryopreservation brings to aquaculture production could parallel the gains in the dairy industry. The added efficiency to reproduction and production techniques could lead to increased producer profits. The ability to selectively breed fish could also lead to more profitable outcomes. The most obvious potential profits would be from improved fish stocks, resulting from the use of selected males. Selective breeding is a key way to improve the productivity of plant and animal species (Kerr 1984). Some fish characteristics that may be deemed desirable include: faster growth, higher dressing percentage (more meat and less waste), greater feed efficiency, increased resistance to disease, and higher tolerance to poor water quality and stressful conditions (Avault 2002). The use of selective breeding leads to controlling the genetics of a population. Hatcheries can benefit economically by controlling the genetics of the products that they provide. With controlled genetics, the stocks that they offer will be superior and more consistent. A better and more consistent product from hatcheries may allow them to receive a price premium, as well as establish a dependable relationship with the grow-out producers that they supply. For example, a grow-out producer may be pleased with the lot of fish received the previous year. By controlling the genetics and using cryopreservation services, the hatchery could be able to offer the same, or better, fingerlings the following year.

Cryopreservation services may also enable farmers to more easily access and control the improved genetic attributes they desire in their product line. For instance, if a hatchery operator has broodstock that survived a fatal disease, the sperm of those fish could be frozen and used for producing disease resistant offspring. By freezing sperm, the hatchery operators can utilize the genetic makeup of particular fish, or groups of fish, for multiple years. Also, cryopreservation offers the most efficient way to control genetics. Currently it takes years of breeding to establish a defined genetic line. Cryopreservation may allow hatcheries to do this in less time. Presently, the species with the most prevalent genetic control is salmon. Because they use domesticated broodstock, the genetic lines are well established. On the other hand, the hybrid striped bass industry has essentially no genetic control. This is because they use wild caught broodstock each year to artificially spawn within the hatchery.

K. Genetic Improvement

To suggest that cryopreservation can increase the efficiency in which specific fish stock attributes are improved**,** there must be a link between the observed attributes and genetics. The attributes a fish displays (phenotype) is determined by environmental influences and genetic influences. One major genetic influence is additive genetic variance (heritability), which refers to the correlation that an individual's phenotype will have with the phenotypes of its offspring[2]. For genetic improvement to occur through selective breeding there must be a significant level of heritability associated with the specific traits. Low heritability implies that little genetic improvement can be gained from one generation to the next with the use of selective breeding because there are too many other contributing factors to the phenotype of the offspring (Lutz 2001). However, even with high heritability a fish stock that is bred to grow bigger may not, simply because the environment does not allow for large growth. If the stocking rate is too high or the water quality too low, the stock is not going to grow beyond what the environment allows, no matter how high the level of heritability.

Numerous studies have focused on determining the heritability of specific attributes for specific species. In one study, the average heritability of body weight represented 34% of the phenotypic variation for 3 strains of channel catfish (Dunham and Smitherman 1983). Reagan, Pardue, and Eisen (1976) also showed high heritability percentages for weight as well as length in channel catfish. One catfish study found that there were heritability influences on the resistance to enteric septicemia of catfish, which is caused by a highly virulent bacterium (Wolters and Johnson 1995).

Heritability estimates for disease resistance have also been studied in the Atlantic salmon (*Salmo salar*) industry. One study (Gjedrem, Salte, and Gjoeen 1991) found that selective

[2] Heritability is reported as a percentage of the total phenotypic variation for the trait in question.

breeding would be a practical and effective way to increase the resistance to furunculosis. They found that heritability for resistance to furunculosis represented an average of 40% of the observed variation among the Atlantic salmon used in the study. Heritability for weight in coho salmon (*Oncorhynchus kisutch*) proved to be extremely high in a separate study (Hershberger et al. 1990). The results suggested that a long-term selection program could have significant improvements to the stock.

The Nile tilapia (*Oreochromis niloticus*) has also shown positive benefits from selective breeding. One study found a relatively high heritability for body weight at 16 weeks with an average gain of 12.4% per generation (Bolivar and Newkirk 2002).

Reproductive traits have also been linked to heritability. A rainbow trout study found high heritability estimates, in females, for spawning date, egg size, number of eggs, and egg volume (Su, Liljedahl, and Gall 1997).

The influence of heritability on phenotype differs between species and among traits within a species. Heritability is not the only determining factor in the phenotype. However, heritability has proven to play a role in the expression of specific genetic traits in many aquatic species (Lutz 2001). This solidifies selective breeding as a way to attain genetically improved fish stocks.

L. Problem Statement

Barriers that restrict aquaculture operations from adopting cryopreserved sperm may be limiting growth and profit opportunities. Whether it has been resistance to change, or perceived increased costs associated with using cryopreserved sperm, aquaculture industries have been slow to adopt cryopreserved sperm. The primary problem addressed by this study is to analyze the willingness-to-pay for specific genetic improvements in selected aquaculture industries.

These improvements may be accomplished with the use of cryopreserved sperm. I also evaluate the perceptions of cryopreservation and genetic improvement within the aquaculture sector.

M. Research Question

The principal question this study will address is whether there is a potential market for frozen sperm in current and future aquaculture industries. I will evaluate which types of aquaculture businesses may be most interested in the use of genetically improved fingerlings, and calculate their willingness-to-pay for specific genetic attributes. I will also evaluate producer perceptions on the future of cryopreservation in aquaculture industries.

N. Specific Objectives

The objectives of this study are:

1. To determine which genetic improvements are most important to grow-out producers, for selected species.
2. To estimate grow-out producers' willingness-to-pay for selected genetic attributes.
3. To analyze the interest in adopting cryopreservation for U.S. aquaculture hatcheries.

O. Organization of the Study

Following the introduction in Chapter 1 will be a literature review of aquatic cryopreservation in Chapter 2. Chapter 3 will discuss the methods used in conducting the research. Topics in Chapter 3 include an overview of willingness-to-pay theory and elicitation techniques, survey design, and analysis procedures including econometric models. Chapter 4 discusses the data obtained in the survey by reporting descriptive statistics and interpreting the results of the econometric models. To address Objective 3, an ordered probit model will be used to evaluate hatchery producers' interest in cryopreservation services. Also in Chapter 4 will be the results of a conditional logit model used to analyze the responses to choice-based questions asked to foodfish grow-out producers. The results of the conditional logit model will be used to address Objectives 1 and 2. The results of a double-hurdle model estimating the willingness-to-pay for supply reliability and genetic uniformity will also be included in Chapter 4. The results of the double-hurdle model will also satisfy Objective 2 of this study. Chapter 5 concludes with a summary of the research and results as well as presenting limitations, implications and future research alternatives.

CHAPTER II: LITERATURE REVIEW

A. Aquatic Species Cryopreservation

Cryopreservation of aquatic sperm is not an exact science. The procedures are similar to that of the mammalian sperm; however, the specific manner in which they are executed can change significantly. Since the advent of cryopreservation for fish spermatozoa (Blaxter 1953), there has been extensive literature written about the various protocols involved for preservation (Billard 2004; Gwo 2000; Kwantong and Bart 2003). Topics discussed in the literature are milt collection, use and type of extender, use and type of cryoprotectant, dilution rates, cooling apparatus, storage, and thawing procedures (Rana 1995). The variation that exists among cryopreservation techniques is most evident when comparing the procedures for different species. However, because aquatic cryopreservation is an infant industry, there are variations that still occur when freezing the same species (Billard 2004; Gwo 2000; Dong 2005).

Research is currently being conducted to determine optimal cryopreservation procedures for a variety of species. For example, a 2004 study evaluates the differences that freezing rates and dilution ratios (of semen to cryomedia) have on the post-thaw motility of striped bass sperm. The study uses information from previous research that states that DMSO is the most effective cryoprotectant for striped bass sperm (He and Woods 2004). In this study, the sperm was extracted (stripped) by applying gentle pressure around the urogenital vent and placed immediately on ice. The semen was diluted with four different extenders at four different ratios for each type of extender. All samples were mixed with 10% DMSO as the cryoprotectant, resulting in four dilution ratios. The mixtures were placed into 500-µl cryo-straws, sealed, and placed into a Planer Kryosave-Model KS30 freezer. The straws were frozen at a rate of -40 °C per min until -120 °C was reached. At this point, the straws were placed into liquid nitrogen.

Seven days later, the straws were placed in a 35 °C water bath for eight seconds to thaw. The post-thaw motility was determined with the use of a microscope. The two lowest dilution rates produced the highest post-thaw motility rates and were significantly different from the two highest dilution rates. However, they were not significantly different from each other. Four different cooling rates were tested using samples with the same dilution rate. The highest cooling rate yielded the highest post-thaw motility and it was significantly different from the others (He and Woods 2004).

In another study addressing striped bass, slightly different cryopreservation techniques were used (Brown and Brown 2000). Although DMSO was again used as the cryoprotectant, the initial percentage was 4% as opposed to the 10% used in the He and Woods study. The freezing process used in this study was the most significant difference. There was no freezer used. The sealed straws were simply placed onto crushed dry ice for 15 minutes, transferred to a thermos containing liquid nitrogen, and finally into the vapor portion of a cryobiological storage container for long-term storage. The method for thawing was also slightly different. The sperm was thawed at temperatures of 20 to 22 °C for 5 to 10 seconds (Brown and Brown 2000). Although the processing steps to attain and freeze the sperm were the same, there were small technical variations between the Brown and Brown study and the He and Woods study done to achieve the optimal sperm productivity.

Other species, such as channel catfish and blue catfish, cannot be stripped of their sperm. The testes must be surgically removed, which typically requires the execution of the fish. The sperm is extracted by mixing the testes with an extender (HBSS), crushing the testes, and straining the sperm with a 24-μ screen (Lang et al. 2003). Once the extraction procedures are complete, the cryopreservation process can continue. The sperm is mixed with a cryoprotectant, placed into 0.5-ml straws, frozen, and stored in liquid nitrogen. For Lang et al., the use of methanol as the cryoprotectant resulted in the highest sperm motility rate after 30 minutes of exposure. A commercial-scale freezing chamber was used to cool the straws at a rate of 16 °C per minute until a temperature of -140 °C was attained. The samples were placed into -196 °C liquid nitrogen for storage, and eventually thawed in a water bath for 7 seconds at 40 °C (Lang et al. 2003).

The surgical removal of sperm and the stripping of sperm are the two most common ways to extract sperm from aquatic species. There is however, another procedure available to decrease possible contamination by urine. A catheter was used to extract the sperm from rainbow trout for studies involving motility and fertility rates. Catheter usage, led to high fresh sperm motility and high fertilization rates of cryopreserved rainbow trout sperm. Samples of fresh sperm had a mean motility of 90%, and the mean fertilization rate of cryopreserved sperm was 82%. However, the research did not determine any distinct element of the semen which could be used to predict the success of cryopreservation (Glogowski et al. 2000).

Although the process to cryopreserve aquatic sperm is consistent (collecting, extending, cryoprotecting, packaging, freezing, and thawing), there are still variations in the fulfillment of this process. Table II-1 compares the cryopreservation procedures of the four studies cited in this section.

B. Economic Aspects of Aquatic Cryopreservation

Although most of the existing literature on aquatic cryopreservation deals with the technical aspects of the process, there has been at least two studies in which the economics of cryopreservation have been examined. The first study (Caffey and Tiersch 2000a) evaluated the costs that would be incurred by an existing fish hatchery with the incorporation of cryopreservation techniques and services. The study evaluated the costs of specific required materials for both a public and private hatchery. The authors argued that because of a lack of economic analysis, the adoption of cryopreservation technologies has been slow. The comparison of the public and private hatcheries was conducted for three different levels of activity - 3,000, 6,000, and 9,000 0.5-mL straws. Capital costs were estimated for each production level as well as annual operating costs. Some of the equipment was assumed to be required, and other equipment was considered optional. The study determined that private hatcheries, which purchased the required and optional equipment, could realize considerable economies of size by expanding production and storage capacity.

Table II-1. Comparisons Of Cryopreservation Procedures.

Authors	Species Studied	Sperm Collection Method	Cryoprotectant Used	Cooling Rate	Thawing Temperature/Duration
He and Woods (2004)	Striped bass	Stripped	10% DMSO	-40 °C / min to -120 °C	35 °C / 8 seconds
Brown and Brown (2000)	Striped bass	Stripped	4% DMSO	15 min on dry ice	20 - 22 °C / 5-10 seconds
Lang et al. (2003)	Channel catfish	Surgery	10% MeOH	-16 °C / min to -140 °C	40 °C / 7 seconds
Glogowski et al. (2000)	Rainbow trout	Catheter	10% DMSO	dry ice	20 °C / 5-7 seconds

The results of this research showed that public hatcheries can integrate cryopreservation practices at a much lower cost than private hatcheries. Also, as expected, the authors found that as the units of production and storage capacity increase, the per unit costs decreased (Figure II-1) (Caffey and Tiersch 2000a).

Another study (Caffey and Tiersch 2000b), in part, addresses the likelihood of an industry adopting cryopreservation practices. The results will be useful in determining which species will be the early adopters for integrating cryopreservation into their production practices. The examples used in the study were European eel (*Anguila anguila*), channel catfish, and

Atlantic salmon. The three categories used to evaluate potential integration were economic impact of the species, technical feasibility to cryopreserve sperm, and industry utilization of the frozen sperm. All three species have a considerable economic impact somewhere in the world. However, only sperm of channel catfish and Atlantic salmon, at this time, are technically capable of being cryopreserved. And finally, only the Atlantic salmon sperm was likely to be utilized by the industry at the time of the study. This is because they are currently using artificial spawning methods to produce their seed stock. The catfish industry is currently using pond-based spawning techniques. Pond-based spawning is less expensive than artificial spawning, which means the hatcheries are less likely to implement a change. The assumptions are that species with a substantial economic impact, equipped with the necessary technical capabilities, and that are conducive to being utilized by the industry, will be the first ones to integrate cryopreservation services (Caffey and Tiersch 2000b).

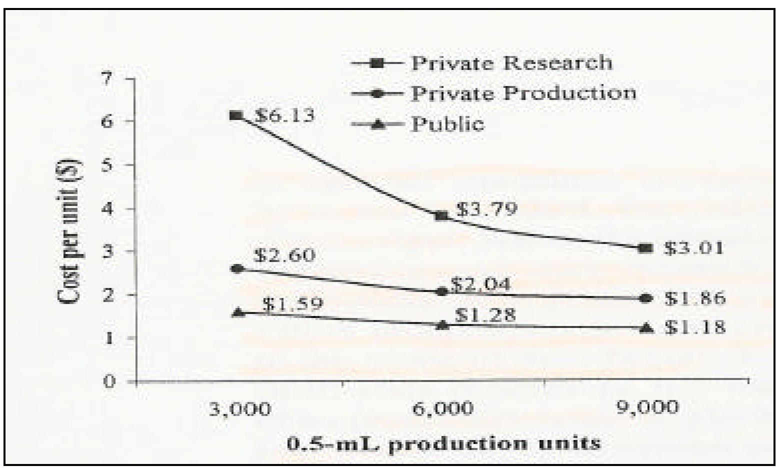


Figure II-1. Projected Production Cost Comparisons For Public And Private Hatcheries That Fully Integrate Cryopreservation Services.

Source: Caffey and Tiersch 2000a.

Another scenario would be for hatcheries to outsource their broodstock to another facility, which would provide the cryopreservation services for them. The individual hatchery would pay for cryopreservation services, but avoid costs associated with total integration. In order for hatcheries to outsource cryopreservation they would want to know if outsourcing reduces production costs, increases the revenue received for the sale of the finished product, or both. For instance, revenues may be increased by receiving a premium price for a higher quality fingerling. Therefore, one goal of this Thesis research was to estimate grow-out producers' willingness-to-pay for genetic improvement and supply reliability, which may be achieved through cryopreservation. No study to date has approached grow-out producers and asked them how much they would pay for specific genetic improvements. Also, no study has evaluated hatchery producers' willingness to incorporate costs associated with cryopreservation services.

C. Aquaculture Economics

Most economic studies regarding aquaculture have dealt with evaluating the production feasibility of a species, determining the cost-effectiveness of a new system, or reviewing a particular policy implication. For instance, the adoption of flow-through and re-circulating technology in soft-shelled crab production, based on the characteristics of the producer, was studied (Caffey and Kazmierczak 1994). The previously mentioned study (Caffey and Tiersch 2000a), concerning the production costs incurred by a farm that incorporates cryopreservation techniques into its existing operation, is a relatively new topic in aquaculture economics. The impacts on a particular industry, like salmon, stemming from government regulations can influence the market structure of that industry (Tveteras 2002).

There have also been studies that examine consumer preferences for fish. However, attributes that consumers are concerned with differ from the attributes that a grow-out farmer might be interested in. Consumers are concerned with price, size, product form, how the product was obtained (farmed or wild-caught), color, presence of an ecolabel, etc. (Wessells 2002). Producers are more concerned with growing the stock as economically efficient as possible. No research has been directed towards the valuation of specific genetic attributes of aquatic species by producers.

Previous research by Halbrendt, Wirth, and Vaughn (1991), Holland and Wessells (1998), and Anderson (2000) have focused on consumer preferences for seafood attributes. A 1991 study of the farm-raised hybrid striped bass market determined which attributes were most important to the mid-Atlantic seafood buyers. The attributes included in the study were size, form (fish product form), season (seasonal availability), and price. The results of the study determined that price and product form were the two most important factors in the purchasing of hybrid striped bass in the mid-Atlantic region (Halbrendt, Wirth, and Vaughn 1991).

A second study determined the relative importance, and value, of selected salmon attributes (Holland and Wessells 1998). The attributes used in the study were seafood inspection, production method, and price. The study was conducted to determine if seafood inspection is an important attribute in the selection of salmon. The identity of the company doing the inspection was also studied as an attribute for product selection. This study indicated that the presence of an inspection label was important in the decision-making process of salmon consumers. The study also found that some customers actually preferred paying a higher price for the product they purchased, indicating an assumed relationship between quality and price (Holland and Wessells 1998).

Some of the more recent work in determining the important attributes in consumed fish has focused on the color of the product and also on the presence of an ecolabel. A 2001 study evaluated the propensity to purchase an ecolabeled product based on country, species, certifying agency, and consumer group (Johnston et al. 2001). In another ecolabel study, the authors determined there was a willingness-to-pay for the presence of an ecolabel. However, consumers were not willing to sacrifice the taste of their favorite species for a less desirable ecolabeled species (Roheim and Johnston 2005). The way a product looks is always an important attribute in the buying process. When buying salmon, the color is the attribute that most consumers use to help determine the best product. Many consumers believe that a redder fish means a fresher, better tasting, and more expensive product (Anderson 2000).

CHAPTER III: METHODS

A. Overview

To accomplish the research objectives, willingness-to-pay estimators were utilized for the selected aquaculture species. The instrument used for collecting the data was a national mail survey of hatchery and grow-out aquaculture producers. Demographic information and willingness-to-pay values for selected genetic improvements and specified services were evaluated. The survey was intended for producers of finfish, especially species considered foodfish. To make the results more applicable, five specific species were selected as the focus of the study.

B. Selected Species

The species selected for our study were: channel catfish, hybrid striped bass[3], rainbow trout, tilapia[4], and Atlantic salmon. These species were selected because they are the primary foodfish industries in the U.S. and they represent a variety of production techniques. Production methods represented in the five selected species are pond cultures, net pens and cages, closed re-circulating systems, and flow-through systems. Another reason for their selection is the presence of artificial spawning. The industries that currently use artificial spawning are assumed to be the ones most likely to be early adopters of cryopreserved sperm.

The catfish industry is the largest foodfish aquaculture industry in the U.S., so it makes sense to include it in this study. Catfish farming also has a major impact on southern economics, with almost all production coming from the deep south. Louisiana is directly impacted by changes in the catfish industry. The hybrid striped bass industry is rapidly growing, and ranks in the top five in total production and overall value (Carlberg, Van Olst, and Massingill 2000). The

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[3] Although hybrid striped bass are not a distinct species, they will be referred to as one of the selected species in the context of this Thesis.
[4] All varieties of tilapia are included.

bass industry is also an important aquaculture industry to the south. Rainbow trout were chosen because trout, according to 1998 data, are the third largest foodfish product in the U.S. (Carlberg, Van Olst, and Massingill 2000). Rainbow trout represent the largest percentage of farmed trout species (Cain and Garling 1993). Tilapia is one of the most imported seafood commodities in the United States. In 2005, the U.S. imported nearly 300 million pounds of tilapia at an estimated value of almost $400 million (Harvey 2006).

C. Willingness-to-pay Theory for Consumers

A consumer's maximum willingness-to-pay for a product is the point where his indifference curve meets his budget constraint. The various combinations of budget constraints and indifference curves make up a particular consumer's demand curve. The budget line is a function of the consumer's income over the price of the product. The consumer's utility function is a mathematical representation of the "utility" (or satisfaction) received from consuming goods or services. For example, the utility function for products A and B may be,

$$U(A,B) = A + 2B \qquad (1)$$

where one unit of A plus two units of B yields a certain level of utility. Any combination of products A and B that generate the same level of utility are located on an indifference curve. In this example, product B is providing the consumer with twice as much utility as product A. Each combination, or bundle, of goods can be considered a "market basket." If the sum total of one basket is higher than another, then that bundle of goods will be located on a higher indifference curve (Pindyck and Rubinfeld 2001). Figure III-1 shows two different indifference curves for the function of $A + 2B$. The lower indifference curve (U^1) represents the combinations of goods A and B that will produce a utility level of 9 for the consumer. The higher indifference curve

(U^2) represents a utility level of 13 for the same consumer with combinations of products A and B.

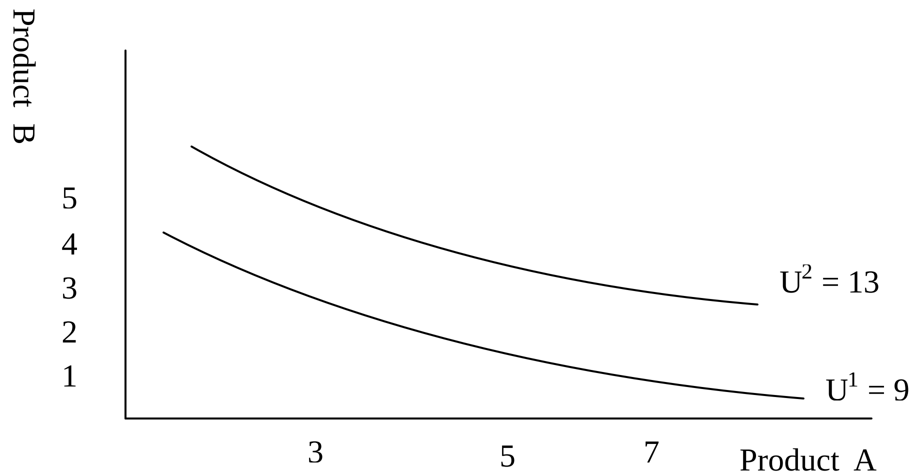

Figure III-1. Indifference Curves.

Figure III-2 represents the intersection of the budget constraint and the indifference curve. The optimal point, where the indifference curve (U^1) is tangent to the budget constraint (CD), is at point F. The optimal output quantity is labeled as O for both products. Now assume that there is an increase in the price of product A. This price increase causes the budget line, CD, to pivot inward, increasing the slope, to the new line of CE. Because the price of good B did not change, the budget line still intersects at the original point of C. However, because the price of A increased, the consumer will not be able to consume as much. Because of this pivot, he can no longer consume on his previous indifference curve, U^1. He will now consume where his new budget line is tangent to his lower indifference curve (U^0); this is at point H. The new quantities of each good consumed is represented by the letter I. The consumption amount of product A is considerably lower; while the reduction in the consumption of B is slightly lower (Nicholson 2002).

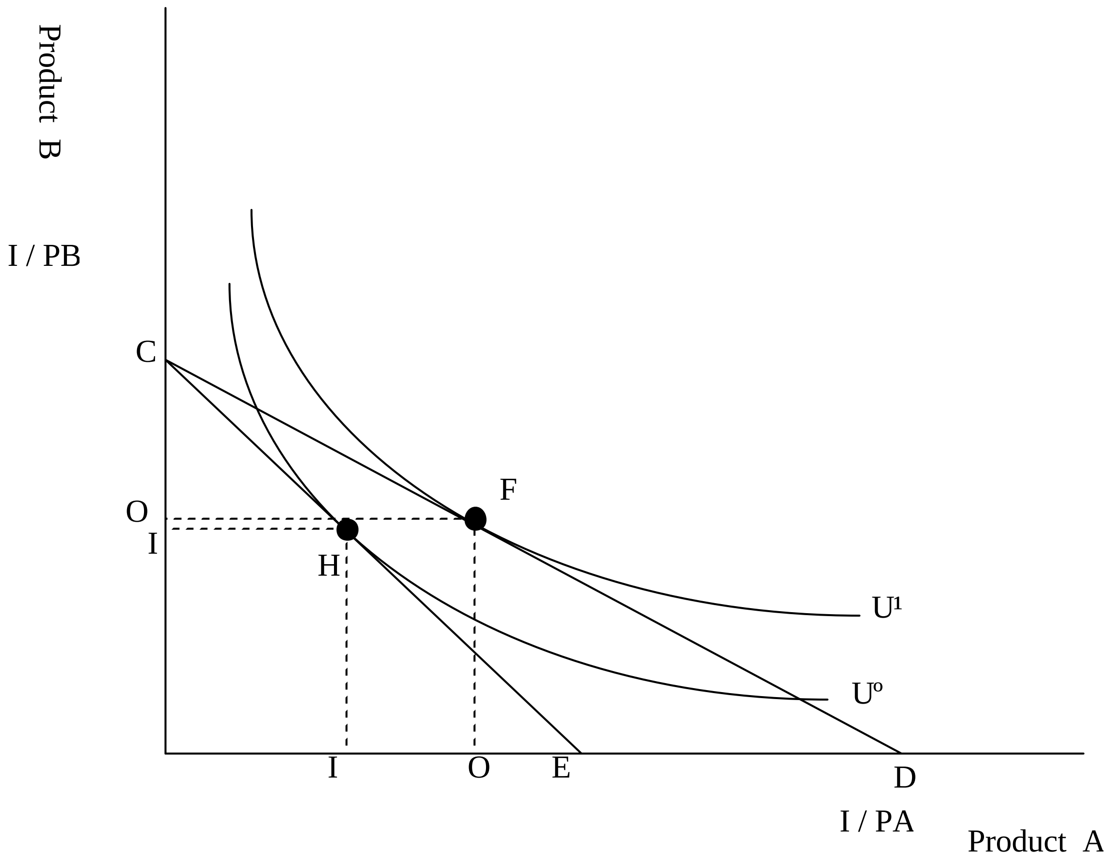

Figure III-2. Price Increase For Product A.

Consider the scenario in which the consumer is compensated for the increase in price to product A, in order to make him at least as well off as he was before the price increase. In order to do this, we would shift the budget line, CE, outward, until it became tangent with the original indifference curve, U^1 (Figure III-3). This budget line C'E' has the same slope as CE and results in a utility maximizing point at G. The difference between the original point of F and this new point G is called the substitution effect. This substitution effect represents a movement along an indifference curve, and the fact that even if this consumer could stay on his original indifference curve, his consumption would change because he would still want to equate the new price ratio to his marginal rate of substitution. This change represents the fact that product B has now become relatively cheaper than A (Nicholson 2002; Pindyck and Rubinfeld 2001).

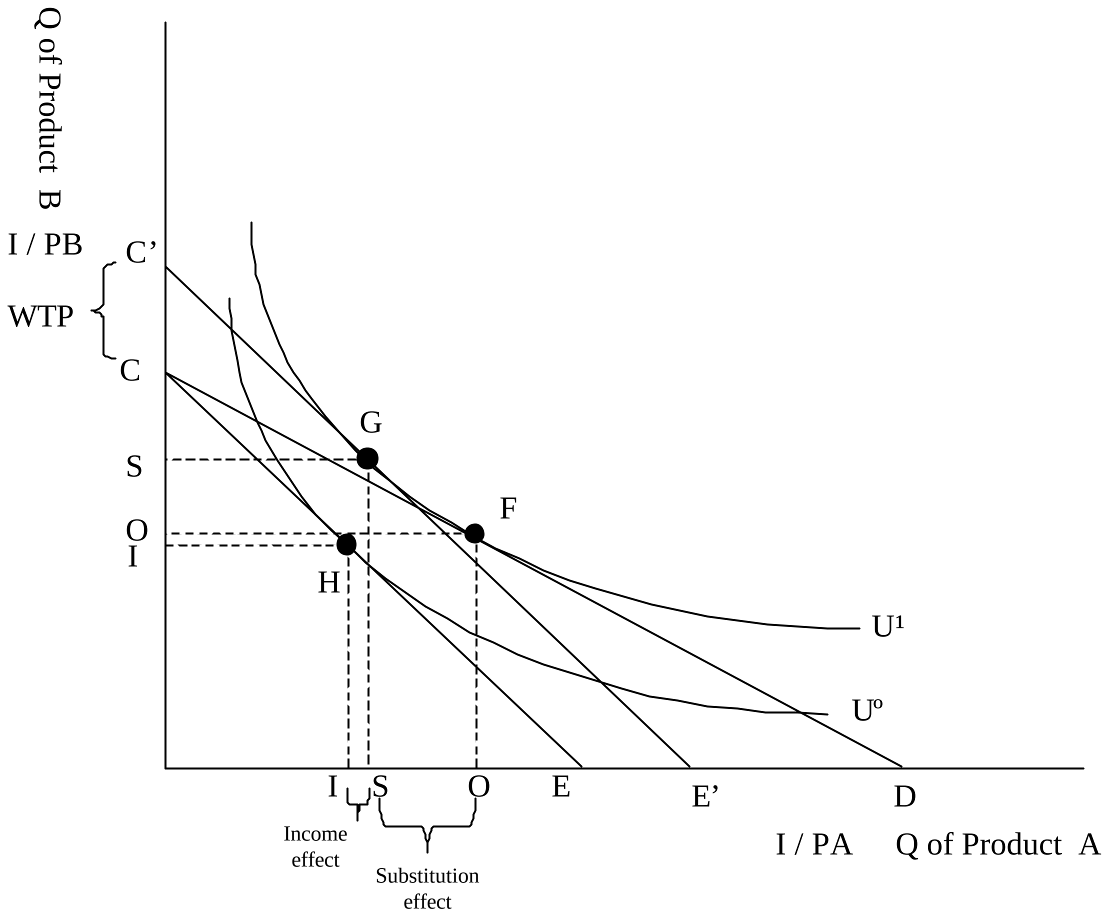

Figure III-3. Quantity Consumed In A Two Product Market: Income And Substitution Effects.

The information from a graph like Figure III-3 can be translated into two separate demand curves for the product that experiences the change in price. Figure III-4 represents the compensated and uncompensated demand curves for product A. The graph shows how as the price of A increases, the consumer is made worse off. This demand curve is drawn with the assumption that the consumer's nominal income and other prices are both held constant. The uncompensated demand curve is a function of both price and income.

The compensated, or Hicksian, demand curve shows the relationship between the quantity of a good purchased with the assumption that other prices and utility are held constant. It shows the movement from point F to G. The Hicksian demand curve is a function of price and utility (Nicholson 2002). Obtaining the Hicksian demand is important because it will help in determining the willingness-to-pay estimates.

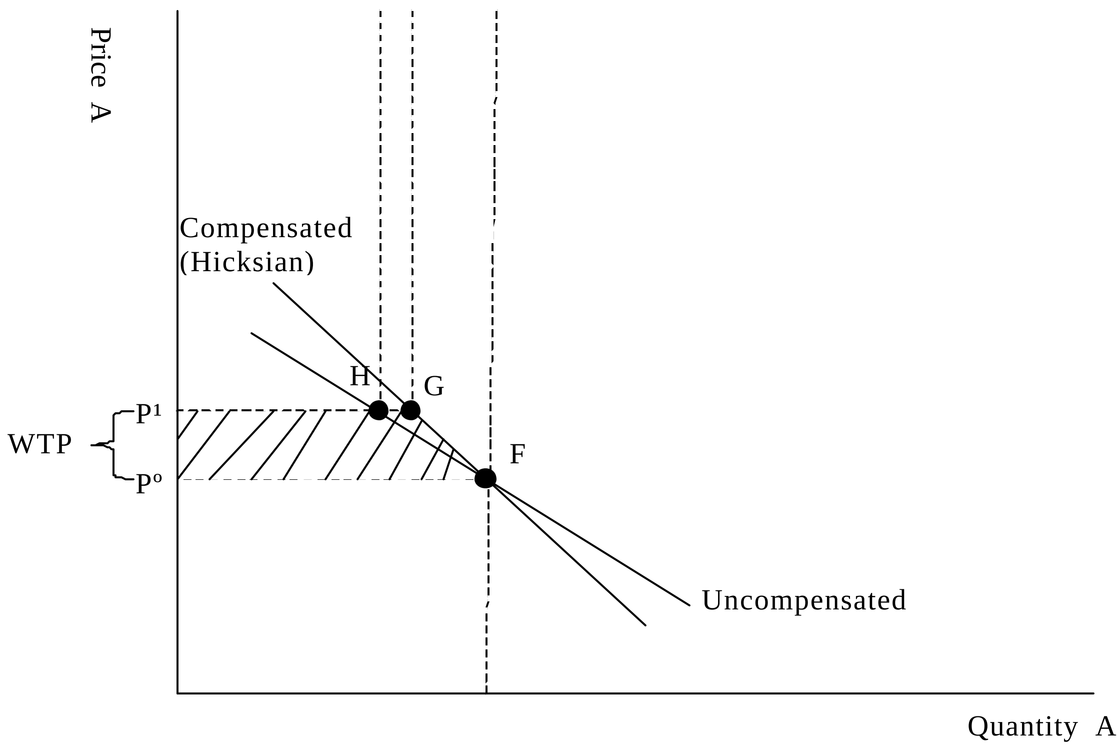

Figure III-4. Compensated And Uncompensated Demand Curves For Product A.

The income associated with the distance from C to C' (Figure III-3) represents the compensating variation, which represents the amount by which the consumer must be compensated so that he will have as much utility as he did before the price increase. Compensating variation can also be interpreted as willingness-to-pay (WTP). The shaded region in Figure III-4 contains the area under the Hicksian demand curve between points P^1 and P^0 all the way to point F. This area also represents the WTP. The specific value can be estimated by calculating the area within this region.

Because F is the original utility maximizing point, both demand curves are going to pass through it. Because H and G represent the quantity consumed at the same price, they are now next to each other as opposed to one being higher than the other (as in Figure III-3). Typically, for a normal good, the Hicksian (compensated) demand curve GJ is steeper than the uncompensated demand curve HK. This is because the compensated curve only reflects the substitution effect and is therefore less responsive to price changes than the uncompensated curve, which reflects the substitution and income effects.

D. Willingness-to-pay Theory for Producers

A producer's WTP is based on the profit maximizing decision subject to a given production function. Assume that a firm is considering a change from one quality of input to another (i.e. q_0 to q_1). The WTP for that change would be,

$$WTP = ?_1(p, w, | q_1) - ?_0(p, w, | q_0), \qquad (2)$$

where w is a vector of input prices, p is a vector of output prices, and q is a given quality of a primary input in production. This yields the indirect restricted profit function, $? (p, w, | q)$, where $?_0(p, w, | q_0)$ is the indirect profits given an input quality of q_0. The WTP represents the maximum amount of profit the producer is willing to relinquish in order to acquire q_1 instead of q_0 (Lusk and Hudson 2004).

In the context of this study, the initial profit $?_0(p, w, | q_0)$, consists of input prices (w) that grow-out producers are paying for conventional fingerlings. The adoption of genetically improved fingerlings will affect $?_0(p, w, | q_0)$ through improved fingerlings (q_1). Improved fingerlings (q_1) are expected to increase the production efficiency of the operation. This may be through improved growth rates, enhanced disease resistance, etc. Improved efficiency would presumably reduce costs, thereby leading to higher profits. The difference between $?_1$ and $?_0$ represents the grow-out producers WTP for improved fingerlings.

The information needed to complete this formula, in the context of this study, was obtained through the questionnaire. Respondents were asked to record the amount that they currently pay for their fingerlings (*w*), as well as the amount that they currently receive for their grow-out stock (*p*), so that the initial profit function could be derived. To complete the new profit function, the information selected in the questionnaire by the respondents[5] served as the new input prices (*w*). However, the new output prices (*p*) were assumed to be equal to the current output prices. This is due to the uncertainty of the end product. Because of the inability to predict how each grow-out producer would utilize his genetically improved stock, it is impossible to determine a new price for the fish. Some producers may choose to hybridize their stock, and some may choose to increase the resistance to disease. It would be impossible to derive a general estimate for the output price (*p*) of fish with the many different scenarios that could exist through the use of fingerlings produced from cryopreserved sperm. Therefore, a zero change in output price (*p*) was assumed.

E. New Products/New Technology and Early Adopters

When a new product, or technology, is made available to an industry, individual firms must decide whether or not to adopt it. Firms who are the first to incorporate the new product, or procedure, are called early adopters. A general distinction between technology innovations and new products is that new technology typically entails some increased fixed costs, while new products typically require increased variable costs. In the case of cryopreserved sperm being used to produce improved fish stocks, it can be considered a combination of both a new product and a new technology. The method in which fish are spawned will change, as well as the end product from the spawned species.

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[5] This information was derived from the responses given in the WTP elicitation sections.

An important issue for this study was to determine what separates early adopters from the rest of the industry, and how to identify the early adopters. Studies show that the major determinants of early adoption are human capital, firm-specific characteristics, and knowledge about the new technology[6] (Olmstead and Rhode 1995; Wozniak 1993; Wozniak 1987). Human capital is a measure of the manager's education, experience, and may also include personal wealth. Firm-specific characteristics include debt, off-farm wage, and scale of production. Knowledge about the new technology is the amount of information known by the manager regarding the product, or service, being offered (Wozniak 1993; Wozniak 1987). The ability to apply new technologies depends on the manager's capacity to identify sources of information, and then process and decode the relevant information (Wozniak 1993). Results show that higher levels of education and more information about the product reduce the costs and uncertainty of adoption, and therefore increase the likelihood of early adoption. As expected, results also suggest that producers with larger scales of production are more likely to be early adopters than producers with smaller scales of production (Wozniak 1993; Wozniak 1987).

Questions concerning the prior knowledge about cryopreserved sperm were included in the questionnaire to help determine whether that firm was a potential early adopter. One example, was asking the respondent to answer specific questions with regards to the cryopreservation process. Firm-specific questions, such as farm size and gross sales, were also asked to help segregate the potential early adopters from those who are not. Questions inquiring about the education levels of the farm managers were also included. The managers selected the profile that most accurately described their highest degree completed: for example, high school diploma, Bachelor's degree, Master's degree, etc. Also included were questions specifically

[6] The terms "New technology" and "New product" will be used interchangeably throughout the text.

asking managers their history, and potential likelihood, of adopting a new technology or service before it becomes the majority practice.

F. Applying Willingness-to-pay Estimates

For products that have not yet been introduced into the marketplace, WTP estimates are important to firms because they can be used to construct inverse-compensated demand curves. The sum of individual demand curves (price = WTP, quantity = 1) for the entire market provides companies with the inverse market demand curve. Formulation of the inverse market demand curve can be done using a variety of methods. One method is to use a probabilistic model like logit or probit. Another possibility is to use the estimated WTP means and standard deviations. This can be done if the WTP is assumed to be normally distributed across the population. If normality cannot be assumed, and a direct method of elicitation is used, the inverse demand curve can be formulated by simply plotting the data against a linear time trend. It is important to recognize that the profit-maximizing price is not necessarily the mean WTP. One reason may be the existence of a niche market. Knowing the distribution of the WTP values is the most important information to firms in each specific industry (Lusk and Hudson 2004).

The method chosen to formulate the inverse market demand curve depends on the elicitation technique used to collect the data. After a firm has derived the demand curve for the market, the firm can determine where it can maximize profit along that curve (Lusk and Hudson 2004). This will be the point at which the firm produces, revealing the price that will be charged in the market.

G. Willingness-to-pay Elicitation Techniques

There are a variety of ways to determine willingness-to-pay for a certain good or service. These techniques are commonly used to estimate the value that is placed on current market goods (e.g. food products), non-market goods (e.g. hunting rights), as well as for determining a price for products or services that at the current time do not have a market value (e.g. frozen aquatic sperm). The most widely used techniques to obtain willingness-to-pay estimates are contingent valuation, conjoint analysis, and experimental auctions. Conjoint analysis and contingent valuation are hypothetical valuation methods. These methods use survey responses to elicit consumers' willingness-to-pay. These methods can also be used to determine the price premium that a company, or industry, will pay to incorporate a product or service believed to increase profits. Experimental auctions can also be used to determine how much consumers will pay for a good or service. However, with the auction setting, surveys are not used, and in most cases, it is no longer a hypothetical situation. The strengths and weaknesses of each technique will be evaluated so that the one most appropriate to this study can be selected.

H. Conjoint Analysis

Conjoint analysis (CA) is a multivariate technique that is used specifically to understand how respondents develop preferences for certain products or services (Hair 1995). Conjoint analysis is a set of methods aimed at predicting consumer preferences for multiattribute options in a variety of products and services, both in the public and private sector. This technique assumes that the consumer derives separate amounts of utility provided by each attribute of a product. After analyzing the responses to a set of "total" profile descriptions, the analyst should be able to describe the product in terms of its attributes and relevant values for each of the attributes. This decompositional approach is what makes CA different from similar methods (Green and Srinivasan 1978). For example, some attributes that might be associated with orange juice may be brand name, container, and price. The values, or levels, for the brand name attribute may be a private company versus a supermarket generic brand. The same process continues for each attribute. For this example, assume that each attribute has two levels. This would lead to a total of eight combinations that could be formed. An example of a specific combination that might be made available is the private brand, in a ½ gallon carton container, at a price of $3. To determine the preference structure, respondents will be asked to either rate each of the combinations on a provided scale, rank the combinations in order of their least desired to their most desired, or possibly to select their most preferred option in a set of alternatives. The preferred combination for the respondent is then revealed. Conjoint analysis can be used to predict the market share of product and service profiles if they were in the market competing with each other (Green and Srinivasan 1978). This information can also be used to evaluate the "part-worth" of each level in the combination. Theoretically, one could determine how much the presence of a popular brand name contributes to the willingness to buy orange juice. The addition or interaction of the "part worths" gives us the "total worth" (Hair 1995).

Conducting a CA allows marketers to: 1) determine the optimal combination of features, 2) show relative contributions of each attribute, 3) predict market share, 4) define groups of potential customers, and 5) identify marketing opportunities for unavailable combinations. Conjoint analysis is different from other models, like some regression applications, because instead of getting ratings and trying to determine the best combination, CA already gives you the most preferred bundle (Hair 1995). In choice-based conjoint analysis studies, respondents are provided alternative products and asked to choose which of the products they would purchase, given the attributes and descriptions of the competing products (Lusk and Hudson 2004). Another benefit of using CA is that the analyst can get a separate "model" for predicting preference for each respondent. Because CA observes the preferences of all the combinations of goods or services, researchers are able to obtain an overall look at the specific respondent's preferences, as well as being able to aggregate the data and obtain the preferences for the overall market. Conjoint analysis is easily adaptable to nonlinear relationships in the data. Conjoint analysis allows researchers to make separate predictions for the effects of each level of the independent variable and does not assume that they are related at all. Conjoint analysis has consistently been used in determining consumers' willingness-to-pay for products that embody certain characteristics or groups of characteristics (Hair 1995).

Within the CA framework, there are three major elicitation techniques. They are ranking, rating, and discrete choice. When utilizing the ranking method, respondents are asked to rank the alternative bundles from least favorite to most favorite. Respondents are asked not to repeat rankings for any two of the alternatives. This restriction is relaxed when using the rating method. Respondents are asked to rate the alternatives on a scale determined by the researcher (e.g. 1 to 10, 1 to 7, 1 to 5). However, a rating value may be used more than once. For the discrete choice analysis respondents are only allowed to choose one option per set of options given.

Conjoint analysis is commonly used to help producers or retailers determine which specific product attributes their customers prefer. It is also important for firms in their evaluation of new product or service concepts (Green and Srinivasan 1978). One specific study was conducted to determine the product attributes that are important to landscapers and retailers when they purchase their nursery stocks from wholesale firms (Gineo 1990). The study analyzed the purchasing information of Connecticut landscapers and retail garden centers when they purchased a popular ornamental plant (rhododendron). The researchers used personal interviews as a vehicle for the questionnaire. The survey asked respondents to rate the attributes that were important to them when buying rhododendrons. Eight attributes were used, with a rating scale of

0-100. The attributes were: delivery time, flower color, origin, price, product range offered by seller, quality, size, and terms of payment. Quality received the highest rating with an average score of 94. Respondents were also asked to rank 9 sets of product combinations in the order in which they would purchase the product, with the highest ranking being placed on the most preferred set of attributes. This procedure also revealed a high level of preference for better quality products. The results of this study found that producers and wholesalers should focus on selling large, high quality plants, with a wide variety of nursery stock (Gineo 1990). This particular study demonstrated how conjoint analysis can be used to increase the marketing power of a company, by allowing that company to specialize in providing a product comprised of the attributes that consumers feel are the most important.

Conjoint analysis has also been used in the evaluation of non-market characteristics for various goods, services, and activities. One such study was done to valuate the characteristics, or attributes, that influence waterfowl hunting decisions, specifically in Louisiana (Gan and Luzar 1993). The attributes selected for this study were travel time, site congestion, type of hunting party, total cost, duck bag limit, type of hunting area, and length of season. Hypothetical waterfowl hunting trips were created by generating various combinations of the attribute levels. These hypothetical trips were then rated on a scale of 1 to 10 by survey respondents. A rating of 10 was considered an ideal hunting season. The data used for the study was collected through a mail survey of 7,022 hunters who purchased waterfowl stamps in Louisiana for the 1990-91 hunting season. A total of 3,319 surveys were deemed usable. Results of the study suggested that increases in the length of season and the daily limit were very important to hunters in their rating of the hypothetical trips. The researchers also determined that hunters did not prefer to hunt on public lands, and as expected, their utility decreased as costs increased. This study also derived some willingness-to-pay estimates from the information provided by the hunters. For example, it was estimated that the hunters were willing to pay $30.67 to extend the hunting season, and $395.77 to increase the limit of ducks per day. Other implied WTP estimates were $318.07 to lease land rather than hunt on a public site, and $1,189.94 per season to hunt with close friends as opposed to strangers (Gan and Luzar 1993). This study allows decision makers in Louisiana to better serve the hunting community by providing a more enjoyable experience, and if used properly the information provided could help to increase the economic resources of the state.

Another type of study that has utilized the conjoint analysis technique is the evaluation of food safety preferences by consumers. Red Delicious apples were the product used in a particular food safety preference study (Baker 1999). The specific attributes related to the product, and used in this study were: 1) price, 2) level of damage on the fruit, 3) pesticide usage policy and the associated cancer risk, and 4) assurance of compliance with food safety regulations. Respondents were asked to rate 11 hypothetical products generated from the various combinations of attribute levels for the apples on a scale of 1 to 11 with 11 representing the most preferred bundle. There were 510 usable surveys of the original 1,850 which were mailed to random addresses across the United States. The results of this study suggested that there were four well-defined market segments. First, there were the Safety Seekers, which preferred the low pesticide use and were considered family-oriented. Next, there were the prototypical American buyers that preferred a more balanced price, and were appropriately labeled as Balanced Buyers. Price Pickers, the third segment, placed a high emphasis on price and tended to be non-white consumers. The last segment, the Perfect Produce buyer, represented the high income consumers who typically preferred the undamaged produce. This study attempted to relate the socioeconomic characteristics of shoppers with the buying preferences of Red Delicious apples (Baker 1999).

Commercial buyer preferences have also been evaluated using the conjoint analysis framework. Unlike consumers, who are making purchasing decisions based on utility, companies make decisions based on expected profits. Buyer preferences for durum wheat were evaluated to determine which characteristics of the wheat were most important to buyers (Lee, Lerohl, and Unterschultz 2000). The purchasing decisions of wheat buyers were directly related to the expected profitability of the product. Wholesale seafood buyers also have to evaluate their purchasing decisions based on the expected profits earned by the fish they buy (Halbrendt, Wirth, and Vaughn 1991). Because these types of buyers are going to re-sell their product (typically in a different form) they will presumably have a different set of attributes, relative to consumers, that make up their purchasing preferences.

A review of conjoint analysis determined that approximately 60% of all conjoint studies pertained to consumer goods. It was also concluded that new product evaluation, pricing, and market segmentation were some of the principal applications of CA in recent years. One problem that was reported with the use of CA was the limitations that are placed on the number of product attributes that can be accommodated (Green and Srinivasan 1990).

I. Contingent Valuation

A technique that was also considered for use in this study was the contingent valuation approach. This willingness-to-pay technique was considered because of its ability to estimate values contingent on certain improvements made to a product or service. Because the implementation of cryopreservation services to aquaculture industries could make considerable improvements to genetic uniformity and supply reliability, this fits well with typical contingent valuation scenarios. An example of this would be the difference that a grow-out producer would pay for the ability to buy more genetically uniform fingerlings as opposed to the stock the producer is currently buying. For instance, if a grow-out producer is paying “X” amount of dollars for his current fingerlings, how much more would the producer be willing to pay for the ability to buy a more uniform stock? Presumably, producers would be willing to pay different amounts for the improvements that can be provided with the introduction of cryopreserved sperm.

Contingent valuation (CV) is a stated preference technique that has been gaining legitimacy since 1993 when the National Oceanic and Atmospheric Administration (NOAA) determined that CV study results could in fact be used as a valid estimate of damage assessment. The panel was organized to determine if the estimates gathered, by use of CV, on the non-use damages caused by the Exxon Valdez oil spill were in fact reasonable. The panel found that CV could be used as a starting point as long as it followed certain recommendations (Portney 1994).

Like CA, CV has various question formats that can be used. The first is simply an open-ended question, the second is a dichotomous choice, and a third is the payment card approach. An example of an open-ended question would be, “What is the maximum amount per year that you would be willing to pay to see the lake restored to fishable conditions?” This will allow the respondent to write what he feels is the most that he would pay for a fishable lake. This method tends to be difficult for respondents dealing with products or services that they are not familiar with. A second method is the dichotomous choice questions. Here the survey would have a randomly selected amount (between an established range) with a question like, “Suppose the city charged each member of the community $20 per year to get the lake to where it would be safe to swim, would you be willing to pay this fee?” Yes / No. Typically in these cases a pilot survey is used to determine the range in which the choices should be from. A double-bounded dichotomous choice format would include a follow-up question based on the response to the first question. If the respondent chose "No" to the first question, then the respondent would be asked the same question with a smaller price. If the respondent chose "Yes," he would be asked the same question with a higher price. A potential problem with this is that some respondents may be persuaded by the first option thinking that that is what the actual price is supposed to be. An example of the payment card method is, "What is the maximum amount per year that you would be willing to pay for the lake to be clean enough for swimming?" (Circle one)

$20 $30 $40 $50 $60 $70 $80 $90 $100

This method allows the respondent to choose which value is the highest he would be willing to pay. This method, does however, limit the respondent to the suggested values given by the researcher.

Today CV methods are used in many fields, mainly in the determination of values placed on non-market, or public, goods. For instance, the value that someone might place on seeing the Grand Canyon. More recently, researchers are using CV methods to determine how much consumers are willing to pay to adopt a particular policy, receive a service, or reduce their risk.

Service provision and risk reduction are particularly important to this study. In a particular CV study (Tiller, Jakus, and Park 1997), a survey was used to elicit the WTP for a recycling service provided to Williamson County, Tennessee. This recycling service study used double-bounded dichotomous choice questions to obtain the WTP. The results of the study were encouraging for proponents of the CV methods, because results were consistent with recycling rates of other cities across the country (Tiller, Jakus, and Park 1997).

This study evaluated the WTP of producers for the reduction in the risks associated with the supply of fingerlings. The measuring of risk reduction has been studied in various fields, the most prominent being food safety. In one particular study (Buzby 1995), consumers were asked to state how much they would be willing to pay for a grapefruit that did not contain a certain postharvest pesticide; this grapefruit was considered a safer grapefruit. Contingent valuation techniques were used to estimate the benefit of a perceived reduction in health risks to the consumers. The WTP, or benefit, was defined as the highest amount someone would pay for a grapefruit that was not treated with the certain pesticide over the price of a grapefruit that had been treated. A mail survey was distributed using the payment card method. Results revealed that the benefits of eliminating the pesticide outweighed the costs of doing so (Buzby 1995). When eliciting WTP estimates from consumers who will potentially reduce their risks, it is important to evaluate the factors that influence this amount (Kim and Cho 2002). For example, the amount of people that live in the household, the family income, the presence of children, would all factor in to the decision-making process.

Contingent valuation techniques have been criticized in the past for not providing accurate estimates of the true "values," or market prices, for the goods or services that are in question. However, in recent years the CV techniques have gained popularity and made considerable progress, especially in assessing the market potential of novel goods and services (Cameron and James 1987). Additionally, there are numerous studies that defend the validity of CV methods by comparing them to other techniques, or actual market prices. One example is a study (Spencer, Swallow, and Miller 1998) which compared hypothetical WTP responses to those made through real-money transfers. The study did in fact find that the hypothetical responses were higher than the real-money amounts. However, due to the high standard errors on the hypothetical estimates, the authors could not say that the responses were statistically different (Spencer, Swallow, and Miller 1998). Another way to assess the validity of the CV results is to test the CV estimates against a credible source. One study set out to prove that CV respondents could make judgments that were consistent with the responses made by experts in a particular field. In this case, the respondents were randomly selected passengers who had participated in a white-water rafting trip the previous year, and the "experts" were randomly selected guides. A mail survey was sent to the selected passengers and guides to determine if the responses for each would be significantly different. The study found that the responses of the guides and passengers were almost identical (Boyle et al. 1995). Although this does not prove that the numbers generated through CV surveys are precise, it does help to diminish some of the doubt in regards to their usefulness.

J. Experimental Auctions

A third technique considered for use in this study was the experimental auction approach. When conducting an experimental auction, researchers interact with the respondents to discover a price for a concrete good with distinguishable characteristics. For example, researchers may tell a group of participants about the pros and cons of two particular goods or services, and then ask how much they would be willing to pay for their preferred good or service in place of the less desirable one. Auctions, as opposed to surveys, typically include participant interaction with tangible goods, and actual money changing hands. This technique has gained popularity in the last few years because of its ability to obtain more practical willingness-to-pay estimates. The information that is generated through the use of auctions is thought to be a more reasonable approximation of the actual amount that consumers will spend when the product makes it to the market, or when the consumers are actually expected to pay for a service. The reasoning behind this theory is that if people are put into situations where the actual products are available to them, or real money is changing hands, participants will respond as if they were in a working market situation. Instead of being told about a hypothetical situation, respondents are now experiencing something real. An advantage of the auction system is that the analysts can interact with the respondents and make adjustments to the study if necessary. The interaction also allows for any clarification that may be needed by the respondents.

Auctions sometimes have more than one "round," which means that the respondents can get a better feel for what they are doing as the study continues. For example, let's say that we are trying to see how much consumers are willing to pay for strawberries that they know were produced in the United States versus those that were produced in Mexico. The analysts may ask the respondents how much they would pay to know that their strawberries were produced domestically. The respondents would offer a concealed bid, and this would be the first "round." The next "round" might consist of the same question, only this time the consumers would be told that the alternative was strawberries that were produced in Mexico. The next time, for instance, the consumers may actually be shown the strawberries in order to compare. This process will continue for however many "rounds" the analysts deem necessary, with bids being made every time. The additional information, as well as the experience that the respondents gain, can influence the bids. This is just one way in which an experimental auction can occur.

There are plenty of techniques used to conduct auctions, as well as different ways to extract the groups' willingness-to-pay. One way might be to take the mean of the bids, another might be to take the median bid, or possibly the 5^{th} highest bid, or perhaps any other *n*'th bid that the analyst considerers to be significant. Another auction technique is to ask respondents to state a price for a specific good or service presented to them. One last example may be if the analysts gave each respondent a certain amount of money, and told them to make bids on a certain product knowing that only the five highest bids would receive the item. The more realistic the event, some analysts feel, the more realistic the results will be. This is why experimental auctions are gaining popularity among researchers around the country.

One of the most classic uses of experimental auctions is in regards to the food safety issue. In recent years, research has compared genetically modified products to those that have not been modified. A 1996 study used an auction setting to elicit the value consumers place on alternative methods of improving food safety. Multiple bidding trials were used and one trial was randomly selected as the binding trial. The authors believed that they received accurate results because they assumed that the participants treated the auction seriously because of the requirement to eat the product at the conclusion of the study (Fox et al.1996). Another study, (Umberger et al. 2002), used an auction to determine how much consumers would pay for a steak that had a preferred flavor. Consumers were supposed to choose which steak they liked best, either the corn-fed domestic brand or the grass-fed imported brand, and state how much more they would pay to be able to get their preferred steak. The results were not only important in the determination of the consumer's preference for flavor, but also to establish a price premium for that preference. In this case a 4th price Vickery auction was used and the top three bidders would be required to buy the steaks that they preferred at the price of the fourth highest bidder. Two groups participated in the auction. One group was from San Francisco and the other was from Chicago. The results showed that the respondents, from both locations, were willing to pay similar amounts for their preferred steaks (Umberger et al. 2002).

Another experimental auction was used to determine the preferences for products that were grown in different countries (Sterns et al. 2004). Here the focus was on the consumer's preference, not for taste, but for the country of origin of the product. Consumers from two different cities participated in the study. Here the consumers were asked to tell how much they would be willing to pay to exchange a pound of tomatoes or apples, from an unknown or foreign source, for ones that were produced in the United States. The results of the 5th price Vickery auction determined that the majority of participants were willing to pay $0.36 more, on average, for the U.S.-produced commodities (Sterns et al. 2004).

Auctions have been used in conjunction with questions asking participants to rate personal preferences or opinions about the subject being studied. These questions are called scale-differential questions and they are used to calibrate the willingness-to-pay estimates. One particular study (Lusk et al. 2001) sought to determine the willingness-to-pay for non-genetically modified corn chips. Before the participants began the auction, they completed a questionnaire that asked general demographic information as well as scale-differential questions which asked respondents to state their preferences for genetically modified (GM) foods. Five trials were conducted in which the participants were given $1 and a bag of chips which were produced with GM corn. Participants were asked to indicate how much they would pay in order to exchange their bag for one that was manufactured without GM corn. Another stipulation was that the participants were going to have to consume their bag of chips at the end of the experiment. In the responses to the scale-differential questions, most participants indicated that there was only a slight concern about GM foods. This may be why 70% of the participants said that they would not pay anything extra for the chips that did not use GM corn. The average price to exchange bags was $.07 per bag (Lusk et al. 2001). Using scale-differential questions may in fact add to the validity of the auction results.

K. Selected Methods

The conjoint analysis and contingent valuation WTP elicitation methods were selected for use in this study. Conjoint analysis was used to determine grow-out producers' preferences for combinations of genetic improvements, along with their willingness-to-pay for those improvements. The ability of the conjoint technique to derive willingness-to-pay estimates for a bundle of attributes, rather than just a single attribute, is what determined its selection. Contingent valuation was also chosen for this study. The CV framework was used to elicit WTP values for two specific benefits made possible by cryopreservation. Because the benefits were isolated, and not grouped, it was determined to be suitable for CV analysis.

K.1. Discrete Choice Analysis

The CA method used in this study was the discrete choice technique. Discrete choice analysis, also known as stated choice, contingent-choice, choice experiments, or choice-based conjoint analysis, is a type of conjoint analysis in which hypothetical products (as defined by various levels of attributes) are evaluated by a subject. In a stated choice experiment, respondents are asked to choose their preferred alternative, rather than ranking or rating the alternatives, which is a more typical conjoint analysis format (Adamowicz et al. 1998). Consumer researchers have found discrete choice methods to be a superior method relative to the ranking or rating techniques (Pinnell 1994). Stated choice techniques are a means to evaluate the potential market for a new product, or to identify the most important attributes of an existing product (Lee, Lerohl, and Unterschultz 2000). These techniques enable researchers to evaluate market situations that do not yet exist.

In stated choice analysis, respondents are only allowed to choose one option per choice set. The researcher determines the number of alternatives per choice set. Alternatives are typically limited to two to four per choice set. The inclusion of an opt-out, or "neither," option is also common. This serves as the base and is available to all respondents. The stated choice method was chosen because it mimics real market situations better than ranking or rating. In a market situation, individuals are faced with the choice of purchasing one product over another, or not purchasing either. While the ranking or rating methods allow for more responses per respondent, the reliability of the information is questionable for certain situations. Certain options would never be chosen in a real market environment. There is no real way to establish which options would never be chosen if there is no inclusion of an opt-out response. Also, response bias and respondent fatigue increase as the number of alternatives increase (Louviere, Hensher, and Swait 2000). The stated choice methods are in line with the random utility theory and can be analyzed with random utility models, unlike the ranking/rating conjoint methods (Louviere 1994).

A respondent is assumed to choose the alternative that yields the highest amount of available utility. A stated choice study evaluating the buyer preferences for durum wheat, from a sample of U.S. millers, revealed that protein and grade did not significantly influence the purchasing decision. The other attributes included in the study (price, source, bushel weight, and amylase) were significant and did influence the purchasing decisions of the millers. Respondents were asked to choose between three alternatives; a base wheat alternative and two hypothetical wheat alternatives (Lee, Lerohl, and Unterschultz 2000). Another stated choice study (Lawson and Manning 2002) determined which attributes of a wilderness setting have the most influence on the utility of overnight visitors. In this study respondents were asked to choose one of two campsite alternatives. The results showed that extensive signs of human use are relatively more important to the utility of overnight campers than any of the other attributes included in the study (Lawson and Manning 2002).

Environmental valuation has also been evaluated through the use of choice experiments. In one particular study, respondents from the United Kingdom (UK) made choices concerning alternative forest landscapes (Hanley, Wright, and Adamowicz 1998). A survey was administered in which respondents were asked to complete four choice tasks. Each choice task had two hypothetical forest alternatives, option A and option B, and a status quo alternative[7]. Alternative-specific variables were created for both options A and B. Socioeconomic variables were also included in the model (Hanley, Wright, and Adamowicz 1998). In other studies, the alternative-specific constants were combined into one (Adamowicz et al. 1998). If options A and B are not correlated with a specific attribute or alternative, they can be joined to estimate the non-status quo effect.

K.2. Payment Card

The CV format selected for use in this study was the payment card (PC) method. When compared to other CV methods, PC has shown a higher response rate and a lower percentage of protest bids than the open-ended and dichotomous choice methods (Reaves, Kramer, and Holmes 1999). Results of the PC approach have shown to be consistent with other more popular methods such as dichotomous choice and iterative bidding (Boyle and Bishop 1988). In some studies the payment card method was shown to have more consistent and efficient parameter estimates than those of the dichotomous choice method (Jordan and Elnagheeb 1994).

Some potential problems with the PC approach is that the true WTP may not be captured because it may lie between two of the values, it might be beyond the highest choice, or it could potentially be below the lowest choice. Also "free riding" may occur and people could submit

[7] The "status quo" option is an opt-out option and is estimated the same as the "neither" alternative.

artificially low values. To help alleviate these concerns, I elected to include a follow-up "specified-certainty" question (Ready, Navrud, and Dubourg 2001). The follow-up was a certainty scale, where respondents were asked to indicate their level of certainty that they would actually pay the price that they stated they would pay in the previous question[8] (Champ et al. 1997). If the certainty level was below 80%, respondents were asked to write in the amount that they would be at least 80% sure of paying.

There were only two CV type questions included in the questionnaire. This was done to avoid biases associated with contingent valuation methods. The most notable bias is the "starting point bias." This refers to those respondents' whose WTP amount is influenced by the first value that is suggested to them. This would either decrease the true WTP, by starting with an extremely low bid, or increase it, by starting with a high one. The PC method was created to mitigate this bias (Boyle and Bishop 1988; Cameron and Huppert 1991). Another possible bias is the "ordering effect." This bias suggests that a respondent's bid is influenced by the order of the questions. The respondent could be providing his true WTP for all cases. On the other hand, the respondent may take into account his first bid and then report a lower bid on the fourth question to offset his total spending. This type of bias will also occur if the respondent becomes annoyed from answering the same types of questions repeatedly, and does not give as much thought and consideration to the last questions as he did the first. These biases can prove to be detrimental to the research.

The payment card technique has mainly been used for topics relating to the environmental sector. It has been used in the valuing of environment aspects like how much people would be willing to pay to protect a rain forest. The results of one study showed that U.S.

[8] The scale was from 1 to 10, with 10 representing 100% certain.

residents were willing to pay $31 per household to protect a tropical rain forest (Kramer and Mercer 1997).

Willingness-to-pay studies concerning food safety and policy issues have also utilized the payment card approach. A study was conducted to find a niche market for Colorado potato growers. Willingness-to-pay estimates for potatoes grown in Colorado, GMO-free potatoes, and for organic potatoes were all positive with the highest mean WTP associated with the locally grown potatoes which averaged a 9.37 cent per pound price premium (Loureiro and Hine 2002). A food policy study evaluated the costs and benefits of adopting a specific post-harvest pesticide ban. The WTP values were elicited with the payment card method. In this study the estimated benefits (the WTP of the consumers) of banning the pesticide far outweighed the projected costs to producers who would be unable to use the pesticide (Buzby, Ready, and Skees 1995).

K.3. Concluding Remarks

The experimental auction approach was not chosen for this research, because of the inability to show the true characteristics of the product. One of the advantages of using experimental auctions is that consumers can see the product and its characteristics, and make bids based on what they know about the product. If I was to conduct an experimental auction with frozen fish sperm, it would be difficult to show producers the true benefits of the end product. Another disadvantage of the auction method is the cost that is required to thoroughly complete one. It would be nearly impossible to organize a meeting of grow-out producers from around the country, let alone pay for it.

Table III-1 is a summary of the advantages and disadvantages of the three WTP acquisition techniques that were considered for this research (Nalley 2004; Lusk and Hudson 2004). The advantages of CV and CA questionnaires are that they can be done at a lower cost than experimental auctions. With auctions, the cost of getting people to the place where the research is being conducted, the cost of the actual products used in the transactions, and any monetary values that are provided to the respondents can be expensive. Contingent Valuation and CA studies also allow for a larger sample size than auctions. With auctions, you are limited

Table III-1. Comparisons Of The Three Willingeness-To-Pay Acquisition Techniques.

Method	Advantages	Disadvantages
Contingent Valuation	More cost efficient than auctions Allows for a larger sample size than auctions Ability to focus on specific attributes	Susceptible to overestimation, due to the lack of consideration for budget constraints, and underestimation, due to the respondents attempts to receive a lower price. Vulnerable to question format bias
Conjoint Analysis	More cost efficient than auctions Allows for a larger sample size than auctions Specializes in product attribute combinations Mimics typical shopping experience Investigate trade-offs between competing attributes	Less focus on specific attributes Allows for a limited number of production profiles due to the difficulties in rating or ranking more than about nine profiles Restricts number of attributes being tested Limited to discrete choices Confusing to respondents
Experimental Auctions	Constant reminder of budget constraints due to the use of money Respondents can see the product and address all questions related to it Controls for external distractions Elimination of non-response bias	Higher costs per respondent Limitations on samples because of geography Possible bias in estimates due to potential participation payments

Source: Nalley 2004; Lusk and Hudson 2004.

to respondents within a certain region. Contingent Valuation questions do a better job of eliciting a value for a specific attribute than CA questions. The vulnerability of CV questions to various biases, leading to over and under estimations, is one distinct disadvantage of the CV method. A distinct advantage of the CA method is the ability to specialize in product attribute combinations. This can also be considered a disadvantage, because its effectiveness in focusing on specific attributes is restricted. Another advantage of the CA method is that it mimics the typical shopping experience more so than a typical CV format. Other limitations placed on CA questionnaires, are the amount of product combinations being ranked or rated, and the number of attributes allowed for each product. Other disadvantages associated with the CA formats, are the possibility that they can be confusing to the respondents as well as the limitations to discrete choices as answers. One advantage of the experimental auction design is the constant reminder to the respondent of his budget constraint. This can eliminate some of the biases that CV and CA questionnaires are vulnerable to. Respondents are also more informed in an auction setting, because they can actually see and feel the product, and also because the environment is controlled so as to reduce external distractions and keep the respondent constantly involved in the process. This cannot be done when conducting a mail survey. Two major disadvantages of the auction method are the high costs per respondent and the limitations on geographical area. Some auctions pay respondents, and this may also lead to some biased responses. Respondents may think that they will earn more money if they answer in a certain way (Nalley 2004; Lusk and Hudson 2004).

L. Survey

L.1. Mailing List

The data analyzed in this study were obtained from a nationwide mail survey of aquaculture producers. A mailing list was purchased from *Info*USA for all aquaculture producers in the United States. The original list sent to us had 1,068 addresses. An effort was made to eliminate duplicate companies as well as companies that clearly did not produce finfish[9]. Companies that were not farms (e.g. consulting firms, equipment supply stores, and government agencies not involved in farming activities) were also purged from the list. Companies that clearly practiced only wild catch methods were also removed, along with companies which were found not to be in operation[10].

In an effort to expand the list, approximately 485 companies were added by the researcher. This was done through internet searches and a review of the "Aquaculture Magazine: Buyer's Guide & Industry Directory" of 2003. These companies were compared to the existing list so that duplications were avoided[11]. The final mailing list totaled 1,293 listings.

L.2. Mail Out Procedure

The 1,293 surveys were delivered to the post office for mailing on June 16, 2005[12]. The surveys were accompanied with a cover letter addressed to "Aquaculture Producer" asking the general manager of the operation to please fill out the enclosed questionnaire. A copy of the cover letter is included in Appendix VIII. A second questionnaire was mailed out on July 6, 2005, to all farms who had not already responded to the first questionnaire. A second cover

[9] For example, crawfish farms and oyster farms were deleted from the list.
[10] Elimination of firms was done using information obtained over the internet.
[11] It is thought that duplication did still exist in the list due to different address listings for the same company name or different company names at the same address. Typically in these scenarios, both listings were left in the list, in an effort to increase the likelihood of reception by potential respondents.
[12] The surveys were sent out as "bulk mail."

letter was included for the second mail out, also available in Appendix VIII. After the second mailing, an electronic version of the survey was sent to those farms for which I had an e-mail address. The e-mail was sent on August 15, 2005, to farms that had not responded to the previous two mailings. The contents of the e-mail are included in Appendix VIII. On August 23, 2005, a postcard requesting those farms who had not responded to the previous surveys to please fill one out and mail it back. The potential respondents were instructed to call or e-mail for another copy if they had misplaced one of the other ones. This mailing was sent only to the farms that had not yet responded, and only to farms who did not receive the e-mailed questionnaire.

L.3. Design Preparation

The purpose of the questionnaire was to obtain information regarding the preferences, beliefs, and opinions of aquaculture producers across the U.S. about topics such as cryopreservation, genetic improvement, and the future of the aquaculture industry. These responses were used to determine which issues are most important to the various groups and segments of the aquaculture industry. The design of the survey went through many stages. The first stage was the evaluation of relevant questions by committee members[13]. After this stage was complete, the revised survey was sent to 6 aquaculture extension agents[14] for comments and critiques. Conversations with four of the agents led to more revisions of the questionnaire. The last revisions came from a current aquaculture producer. A meeting took place in which the producer went through the entire survey and commented on each question. Comments were

[13] Expertise of five committee members are as follows: Agricultural marketing, aquatic genetic improvement and cryopreservation, agricultural production economics, renewable natural resource economics, and aquaculture extension.

[14] The aquaculture extension agents were from AL, AR, LA, MS, NC, and TX.

made on the wording of the questions as well as the likelihood of a respondent actually answering specific questions. Final changes were then made to the questionnaire.

L.4. Survey Design

There were 3 versions of the questionnaire sent out[15]. Versions 1, 2, and 3 were equally and randomly distributed to the addresses on the mailing list. There were 431 addresses for each of the three versions. The survey was composed of three sections. The first was the hatchery section which applied only to farms that had spawning operations. Section 2 was to be completed by farms with foodfish grow-out operations. The third section applied to all aquaculture farms and included mostly demographic information. Farms were only asked to fill out the sections that applied to them. If a farm did not spawn fish, but grew them out, they would only have completed sections 2 and 3. The questionnaire was a total of 8 pages (including cover page) and included 39 numbered questions[16]. Copies of all three versions of the survey are included in Appendix X and XI[17].

M. Econometric Analysis

M.1. Discrete Choice WTP

M.1.a. Fish Stock Attribute Selection

Pre-testing of survey design and attribute selection were completed using the assistance of aquaculture extension agents and farm operators. The attributes selected for the study should be representative of the various aquaculture species that make up the foodfish sector. Also, there was a need to keep the amount of attributes to a minimum, so that the resulting choice scenarios would not be too taxing on the respondent. The four attributes used in the final version of the

[15] The only differences in the three versions were the two stated choice questions. Each version had a different set of stated choice alternatives. All other questions were exactly the same.
[16] Some questions required more than one response, making the total number of possible questions 60.
[17] Results of the survey are reported in Chapter 4 and in the Appendices.

survey were growth rate, disease resistance, resistance to 10% lower dissolved oxygen levels, and price. All the attributes are important in the production of any species within any production method. They also have important economic impacts. The faster a fish grows, the quicker it can be sold in the marketplace. If fewer fish die due to disease outbreaks the production efficiency will increase. A higher tolerance to less than desirable oxygen levels means less money needs to be spent on regulating the oxygen, as well as a better chance of more fish surviving poor conditions.

Each attribute was associated with either two or three levels. Growth rate and disease resistance were expressed as being at their current levels, a 10% improvement, or a 20% improvement. For example, if a producer currently averages a loss of 200 fish per season, then a 10% increase in disease resistance would result in an average loss of only 180 fish. The attribute resistance to 10% lower dissolved oxygen levels refers to the ability of the fish stock to tolerate 10% lower levels of dissolved oxygen within the water supply without dying. This attribute was either present (Yes) in the fish stock, or not (Current). The price attribute is expressed as a price premium. An amount that producers would pay above their current fingerling price – the levels were 20%, 40%, and 60%[18].

M.1.b. Model Description

A Conditional logit model was used to analyze the results of the discrete choice conjoint analysis section of the survey. Choice-based modeling is derived from random utility theory, which assumes that consumers maximize their utility with the choices that they make (Louviere, Hensher, and Swait 2000). Consumer utility maximization is comparable to the subjective profits of the producers in the context of this study. Producers are assumed to choose the product or method that will maximize their profits, just as consumers are assumed to select a product or

[18] It was determined that producers should realistically expect to pay a higher price for a higher quality fish stock.

service that will maximize their utility. Because researchers have incomplete information regarding the characteristics that make up the decision process, the random utility model separates total utility into two parts. The first is a deterministic component, (V_{ij}) and the second is a stochastic, or random, error component (e_{ij}) (Heiss 2002; McFadden 1974; Louviere, Hensher, and Swait 2000). The resulting utility equation is:

$$U_{ij} = V_{ij} + e_{ij}, \qquad (3)$$

where U_{ij} is the utility of the i^{th} consumer choosing the j^{th} product. Individual i will choose product j only if $U_{ij} > U_{ik}$, where k represents an alternative product. The probability that individual i will choose alternative j out of a set of k alternatives is:

$$\Pr_{ij} = \Pr\left(V_{ij} + e_{ij} \geq V_{ik} + e_{ik}; \forall k \neq j\right), \qquad (4)$$

for all k in the choice set not equal to j.

The conditional logit (CL), multinomial logit (MNL), and nested logit (NL) models are common tools used to analyze discrete choice variables. The NL model relaxes the independence of irrelevant alternatives (IIA) assumption. The IIA implies that the ratio of choice probabilities, for choosing one alternative over another, is not affected by adding or omitting additional alternatives. The MNL and CL do not relax this assumption.

M.1.c. Model

The MNL and the CL models are similar and can be used for many of the same types of analysis. The MNL utilizes individual-specific explanatory variables, whereas the CL model focuses on the characteristics of the alternatives for each individual and uses the alternative characteristics as the explanatory variables. The difference between the two models is shown in the following equations:

MNL: $$P_{ij} = 1 / \sum_{k=1}^{J} \exp\left[X_i\left(b_k - b_j\right)\right] \qquad (5)$$

CL: $$P_{ij} = 1 / \sum_{k=1}^{J} \exp\left[\left(Z_{ik} - Z_{ij}\right)a\right], \qquad (6)$$

where X_i is the individual-specific characteristics of individual *i*, *ß* and *a* are the parameter vectors, and Z_{ij} represents the characteristics of the j^{th} alternative for *i* individual. The probability in the MNL model is subject to the difference in coefficients for the alternatives. However, the CL model's probability depends on the difference in the value of the characteristics across alternatives (Hoffman and Duncan 1988). The CL allows explanatory variables to differ among choice options. The CL model allows for the analysis of the attributes in the alternatives as opposed to analyzing the attributes of the individual selecting the alternative (Jepsen and Jepsen 2002).

This study utilizes the CL model to analyze the data in the choice-based portion of the questionnaire. The conditional logit model assumes independent and identically distributed (i.i.d.) error terms with a Type I extreme value distribution. This study was interested in determining the relative importance of the selected attributes, as well as the willingness-to-pay for those attributes. The CL model allowed for the estimation of both.

Relative importance weights were calculated for each attribute group. To calculate the relative importance weight for each attribute, the utility range was determined. The utility range is the difference between the highest and lowest part-worth value for each attribute. Using the utility range for each individual attribute, the relative importance for a specific attribute was calculated by using the formula:

$$RI_i = \frac{UR_i}{\sum UR(\forall Attributes)} X100, \qquad (7)$$

where RI_i is the relative importance of the ith attribute and UR_i is the utility range for the ith attribute (Harrison, Stringer, and Prinyawiwatkul 2002). The willingness-to-pay values in this study were interpreted as the percentage increase that producers were willing to pay to obtain the specific genetic attribute. Willingness-to-pay for attribute i was calculated as the negative ratio of the coefficient for attribute i and the price premium coefficient. It was calculated as:

$$WTP_i = -\frac{b_i}{a}, \qquad (8)$$

where $ß_i$ is the coefficient of attribute i and a is the price premium coefficient.

M.1.d. Literature

Stated preference studies have utilized conditional logit models to estimate the data. The buying preference of commodities has been the focus of some stated preference studies. One such study evaluated the attributes that contribute the most to the purchasing of durum wheat (Lee, Lerohl, and Unterschultz 2000). Other studies utilized the CL model to evaluate the attributes that contributed to the choice of a recreational site. Here attributes in question included the presence of other hunters, trail availability, moose populations, road quality, as well as other attributes (Adamowicz 1997). One CL study tried to determine the selection of a partner by evaluating the characteristics that make up the decision making process of choosing a mate. The study compared results between same-sex couples and opposite-sex couples (Jepsen and Jepsen 2002). Wetland management programs have also been analyzed with the use of a CL model. Attributes included in one particular study included biodiversity, open water surface area, research and education, re-training, and the payment of the program (Birol, Karousakis, and Koundouri 2005).

M.2. Discrete Choice WTP with Interaction Effects

M.2.a. Description

The conditional logit model with interactions (CLI), or mixed model as it is sometimes referred, allows preferences to be heterogeneous by incorporating individual-specific characteristics into the model as interaction terms. Preference heterogeneity allows preferences to vary among individuals. This means that the impact on utility from changes in fish stock characteristics can vary across grow-out producers either randomly or logically (Breffle and Morey 2000; Birol, Karousakis, and Koundouri 2005). It is reasonable to assume that the characteristics of the farmer, as well as the farm, will have a significant impact on the preferences for selecting a fish stock alternative. The use of interaction variables allows me to model heterogeneity which is dependent on observed characteristics. A separate model would need to be used to estimate the impact of unobserved heterogeneity in the sample (Viton 2004). These individual-specific characteristics may include socioeconomic characteristics as well as variables representing the respondent's attitude towards a certain subject.

M.2.b. Model

The CLI utilizes individual-specific explanatory variables, which are estimated in a MNL, as well as the alternative-specific variables, which are estimated in the normal CL model, to form a mixed model. The model is shown in the following equation:

$$\text{CLI:} \qquad P_{ij} = \sum_{k=1}^{J} \exp\left(X_i b_j + Z_{ij} b\right) / \exp\left(X_i b_k + Z_{ik} a\right), \qquad (9)$$

where X_i is the individual specific characteristics of individual *i*, *ß* and *a* are the parameter vectors, and Z_{ij} represents the characteristics of the j^{th} alternative for *i* individual (Hoffman and Duncan 1988). The CLI allows explanatory variables to differ among choice options. The CLI model not only allows for the analysis of the attributes in the alternatives, but it also allows me to see which attributes of the individual affect choice selection (Jepsen and Jepsen 2002).

The CLI model was applied to the data in the choice-based portion of the questionnaire. The CLI model keeps the assumption of independent and identically distributed (i.i.d.) error terms.

M.2.c. Literature

One study, which evaluated the attributes contributing to the utility of a moose hunting trip, utilized the addition of interaction terms to the normal CL model in order to evaluate the impact of being from an urban area on the choice selection of a hunting site (Adamowicz et al. 1997). Another study evaluated the socioeconomic impacts on the selection of a forest design (Hanley, Wright, and Adamowicz 1998). In a study that evaluated the attributes associated with a wetland management program, interaction effects were measured for various individual-specific variables (Birol, Karousakis, and Koundouri 2005). The practice of using interaction terms can allow results to be more individual specific.

M.3. Contingent Valuation WTP

M.3.a. Description

For the evaluation of the influences on WTP from the contingent valuation questions, the use of a limited dependent variable model is considered. The dependent variable (WTP) associated with each of the two contingent valuation questions is considered to be a continuous variable. In some cases, the values associated with the dependent variable in the payment card method are considered ranges, and the valuations are assigned a log-normal conditional distribution (Cameron and Huppert 1991; Kramer and Mercer 1997). However, in this case, the ability of the respondent to write-in a bid in which they were at least 80% sure of paying led to the assumption of a totally continuous WTP variable. Therefore, a normal distribution of the dependent variable was assumed. Each respondent also had the opportunity to not pay anything. By responding "No" to the initial WTP question, a zero bid was recorded as their WTP. When evaluating the responses to CV type questions, there is always a possibility of receiving a high number of zero bids. I found that to be the case in this study as well. Forty-seven percent of respondents were not willing to pay a premium for genetic uniformity and 62% were not willing to pay for supply reliability.

I must account for the censoring of the sample from the zero bids or the parameter estimates will be biased (Shrestha et al. 2002). For this reason the Ordinary Least Squares (OLS) model would not be an appropriate estimation tool for my results (Coady 1995; Gourieroux 2000). The application of a censored or truncated regression model is needed. The tobit model, proposed by Tobin (1958), is frequently used in situations where there are a large number of zero values observed from payment card or open-ended CV studies (Afroz et al. 2005; Kramer and Mercer 1997). Cragg's model, which is often referred to as the double-hurdle model, is a truncated regression model that is an alternative to the tobit model (Lin and Schmidt 1984; Coady 1995; Cragg 1971; Haines, Guilkey, and Popkin 1988).

M.3.b. Tobit Model

The tobit model has been used in a number of open-ended and payment card CV studies in order to evaluate the explanatory variables affecting WTP (Shrestha et al. 2002; Afroz et al. 2005; Kramer and Mercer 1997; Kim and Cho 2002). The tobit model is:

$$Y_i^* = X_i b + e_i, \qquad (10)$$

where X_i is a vector of explanatory variables, *ß* is a vector of coefficients, and e_i is an error term assumed to be an independently, identically, normally distributed random variable with a zero mean and a variance of s^2, where i denotes individuals in the sample. The Y_i^* , or WTP, are unobserved latent continuous variables[19]. The observed WTP variable, Y_i is:

$$Y_i = \begin{cases} Y_i^* \approx Y_i^* > 0 \\ 0 \approx \textit{otherwise.} \end{cases} \qquad (11)$$

P(Y_i = 0) = F(-X_iß / s) is the probability of observing a limit observation. The log likelihood of the censored regression is:

$$\ln L(b, s) = \sum_{Y_i=0} \ln\left[1 - \Phi\left(\frac{X_i b}{s}\right)\right] + \sum_{Y_i>0}\left[\ln\left(\frac{1}{\sqrt{2p s^2}}\right) - \left(\frac{1}{2s^2}\right)(Y_i - X_i b)^2\right]. \qquad (12)$$

Once the ß and s values are optimized, the expected Y_i can be derived from:

$$E[Y_i] = X_i b^e_{tobit} \Phi\left(X_i b^e_{tobit} / s^e\right) + s^e f\left(X_i b^e_{tobit} / s^e\right), \qquad (13)$$

where b^e_{tobit} and s^e are the estimated optimal values, f is the normal distribution function, and F is the normal cumulative distribution function (Kim and Cho 2002; Shrestha et al. 2002; Haines, Guilkey, and Popkin 1988).

The tobit model is limited in its analysis. For one, the ß values not only determine the probability of observing a positive WTP value, they also determine the mean of the positive WTP values. Therefore, any variable that increases the probability of paying some amount greater than zero would also increase the mean of the WTP amounts. The tobit model also links the shape of the distribution for positive WTP values to the probability of a positive WTP value (Haines, Guilkey, and Popkin 1988; Lin and Schmidt 1984). Another assumption which limits the range of the model's analysis is the assumption behind the "zero" bids. The tobit model

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[19] In some payment card studies ranges are used for the dependent variable. When using ranges, a log-normal structure might be considered (Kramer and Mercer 1997).

assumes the "zero" bids are a reflection of the farm not adopting due to the cost associated with the cryopreservation service or some other fixed farm characteristic. In reality, the farm may choose not to pay for various other reasons. The farm manager may have limited knowledge about the service he is being asked to pay for. The farm may simply not have any disposable income at the present time. Other factors, not related to the price of the service, may have an impact on the decision to pay for a service. This is not taken into account in the assumptions of the tobit model (Coady 1995).

M.3.c. Cragg's Model

An alternative to the tobit model, proposed by Cragg (1971), is less restrictive and allows for a more detailed analysis of WTP explanatory variables. Cragg's model, often referred to as the double-hurdle model or the two-step approach, has two separate equations to analyze responses. The first is a sample selection, or participation, equation estimated with a probit model. The probit model represents the probability of a limit observation, which is given by:

$$P(Y_i = 0) = \Phi(-X_i b_1), \qquad (14)$$

where Y_i is the WTP dependent variable, X_i are a vector of explanatory variables, ß are a vector of parameters, and F is the standard normal cumulative distribution function (Haines, Guilkey, and Popkin 1988; Lin and Schmidt 1984). With this part of Cragg's model, I can evaluate the attributes that are most important in the decision of whether or not a farmer would be willing to pay for the service offered to him. All responses are included in the probit model.

The second equation in Cragg's model is an outcome equation, which uses a truncated model to estimate the parameters of the individuals who have a positive outcome in the first equation. This second stage uses observations only from those respondents who indicated a positive WTP value. Therefore, I assume Y_i is positive with a normal mean and variance, $N(X_i \beta_2, s^2)$, truncated at 0. The equation is therefore:

$$f(Y_i / Y_i > 0) = \{1/s\, f([Y_i - X_i b_2]/s)\} / f(X_i b_2 / s). \qquad (15)$$

When the indicator function is defined as $I_t = 1$ if $Y_i > 0$ and $I_t = 0$ if $Y_i = 0$, then the log likelihood function is as follows:

$$L = \sum_{t=1}^{T} \left\{ \begin{array}{l} (1 - I_t)\ln \Phi(-X_t b_1) + \\ I_t \left[\ln \Phi(X_t b_1) - \ln \Phi(X_t b_2 / s) - 1/2 \ln(2 p s^2) - \dfrac{1}{2s^2}(Y_i - X_t b_2)^2 \right] \end{array} \right\}. \qquad (16)$$

In the case that $\beta_1 = \beta_2/s$, this model will contain the usual tobit model (Haines, Guilkey, and Popkin 1988; Lin and Schmidt 1984).

The use of Cragg's model allows for the analysis of factors that influence the decision to purchase and separately analyzes the factors that influence how much someone is willing to pay for the product or service. In Cragg's participation model the zero bids can be related to the price of the service, as in the tobit model, or they can be associated with a true non-consumption of the good (Demoussis and Mihalopoulos 2001). The tobit model is essentially a special, more restrictive, case of the Cragg model. If the restrictions are valid, then the tobit model may be used. If the restrictions are not valid, tobit model results may be misleading or even incorrect (Haines, Guilkey, and Popkin 1988).

M.3.d. LR Test

To determine if the tobit restrictions are valid, a test using a likelihood ratio (LR) statistic is used. This statistic is calculated by using the log-likelihood values for each of the three models. The equation is:

$$l = -2[\ln L_{Tobit} - (\ln L_{\mathrm{Pr}obit} + \ln L_{Truncated})], \qquad (17)$$

where L_{Tobit} is the likelihood value for the tobit model, L_{Probit} is the likelihood value for the probit model, and $L_{\text{Truncated}}$ is the likelihood value for the truncated portion of Cragg's model. This statistic is distributed asymptotically as ?^{2} with degrees of freedom equal to the number of explanatory variables plus the intercept. If the value is greater than the critical value of ?^{2}, then the hypothesis of tobit being a good fit is rejected (Demoussis and Mihalopoulos 2001; Greene 2003). A separate test of significance for use of the tobit model is the Lagrange Multiplier (LM) test. Derived by Lin and Schmidt (1984) it uses only the results of the tobit model. The null hypothesis is that tobit, with its single decision making structure, is the correct model. If rejected the Cragg model would be superior in estimating the results. The LM test statistic is also distributed asymptotically as ?^{2} with degrees of freedom equal to the number of explanatory variables (Haines, Guilkey, and Popkin 1988; Lin and Schmidt 1984). This model is, however, more algebraically cumbersome and therefore was not selected as the testing mode in this study (Greene 2003).

M.4. Hatchery Adoption of Cryopreservation Services

M.4.a. Description

An ordered probit model was used to analyze the responses given to a question located in the hatchery section of the survey regarding the willingness to incorporate costs associated with cryopreservation services. Question 9 of the survey, located in the hatchery section, asked respondents to "Select the answer that most clearly represents your opinion." Question 9 was divided into four separate questions. These questions dealt with benefits and services associated with cryopreservation. The fourth question was, "Assume there was a service that would freeze the sperm of your fish, store it until you were ready to fertilize your eggs, and then transport it to you. Would you be willing to pay the storage and processing costs that are required to maintain this service throughout the year?" The answers available in the survey were, "Definitely," "Maybe," "Not sure," "Probably not," and "Definitely not." By analyzing this question, I determined which factors impact a farm's willingness to incorporate all services and costs associated with cryopreservation. At present, there are no specific numerical estimates available to include in the question. Specific storage and processing costs for aquatic sperm have not been determined[20]. This question simply allows for the investigation of farm types who are willing to pay some price premium. It does not provide specific price premium values.

The dependent variable in this model is categorical in nature. An Ordinary Least Squares (OLS) model would not be appropriate, even though a linear relationship is assumed for the independent variables. The use of OLS could result in predicted probabilities greater than 1 or less than 0, as well as inefficient parameter estimates due to heteroscedasticity (Jekanowski, Williams, and Schiek 2000). The dependent variable is a discrete choice by the respondent, where the choices have a natural order associated with them. The choices cover a range of opinions by the respondent, beginning with "Definitely not" willing to pay the associated costs, all the way to "Definitely" willing to pay the costs. Due to the essential ranking of the dependent variable, a non-linear ordered response model needs to be used (Franses and Paap 2001; Curtis and Lynch 2001; Jekanowski, Williams, and Schiek 2000). The typical methods to estimate an ordered multinomial dependent variable is through the use of an ordered probit or ordered logit model. The subjective profits[21] achieved by producers purchasing cryopreservation services (C) $?_c$ versus not purchasing (N) $?_n$, is not observable. The subjective profits of individual firm *i* from the utilization of a good with attribute *j* is:

[20] It could be assumed that the storage and processing costs would be similar to the storage and processing costs of dairy sperm because of the similar services being provided.
[21] Subjective profits are comparable to utility values used in consumer theory. This is because we assume a consumer will choose the alternative that provides the highest level of utility, just as we assume a producer will select the alternative that provides the highest subjective profits.

$$\Pi_{ij} = V_{ij} + e_{ij}, \; j = C, N , \qquad (18)$$

where $?_{ij}$ is the producer's subjective profits, V_{ij} is a deterministic component made up of the characteristics of the producer and of the attribute chosen, and e_{ij} is a random component (Hossain et al. 2003). The observed or stated choice, y_i, is used as the dependent variable because Y_i, the true choice, is not known. We assume:

$$y_i = 0 \text{ (Definitely not)} = \text{if } a_{-1} < Y_i = a_0$$

$$y_i = 1 \text{ (Probably not)} = \text{if } a_0 < Y_i = a_1$$

$$y_i = 2 \text{ (Not sure)} = \text{if } a_1 < Y_i = a_2 \qquad (19)$$

$$y_i = 3 \text{ (Maybe)} = \text{if } a_2 < Y_i = a_3$$

$$y_i = 4 \text{ (Definitely)} = \text{if } a_3 < Y_i = a_4,$$

where a's are free parameters which bind the ranges that contain the true Y_i preference (Curtis and Lynch 2001). The probabilities associated with choosing each Y_i are specified as:

$$\Pr[Y_i = j|X_i] = \Pr[a_{j-1} < y_i = a_j]$$

$$= \Pr[a_{j-1} - (ß_0 + ß_1 x_i) < e_i = a_j - (ß_0 + ß_1 x_i)]$$

$$= F(a_j - (ß_0 + ß_1 x_i)) - F(a_{j-1} - (ß_0 + ß_1 x_i)), \qquad (20)$$

for j = 2, 3,…,J – 1, where

$$\Pr[Y_i = 1|X_i] = F(a_1 - (ß_0 + ß_1 x_i)), \qquad (21)$$

and

$$\Pr[Y_i = J|X_i] = 1 - F(a_{J-1} - (ß_0 + ß_1 x_i)), \qquad (22)$$

for the outer categories. F represents the cumulative distribution function of e_i (Franses and Paap 2001). The distribution of the error terms ($e_i = e_{Ci} - e_{Ni}$) is assumed to have a standard normal distribution of $\mu_i \sim N(0,1)$, therefore the ordered probit model was used instead of the ordered logit model[22].

M.4.b. Literature

A variety of topic areas have been studied and analyzed with the use of ordered models. Ordered probit models have been used to evaluate consumer's willingness to purchase specific types of food products such as GM and pesticide free products. A 2003 study evaluated the willingness to consume GM orange juice, breakfast cereal, and hamburger beef based on various demographic variables of the consumer (Hossain et al. 2003). Cranfield and Magnusson (2003) used the ordered probit to elicit willingness-to-pay estimates for pesticide free products. The dependent variable was categories representing increasing levels of price premiums willing to be paid by the consumer. The preference for deer population numbers in Maryland was estimated from the perspective of hunters, landowners, and the general public as a function of numerous demographic variables with an ordered probit model (Curtis and Lynch 2001). Typically ordered models are applied to stated preference data received from a survey type instrument. The categorical type questions which are prominent in surveys lend themselves to be estimated by this type of model.

[22] The ordered logit model assumes a standard logistic distribution of the error terms.

CHAPTER IV: RESULTS

A. Survey Results

Fifty-one of the 1,293 potential respondents were removed from the available population. Reasons for removal included: 20 wrong addresses ("Return to Sender"), 7 farms that were no longer in business, 4 farms that did not produce finfish, 2 companies that were farm supply providers, 1 company that was a consulting firm, 2 duplicate respondents, 2 fish monitoring facilities, and 5 farms that were not aquaculture producers. This left a total available population of 1,242. I received 146 usable surveys, for a response rate of 11.8%. There were some interesting reactions to the postcards. It seemed that many farms did not remember receiving a questionnaire. Other respondents reported inaccurate contact names on the postcards. This led me to believe that many of the contact names provided in our mailing list were either outdated or incorrect[23]. It can be assumed that if the contact names were wrong for the survey mailings, the surveys could have been thrown out by other respondents. It is likely that my response rate was negatively affected by inaccuracies of contact information provided by the mailing list[24].

Descriptive statistics for the data were organized into seven data sets. The first data set reports the results from all respondents to the survey. The two major data sets are the results from all farms with a hatchery operation and the results from all farms with a grow-out operation. The next four data sets are: farms that have both spawning and grow-out operations, farms with only a spawning operation, farms with only a grow-out operation, and those that indicated they are neither a hatchery nor grow-out operation.

[23] A few farms completed the survey, but noted that there was not anyone there by the name on the envelope, nor had there ever been.
[24] Note that not all potential respondents had a contact name on the envelope. Approximately 40% just had the name of the farm and the address.

Table IV-1 reports descriptive statistics for all respondents in the sample. Approximately 58% of respondents reported having a spawning operation, while 48% reported having grow-out activities on their farm. The grow-out section was explicitly for foodfish producers, thereby limiting the amount of possible respondents. The hatchery section asked if the farm had spawning operations, not limiting farms to the spawning of foodfish. Twenty-four percent of farms reported having both a spawning operation as well as a foodfish grow-out operation. Over 77% of the responding farms were private commercial operations. More than half of the total respondents reported being either slightly or strongly in favor of the practice of cryopreserving sperm[25]. While 34% of respondents agreed that cryopreservation would become an integral part of the aquaculture industry within the next 5 years, only 20% agreed that they would incorporate cryopreservation services into their existing operation if the services were available. This shows that the industry is aware of the technology, but most are not yet ready to risk early adoption.

Table IV-1. Summary Statistics For All Survey Respondents.

Variable	Number of Respondents	% of Respondents	Mean	St.dev.
Usable Responses by Version				
Version 1	57	39.04%		
Version 2	47	32.19%		
Version 3	42	28.77%		
Total	**146**	**100.00%**		
Breakdown of Respondent's Operations				
Spawning Operations	85	58.22%		
Grow-out Operations	70	47.95%		
Both Spawning & Grow-out	35	23.97%		
Only Spawning	50	34.25%		
Only Grow-out	35	23.97%		
Only Demographic	26	17.81%		
Public or Private Operation				
Public = 0	32	21.92%		
Private = 1	113	77.40%	0.7877	0.4268
Both = 2	1	0.68%		
Total	**146**	**100.00%**		

[25] Only 3% were actually against the practice. The remaining 44% reported "No Position."

Table IV-1. (cont.)

Employees				
< 10 = 0	121	82.88%		
10 to 50 = 1	23	15.75%		
51 to 150 = 2	2	1.37%	0.1849	0.4235
> 150 = 3	0	0.00%		
Total	**146**	**100.00%**		
Gross Sales				
< $2,500 = 0	11	9.17%		
$2,500-$9,999 = 1	6	5.00%		
$10,000-$49,999 = 2	18	15.00%		
$50,000-$249,999 = 3	35	29.17%		
$250,000-$999,999 = 4	29	24.17%	3.0917	1.5007
$1 million-$4,999,999 = 5	18	15.00%		
$5 million or more = 6	3	2.50%		
Total	**120**	**100.00%**		
Education				
Less than high school = 0	1	0.69%		
High school diploma or GED = 1	20	13.79%		
Some college/technical school = 2	36	24.83%		
Bachelor’s degree = 3	57	39.31%	2.6690	0.9864
Advanced degree = 4	31	21.38%		
Total	**145**	**100.00%**		
Age				
18-25 = 0	1	0.70%		
26-35 = 1	13	9.09%		
36-45 = 2	33	23.08%		
46-60 = 3	80	55.94%	2.6783	0.8188
> 60 = 4	16	11.19%		
Total	**143**	**100.00%**		
Spawning Operations				
Yes = 1	85	58.22%		
No = 0	61	41.78%	0.5822	0.4949
Total	**146**	**100.00%**		
Grow-out Operations				
Yes = 1	70	47.95%		
No = 0	76	52.05%	0.4795	0.5013
Total	**146**	**100.00%**		
Responses by Contact Method				
1st mail out	58	39.73%		
2nd mail out	67	45.89%		
E-mailed	3	2.05%		
Postcard	18	12.33%		
Total	**146**	**100.00%**		

Respondents were asked to report the distribution of gross sales by species farmed on their operation for both the spawning and grow-out sections. The species that makes up the majority of a farm’s sales percentage will hereafter be referred to as the “primary” product of the farm. If a farm produces any amount of a species, it may be referred to as "producing some." Table IV-2 shows the production distribution for farms that have a hatchery. For farms with hatchery operations, most respondents reported "Other[26]" as their primary hatchery species.

Table IV-2. Hatchery Product Distribution For Farms With Hatcheries.

74 respondents reported species totals % of the 74 respondents	**Primary Product[27]**	**Single Product Operation[28]**	**Produce Some[29]**
Channel catfish	14 18.92%	7 9.46%	21 28.38%
Hybrid striped bass	3 4.05%	1 1.35%	6 8.11%
Tilapia	5 6.76%	5 6.76%	8 10.81%
Atlantic salmon	2 2.70%	2 2.70%	2 2.70%
Rainbow trout	13 17.57%	5 6.76%	14 18.92%
Other	37 50.00%	26 35.14%	52 70.27%
Percent of farms with only one product =		**62.16%**	
Percent of farms with multiple products =		**37.84%**	

Table IV-3 shows the foodfish grow-out product distribution for farms with grow-out operations. Channel catfish was reported by the majority of grow-out producers as the primary product on the farm. Twenty-nine percent of grow-out producers reported rainbow trout as their farm's primary product. Additional product distribution tables, along with a detailed description of each question in the survey, by all sets of respondents, are provided in the appendices.

[26] Examples of "Other" species include brook and brown trout, Pacific salmon, abalone, bluegill, largemouth bass, red drum, various species of perch, Baitfish, ornamentals, white amur, and more.
[27] Primary product refers to species that represent the highest percentage of reported sales.
[28] Single product operation refers to species that represent 100% of reported sales.
[29] Produce some refers to species that represent some percentage of reported sales (1% to 100%).

Table IV-3. Grow-out Product Distribution For Farms With Grow-out Operations.

69 respondents reported species totals % of the 69 respondents	Primary Product[30]	Single Product Operation[31]	Produce Some[32]
Channel catfish	22 31.88%	18 26.09%	24 34.78%
Hybrid striped bass	8 11.59%	2 2.90%	10 14.49%
Tilapia	7 10.14%	7 10.14%	10 14.49%
Atlantic salmon	2 2.90%	2 2.90%	2 2.90%
Rainbow trout	20 28.99%	13 18.84%	21 30.43%
Other	10 14.49%	9 13.04%	22 31.88%
Percent of farms with only one product =		**73.91%**	
Percent of farms with multiple products =		**26.09%**	

B. Analysis of Hatchery Operations

B.1. Survey and Data

Eighty-five respondents reported that they conducted spawning operations on their farm[33] (Table IV-1). As seen in Table IV-2, half of the respondents reported "Other" as their primary product[34]. Channel catfish and rainbow trout made up the majority of the remaining responding farms. Thirty-seven percent of farms reported production of more than one species. Table IV-4 reports some descriptive statistics of the hatchery respondents. Just over 70% of farms reported that they were a private company, and about the same amount reported employing less than 10

[30] Primary product refers to species that represent the highest percentage of reported sales.
[31] Single product operation refers to species that represent 100% of reported sales.
[32] Produce some refers to species that represent some percentage of reported sales (1% to 100%).
[33] Seventy-four of the 85 respondents reported the specific species spawned at their operation.
[34] Primary product is defined as the product with the highest reported percentage of sales.

full time people. Eighty-six percent of respondents reported that they maintain their broodstock on-site throughout the year. The primary method of on-site maintenance was ponds. Spawning method responses were nearly split equally between natural and artificial methods, with 9 farms reporting that both methods were used in their operation. The majority of respondents (55%) currently practice selective breeding techniques[35].

Table IV-4. Summary Statistics For Respondents With Spawning Operations.

Variable	Number of Respondents	% of Respondents	Mean	St.dev.
Spawning Operations	**85**	**100.00%**		
Maintain on-site throughout the year				
Yes = 1	72	85.71%		
No = 0	12	14.29%	0.8571	0.3520
Total	**84**	**100.00%**		
Methods Utilized for On-site Maintenance (% of 72)				
Pond	42	58.33%		
Flow-through	25	34.72%		
Net pens/Cages	4	5.56%		
Closed re-circulation	14	19.44%		
Other	0	0.00%		
Collect Broodstock				
Yes = 1	27	32.14%		
No = 0	57	67.86%	0.3214	0.4698
Total	**84**	**100.00%**		
Purchase Broodstock				
Yes = 1	10	12.05%		
No = 0	73	87.95%	0.1205	0.3275
Total	**83**	**100.00%**		
Other Methods				
Yes = 1	4	4.76%		
No = 0	80	95.24%	0.0476	0.2142
Total	**84**	**100.00%**		
Spawning Method				
Artificial = 1	38	45.78%		
Natural = 0	36	43.37%		
Both = 2	9	10.84%	0.6745	0.6646
Total	**83**	**100.00%**		
% of Eggs Fertilized				
<20% = 0	1	2.00%		
21-40% = 1	2	4.00%		
41-60% = 2	6	12.00%		
61-80% = 3	19	38.00%	3.1800	0.9409
81-100% = 4	**22**	44.00%		
Total =	**50**	**100.00%**		

[35] Selective breeding is the mating of specific animals to produce offspring with selected desirable characteristics.

Table IV-4. (cont.)

Utilize Selective Breeding Techniques				
Yes = 1	46	55.42%		
No = 0	37	44.58%	0.5542	0.5001
Total	**83**	**100.00%**		
Grow-out Operations				
Yes = 1	36	42.35%		
No = 0	49	57.65%	0.4235	0.4971
Total	**85**	**100.00%**		
Employees				
< 10 = 0	62	72.94%		
10 to 50 = 1	21	24.71%		
51 to 150 = 2	2	2.35%	0.2941	0.5076
> 150 = 3	0	0.00%		
Total	**85**	**100.00%**		
Total Gross Sales				
< $2,500 = 0	6	8.96%		
$2,500-$9,999 = 1	4	5.97%		
$10,000-$49,999 = 2	7	10.45%		
$50,000-$249,999 = 3	17	25.37%		
$250,000-$999,999 = 4	13	19.40%	3.3433	1.6381
$1 million-$4,999,999 = 5	17	25.37%		
$5 million or more = 6	3	4.48%		
Total	**67**	**100.00%**		
Education				
Less than high school = 0	0	0.00%		
High school diploma or GED = 1	8	9.52%		
Some college/technical school = 2	17	20.24%		
Bachelor's degree = 3	37	44.05%	2.8690	0.9155
Advanced degree = 4	22	26.19%		
Total	**84**	**100.00%**		
Age				
18-25 = 0	1	1.20%		
26-35 = 1	7	8.43%		
36-45 = 2	18	21.69%		
46-60 = 3	48	57.83%	2.6867	0.8253
> 60 = 4	9	10.84%		
Total	**83**	**100.00%**		

B.2. Willingness-to-adopt Cryopreservation Services

Table IV-5 shows the distribution of answers to whether or not the farm would be willing to pay for the costs associated with cryopreservation services. "Definitely not" was coded as 0, and definitely was coded as 4. Most species have means less than two. However, hybrid striped bass farmers have a mean above three, which shows a strong positive interest from the bass producers.

Table IV-5. Attitudes Towards The Adoption Of Cryopreservation Services[36].

	Definitely Not	Probably Not	Not Sure	Maybe	Definitely	Mean
Channel catfish	3	6	3	7	2	1.95
Hybrid striped bass	0	0	0	3	3	3.50
Tilapia	2	1	3	1	1	1.75
Atlantic salmon	0	0	0	2	0	3.00
Rainbow trout	3	5	4	2	0	1.36
Other	10	11	10	14	5	1.86

B.3. Ordered Probit Results

The ordered probit model includes two types of variables. The first type of variables are related to farm specific characteristics. These include dummy variables for species produced on the farm ("some amount"), if the farm maintains broodstock on-site throughout the year, if the farm artificially spawns, if the farm selectively breeds, if the farm has grow-out operations, if it is a private facility, if the farm has adopted two or more of the new technologies inquired about in the survey[37], if there are 10 or more full time employees on the farm, and the years the farm has been in operation. The second type of variables include individual-specific characteristics, such as preferences and beliefs of the farm manager[38]. This was done so that I could evaluate which types of farms, along with which types of managers, are most likely to pay for cryopreservation services. The individual-specific variables that were included are whether an operator had a Bachelor's degree, a positive opinion of the benefits and future of cryopreservation within aquaculture industries[39], if the respondent was in favor of cryopreserving

[36] This table represents the distribution of answers to statement 4 in Question 9. The numbers are based on a farm producing "some amount" of the species.
[37] Question 36.
[38] It is assumed that the manager is the person responsible for completing the survey (refer to cover letter).
[39] Created by evaluating responses from 5 statements in question 39.

sperm[40], and if the respondent was considered knowledgeable about cryopreservation[41]. All variables, with the exception of "years of operation," were (0,1) dummy coded.

According to theory concerning the adoption of new technology by a firm,[42] human capital, firm-specific characteristics, and knowledge about the new technology are expected to be important variables in adoption decisions. A higher level of education achieved by the manager, which is an example of human capital, should theoretically translate into a positive effect on the willingness-to-adopt. An example of a firm-specific characteristic would be the size of the operation. I expect that as the scale of production increases, the willingness-to-adopt a new technology also increases. Therefore, I expected to see a positive effect from the variable "10 or more employees," which represents 10 or more full-time employees on the farm.

Another firm-specific characteristic is previous adoption of new technologies. I expected the variable "Multiple New Technologies" to be positive because of previous adoption practices. I expected the variable "Knowledge," which represents the respondent's knowledge about cryopreservation, to be positive. The more knowledgeable a manager is about a product or service, the more likely that manager is to incorporate the product or service into his production practices. I expected the variables "Artificial Spawning" and "Selective Breeding" to be positive. I believe that the operations which are currently artificially spawning their broodstock, as well as operations that are currently practicing selective breeding techniques, will potentially benefit the most from incorporating cryopreservation services, due to increased efficiency. A positive effect was also expected from hatcheries that maintain broodstock. This is because of the presumed savings to a farm that no longer has to pay costs to maintain a broodstock pond throughout the year. The variable "Private" was expected to have a negative coefficient because

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[40] Statement number 5 in question 38.
[41] Created by evaluating responses from 7 statements in question 10.
[42] Refer to III.E. for review of literature.

public farms, typically, have more funds available to use on research and development, otherwise known as new technologies.

The variables "Positive" and "Favorable to Cryopreservation" represented the opinions concerning cryopreservation, in general, and its future in aquaculture industries. They were expected to be positive in this model because farmers who have a positive opinion of cryopreservation should be willing to pay the costs associated with its services. The two age variables included in the model were expected to be negative. This is because they are relative to the youngest group of farm managers. Younger managers are typically more inclined to incorporate a new technology than the more established older managers (Adesina and Zinnah 1993). The expected sign associated with the years in which a farm has been in operation is ambiguous. There is no rationale enabling me to assume a positive or negative effect from years in operation. The presence of a grow-out operation was expected to have a positive effect. Hatchery operations that also participate in the grow-out sector may anticipate higher profits for both production activities. I expected the "Channel Catfish" variable to be negative because this is an industry that typically naturally spawns and does not utilize selective breeding. At the present time, cryopreservation most likely would not make channel catfish production more efficient. The same is assumed for the "Tilapia" variable. "Hybrid Striped Bass," "Atlantic Salmon," and "Rainbow Trout" were assumed to have a positive effect on the probability of adoption. These industries all currently use selective breeding and/or artificial spawning.

Results of the ordered probit analysis are provided in Table IV-6. The overall model (Table IV-6) was found to be significant at the a = 0.01 significance level with a log likelihood ratio of 81.39. The farming of hybrid striped bass and Atlantic salmon, as expected, had positive

Table IV-6. Ordered Probit Regression Results For Hatchery Producers' Willingness-to-Adopt Cryopreservation Services.

	Ordered probit	
	Coefficient	St. Error
Species Farmed at All		
Channel Catfish	-.182	.455
Hybrid Striped Bass	2.711***	.850
Tilapia	-1.096*	.659
Atlantic Salmon	2.822**	1.169
Rainbow Trout	-1.299**	.505
Other	.544	.437
Maintain Broodstock	2.446***	.896
Artificial Spawning	.213	.487
Selective Breeding	.837**	.405
Grow-out Facility	.738*	.400
Private	-.278	.599
Bachelor's Degree	-.476	.434
Multiple New Technologies	-.324	.425
Positive	1.045***	.402
10 or More Employees	.872**	.393
Favorable to Cryopreservation	1.215**	.493
Knowledge	-.225	.389
Age[43]		
To 60	-1.115*	.623
Over 60	-.552	.810
Years of Operation	.011	.011
Cut 1	1.641	1.034
Cut 2	3.135***	1.086
Cut 3	4.445***	1.141
Cut 4	6.678***	1.264

Number of observations = 64
LR (20) = 81.39***
Pseudo R^2 = .413

* Statistically significant at the $p < 0.10$ level.
** Statistically significant at the $p < 0.05$ level.
*** Statistically significant at the $p < 0.01$ level.

and significant effects on willingness-to-adopt cryopreservation services. The effect of farming tilapia and rainbow trout was negative and significant[44]. The negative effect of being a rainbow

[43] The age variables are relative to the holdout category which represents the youngest group of managers ages 18 to 36.

trout farmer was not as expected. Maintenance of broodstock and selective breeding had positive and significant effects. The presence of grow-out operations proved to be positive and significant in this model. Having 10 or more full time employees, a positive opinion about cryopreservation, and being in favor of the practice of cryopreserving sperm, were positive and significant. The age variable "To 60," representing farm managers between the ages of 36 and 60, had a negative and significant effect on the willingness to pay costs associated with cryopreservation services. The age variables included in the model were relative to the youngest group of farm managers, which were between the ages of 18 and 36. This was expected, assuming that younger managers are more willing to adopt a new technology, as is typical in economic studies.

Marginal effects and predicted probabilities associated with the ordered probit model are presented in Table IV-7. All variables, except years of operation, are dummy coded variables and the marginal effects are interpreted as the effect on the dependent variables when the independent variable goes from 0 to 1, holding all other variables constant at the mean. For example, going from a non-favorable opinion of cryopreservation to a favorable view of cryopreservation has a negative and significant effect on the producer selecting "Probably not" as his response to the question representing the dependent variable for this model. However, going from a non-favorable opinion of cryopreservation to a favorable view of cryopreservation has a positive and significant effect on the respondent choosing "Maybe" as his answer. Going from not producing to producing hybrid striped bass has a strong positive effect on the producer responding "Maybe" to paying the processing and storage costs associated with cryopreservation services.

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[44] Significance levels were 90% or greater for variables considered significant.

Table IV-7. Predicted Probabilities And Marginal Effects For The Ordered Probit Regression Model.

	Definitely Not=0	**Probably Not=1**	**Not Sure=2**	**Maybe=3**	**Definitely=4**
Predicted Probabilities	.023	.287	.482	.207	.001
			Coefficients of Marginal Effects		
Species Farmed at All					
Catfish	.011	.055	-.015	-.050	-.001
Hybrid Striped Bass	-.038	-.349***	-.415***	.510**	.291
Tilapia	.138	.278**	-.208	-.205**	-.002
Atlantic Salmon	-.029	-.312***	-.448***	.413	.376
Rainbow Trout	.162	.320***	-.229*	-.251***	-.003
Other	-.039	-.161	.060	.139	.002
Maintain Broodstock	-.590*	-.125	.449***	.264***	.002
Artificial Spawning	-.012	-.063	.015	.060	.001
Selective Breeding	-.056	-.241**	.072	.222**	.003
Grow-out Facility	-.042	-.212*	.043	.208*	.003
Private	.013	.080	-.008	-.083	-.001
Bachelor's Degree	.021	.135	-.008	-.145	-.003
Multiple New Technologies	.021	.097	-.031	-.086	-.001
Positive	-.058	-.288***	.037	.302**	.007
10 or More Employees	-.038	-.237**	-.002	.270**	.007
Favorable to Cryopreservation	-.112	-.328***	.153	.284***	.004
Knowledge	.013	.067	-.016	-.063	-.001
Age[45]					
To 60	.036	.271**	.077	-.368*	-.016
Over 60	.048	.162	-.083	-.126	-.001
Years of Operation	-.001	-.003	.001	.003	.000

* Statistically significant at the $p < 0.10$ level.
** Statistically significant at the $p < 0.05$ level.
*** Statistically significant at the $p < 0.01$ level.

C. Willingness-to-Pay for Genetic Uniformity

C.1. Survey and Data

The CV questions were located in the second (Grow-out) section of the questionnaire. Question 20, the first CV question, asked respondents if they would be willing to pay a premium for genetically uniform fingerlings. They were asked to respond either "Yes" or "No." If the

[45] The age variables are relative to the holdout category which represents the youngest group of managers ages 18 to 36.

respondent answered “No,” they were told to proceed to the next CV question. If the answer was “Yes,” respondents were asked, “What is the maximum amount, above your current price, that you would be willing to pay, per fingerling, for genetically uniform fingerlings?” Below the question were 10 available price levels. The levels were in intervals of 10%, ranging from 10% to 100%[46]. Respondents were asked to select the price premium level that they were willing to pay by checking the box next to the appropriate level. Following the price selection, the respondents were asked to rate (on a scale of 10% to 100%) how certain they were that they would actually pay the amount stated in the previous question. If the respondent’s answer was less than 80% sure, they were then asked to fill in an amount that they would be at least 80% sure of paying. Because of the ability to fill in an exact amount, I treated the answers as if they were continuous variables[47]. Values in which respondents were at least 80% sure of paying were recorded as the dependent variable, or WTP. Table IV-8 shows some descriptive statistics for all farms that have grow-out operations.

Table IV-8. Summary Statistics For Respondents With Grow-out Operations.

Variable	Number of Respondents	% of Respondents	Mean	St.dev.
Spawning Operations	**35**	**100.00%**		
Grow-out Operations				
Yes = 1	70	100.00%		
No = 0	0	0.00%	1.0000	0.0000
Total	**70**	**100.00%**		
Purchased More Than 50% of Fingerling Stock Last Year				
Yes = 1	24	34.29%		
No = 0	46	65.71%	0.3429	0.4781
Total	**70**	**100.00%**		
Average Size of Fingerlings Purchased				
1-2 inch = 0	7	26.92%		
3-4 inch = 1	11	42.31%		
5-6 inch = 2	6	23.08%	1.1154	0.9089
7-9 inch = 3	2	7.69%		
Total =	**26**	100.00%		

[46] This is the payment card CV method.
[47] This is opposed to treating answers as ranges or possibly using the midpoint as the dependent variable.

Table IV-8. (cont.)

Methods Utilized for On-site Fingerling Maintenance (% of 70)				
Pond	36	51.43%		
Flow-through	29	41.43%		
Net pens/Cages	3	4.29%		
Closed re-circulation	14	20.00%		
Other	0	0.00%		
Average Weight of Foodfish Sold				
<1 pound = 0	14	21.88%		
1-2 pounds = 1	37	57.81%		
2-3 pounds = 2	9	14.06%	1.0625	0.8333
3-4 pounds = 3	3	4.69%		
>4 pounds = 4	1	1.56%		
Total =	**64**	**100.00%**		
Willing to Pay for Genetically Uniform Fingerlings				
Yes = 1	36	52.94%		
No = 0	32	47.06%	0.5294	0.5028
Total	**68**	**100.00%**		
Mean maximum W.T.P.			19.7222	17.3182
Willing to Pay for Supply Reliability				
Yes = 1	25	37.88%		
No = 0	41	62.12%	0.3788	0.4888
Total	**66**	**100.00%**		
Mean maximum W.T.P.			21.2000	18.7794
Choice set 1				
Option A	26			
Option B	16			
Option C	17			
Choice set 2				
Option A	11			
Option B	26			
Option C	24			
Public or Private Operation				
Public = 0	5	7.14%		
Private = 1	64	91.43%	0.9429	0.2892
Both = 2	1	1.43%		
Total	**70**	**100.00%**		
Employees				
< 10 = 0	55	78.57%		
10 to 50 = 1	13	18.57%		
51 to 150 = 2	2	2.86%	0.2429	0.4945
> 150 = 3	0	0.00%		
Total	**70**	**100.00%**		

Table IV-8. (cont.)

Total Gross Sales				
< $2,500 = 0	3	4.69%		
$2,500-$9,999 = 1	3	4.69%		
$10,000-$49,999 = 2	8	12.50%		
$50,000-$249,999 = 3	15	23.44%		
$250,000-$999,999 = 4	21	32.81%	3.4531	1.4134
$1 million-$4,999,999 = 5	11	17.19%		
$5 million or more = 6	3	4.69%		
Total	**64**	**100.00%**		
Education				
Less than high school = 0	1	1.43%		
High school diploma or GED = 1	8	11.43%		
Some college/technical school = 2	19	27.14%		
Bachelor's degree = 3	25	35.71%	2.7000	1.0122
Advanced degree = 4	17	24.29%		
Total	**70**	**100.00%**		
Age				
18-25 = 0	1	1.45%		
26-35 = 1	5	7.25%		
36-45 = 2	18	26.09%		
46-60 = 3	38	55.07%	2.6522	0.8194
> 60 = 4	7	10.14%		
Total	**69**	**100.00%**		

Table IV-9 shows the WTP for genetic uniformity by farms that produce some amount of the selected species. The interpretation of this table is 23 grow-out producers produce some amount of channel catfish. Twelve of those producers said that they would be willing to pay something for genetic uniformity. The average WTP for those 12 who were willing to pay a positive amount was an 11.83% premium above their current price per fingerling. The average of the entire sample (23) was 6.17%[48] above the current per fingerling price. For those producers who were willing to pay a price premium, rainbow trout producers were willing to pay the most, represented by a 20% price premium.

[48] This number includes zero bids (producers who were not willing to pay for genetic uniformity).

Both the tobit and Cragg models were considered for analysis of the attributes affecting the willingness-to-pay for genetic uniformity by grow-out producers. Results of the LR test revealed the Cragg model as the most appropriate model for the data.

Genetic Uniformity LR statistic = 55.67 > ? $^2_{.01}$(13) ˜ 27.69,

where the test statistic was greater than the ? ^{2} (with 13 degrees of freedom) critical value at the .01 significance level. Because the LR statistic was in the critical region, I rejected the null hypothesis (H_o) that tobit is the appropriate model, and accepted the alternative hypothesis (H_1) that Cragg's model is a better fit for the data. Therefore, only results of the Cragg model are presented. The same variables were used in both the probit and truncated parts of the Cragg model[49]. A description of the variables is presented in Table IV-10.

Table IV-9. Distribution Of WTP For Genetic Uniformity For Producers Who Produce Some Amount Of Each Selected Species.

Species	Obs.	Pay for Genetic Uniformity (%)	Mean WTP (Total Sample)	Mean WTP (Truncated sample)
Channel catfish	23	12 (52%)	6.17	11.83
Hybrid striped bass	10	9 (90%)	15.0	16.67
Tilapia	10	7 (70%)	11.7	16.71
Atlantic salmon	1	0 (0%)	0	--
Rainbow trout	21	8 (38%)	7.62	20.0
Other	21	13 (62%)	11.19	18.08

The Atlantic salmon variable was held out of this model due to lack of observations. The variable "Estgenln" represents the grouping of producers whose primary species is rainbow trout or Atlantic salmon. These industries utilize established and consistent genetic lines more regularly than the other selected industries in our study. The variable "Nogenln" represents the grouping of producers whose primary species are channel catfish, hybrid striped bass, or tilapia.

[49] By keeping the variables the same, I could compare the effect that each model had on the data.

Table IV-10. Description Of Variables In The WTP Of Genetic Uniformity.

Variable	Description
Hatch	1 if the farm participates in spawning activities, 0 otherwise
Yrs	Years the farm has been in operation
Bach	1 if the farm manager earned a Bachelor's degree or higher, 0 otherwise
Multitech	1 if the farm has adopted more than one of the new technologies listed in question 36, 0 otherwise
Nogenln	1 if the farm produces channel catfish, hybrid striped bass, or tilapia as their primary species, 0 otherwise
Estgenln	1 if the farm produces rainbow trout or Atlantic salmon as their primary species, 0 otherwise
Medium	1 if the farm sold foodfish weighing between 1 and 2 pounds, 0 otherwise
Large	1 if the farm sold foodfish weighing greater than 2 pounds, 0 otherwise
Favcrs	1 if the farm was in favor of the practice of cryopreserving sperm, 0 otherwise
36-60	1 if the farm manager was between the ages of 36 and 60, 0 otherwise
Over 60	1 if the farm manager was older than 60, 0 otherwise
Great50k	1 if the farm grossed more than $50,000 in sales last year, 0 otherwise

These species, or industries, were grouped together because they do not have as well established genetic lines. The holdout category was producers whose primary product was listed as "Other." The "Other" category includes a wide variety of industries, some of which may utilize established genetic lines and some who may not. The majority of the species included in this holdout group represented an average level of established genetics, as well as a smaller percentage of the aquaculture market share relative to the selected species included in the "Estgenln" and "Nogenln" categories. I expected industries with smaller market shares to be willing to pay more for genetic uniformity because they might be more interested in developing a more consistent product in an effort to penetrate niche markets. I also expected to see farms with more established genetic lines willing to pay less than farms with less established genetic lines because their product is already more genetically consistent.

I expected the variable representing the presence of a hatchery to be negative. This is because if a farm has a hatchery operation, as well as a grow-out operation, the farm should have more control of the genetic makeup of the fingerlings that they produce. This could make the farm less likely to pay a high premium for genetic uniformity. The variables for education, multiple technology adoption, and a favorable attitude towards cryopreservation should all be positive. The variables representing the size of the foodfish sold ("Medium" and "Large") are relative to the smallest category, which represents foodfish less than 1 pound. I expected the farms that sold larger final products to be willing to pay more for genetic uniformity. I expected the two variables for age of the farm manager included in the model to be negative, relative to the holdout variable representing the youngest managers. The sales variable, "Great50K," was expected to be positive. I expected firms with higher sales to be willing to pay more for an improved production input.

C.2. Cragg Results

C.2.a. Probit Component

A binary probit model was used for the selection, or participation, component of the Cragg model. For this model, the dependent variable was whether or not the farm would be willing to pay for genetically uniform fingerlings. This required a "Yes" or "No" answer. The coefficients from the probit model were interpreted as how much of an effect the independent variable has on the decision to pay a premium for genetic uniformity, not as an effect on how much someone will pay.

The results of the model are presented in Table IV-11. The model was significant at the a = 0.01 significance level. The presence of a hatchery proved to be negative and significant. The "Multitech" variable was positive and significant. The variable "Favcrs," representing a favorable view on cryopreservation, was positive and significant in this model. The age variable "36-60," representing the middle age bracket, was found to be negative and significant. The holdout was farms with managers younger than 36 years old. It was expected that those managers who are younger would be more likely to participate in a new opportunity than the older, more established managers who are engrained in their routines. The sales variable, "Great50k," was also significant in the probit model. However, this variable was unexpectedly negative. According to the results, farms that grossed more than $50,000 last year were less likely to pay for genetically uniform fingerlings than those farms that grossed less than $50,000.

C.2.b. Truncated Component

The results of the truncated model are also presented in Table IV-11. The model was significant at the a = 0.01 significance level. The dependent variable in this model was the values reported as the willingness-to-pay for genetically uniform fingerlings. All values in this data set were positive, because the values have been truncated at zero. Only respondents who said "Yes" they would pay for genetically uniform fingerlings were evaluated in this model. The results are interpreted as the effect that the independent variables have on the amount a farm is willing to pay for uniform fingerlings.

If a farm produced channel catfish, tilapia, or hybrid striped bass as their primary product ("Nogenln"), there was a significant and negative effect on WTP values. The "Estgenln" variable included in the model was also negative and significant. However the negative effect on the WTP value was greater than the "Nogenln" variable, meaning that industries with more

Table IV-11. Results From Cragg Model For The WTP For Genetic Uniformity In Fingerlings[50].

	Probit		Truncated	
	Coefficient (St. Error)	Marginal (St. Error)	Coefficient (St. Error)	Marginal (St. Error)
Hatch	-1.234* (.655)	-.449** (.210)	-15.527*** (5.274)	-14.137*** (4.569)
Yrs	.007 (.022)	.003 (.008)	.897*** (.227)	.846*** (.216)
Bach	.045 (.563)	.017 (.216)	15.069*** (5.030)	13.641*** (4.304)
Multitech	1.966*** (.725)	.519*** (.109)	4.770 (4.628)	4.522 (4.406)
Genetic Line[51]				
Nogenlnl	-.157 (.744)	-.060 (.282)	-24.808*** (7.243)	-23.402*** (6.688)
Estgenln	-.802 (.845)	-.309 (.313)	-31.094*** (10.100)	-22.370*** (4.458)
Size[52]				
Medium	.572 (.719)	.219 (.274)	25.202** (10.352)	21.643*** (7.578)
Large	1.116 (.959)	.354 (.232)	11.648 (9.577)	11.178 (9.269)
Age[53]				
36-60	-2.369** (1.110)	-.525*** (.117)	2.153 (6.916)	2.017 (6.433)
Over 60	-1.582 (1.377)	-.534* (.292)	6.861 (13.620)	6.624 (13.363)
Favcrs	2.299** (.938)	.732*** (.194)	-23.745*** (6.876)	-22.423*** (6.372)
Great50k	-1.775* (.945)	-.490*** (.156)	-2.521 (6.223)	-2.391 (5.933)
Constant	2.331 (1.677)		15.655 (11.682)	
s			11.357*** (1.466)	
Y		.617		18.251
No. of obs.=	55		30	
LR (12)=	31.53***		47.92***	
Pseudo R^2=	.416			

* Statistically significant at the p < 0.10 level.
** Statistically significant at the p < 0.05 level.
*** Statistically significant at the p < 0.01 level.

[50] WTP values are interpreted as percentage increases on the current per fingerling price.
[51] Relative to the "Other" category with an average amount of genetic establishment.
[52] Relative to the smallest category of foodfish sold that were less than 1 pound.
[53] The age variables are relative to the holdout category which represents the youngest group of managers ages 18 to 36.

established and consistent genetic lines were willing to pay less than industries with less established genetic lines. Both variables were negative relative to the “Other” species variable, implying that industries with an average amount of established genetics and smaller market shares were willing to pay more for genetic uniformity.

The number of years a farm has been in business had a positive and significant effect on the WTP value. As farms get older, results show that they would be willing to spend a higher amount for genetically uniform fingerlings. The variable “Favcrs” was again significant in this model. However, this time it had a negative effect on the dependent variable. This means that having a favorable view of cryopreservation may have a positive effect on the willingness-to-pay for genetic uniformity[54], but a negative effect on the amount that a farm is willing to pay. A Bachelor’s degree, as expected, had a positive and significant effect on the WTP value for genetic uniformity. Also as expected, the presence of a hatchery had a negative and significant effect on the WTP value. The size variable “Medium” was positive and significant in this model, indicating a higher WTP for genetic uniformity from producers who sold foodfish between 1 and 2 pounds last year, relative to those who sold foodfish that were less than 1 pound.

The results of the Cragg model show that there are separate sets of variables that make up the decisions to purchase and how much to spend for genetically uniform foodfish fingerlings. The results also showed that producers were willing to pay an 18% premium to acquire a fish stock with more genetic uniformity.

D. Willingness-to-Pay for Supply Reliability

D.1. Survey and Data

The second CV question, located in the second (Grow-out) section of the questionnaire was question 24. This question asked respondents if they would be willing to pay a premium for

[54] This is shown in the probit model in IV.C.2.a.

greater reliability in the supply of fingerlings. Respondents were asked to respond either "Yes" or "No." If the respondent answered "No," they were told to proceed to the next set of questions. If the answer was "Yes," respondents were asked, "What is the maximum amount, above your current price, that you would be willing to pay, per fingerling, for this supply reliability?" Below the question were 10 available price levels. The levels were in intervals of 10%, ranging from 10% to 100%. Respondents were asked to select the price premium level that they were willing to pay by checking the box next to the appropriate level. Following the price selection, the respondents were asked to rate (on a scale of 10% to 100%) how certain they were that they would actually pay the amount stated in the previous question. If the respondent's answer was less than 80% sure, they were then asked to fill in an amount that they would be at least 80% sure of paying. Because of the ability to fill in an exact amount, I treated the answers as if they were continuous variables. Values in which respondents were at least 80% sure of paying were recorded as the dependent variable, or WTP.

Table IV-12 presents the WTP for supply reliability from farms that produce some amount of the selected species. The interpretation of this table is the same as Table IV-9 in the previous section. This model also showed that rainbow trout producers were willing to pay the most, out of the producers who declared they would, in fact, pay for supply reliability. According to these results, rainbow trout producers were willing to pay about 27% more per fingerling to increase the reliability of their fingerling supply. Hybrid striped bass producers were willing to pay a 15% premium. The WTP from the hybrid striped bass producers is lower, relative to all other species producers, than expected.

Both the tobit and Cragg models were again considered for the analysis of attributes affecting the willingness-to-pay for supply reliability by grow-out producers. The LR test again confirmed the use of the Cragg model as most appropriate[55]. The test statistic was greater than the $?^2$ (with 11 degrees of freedom) critical value at the .01 significance level, shown by:

Supply Reliability LR statistic = 31.25 > $?^2_{.01}(11)$ ˜ 24.73.

Because the LR statistic was in the critical region, I rejected the null hypothesis (H_o) that tobit is the appropriate model, and accepted the alternative hypothesis (H_1) that Cragg's model was a better fit for the data. The same set of variables was used in both the probit and truncated components of this model. An explanation of the variables is available in Table IV-13.

Table IV-12. Distribution Of WTP For Supply Reliability For Producers Who Produce Some Amount Of Each Selected Species.

Species	Obs.	Pay for Supply Reliability (%)	Mean WTP (Total Sample)	Mean WTP (Truncated sample)
Channel catfish	21	8 (38%)	5.48	14.38
Hybrid striped bass	10	4 (40%)	6.0	15.0
Tilapia	10	4 (40%)	2.7	6.75
Atlantic salmon	2	0 (0%)	0	--
Rainbow trout	18	6 (33%)	8.89	26.67
Other	22	11 (50%)	9.32	18.64

Variables for Atlantic salmon and tilapia were not included in this model. The salmon variable was not included due to a small number of observations. The variable representing tilapia production was not included because due to the rapid reproductive ability of the species, tilapia supply is typically not a problem. The "Hatch" variable was expected to be negative due to the fact that if a grow-out operation also has a hatchery, it is more likely that the managers are able to control their fingerling supply, than grow-out operations that do not have their own hatchery. There was no expected sign for the variable representing a Bachelor's degree earned by the manager in the first stage probit model. Unlike genetic uniformity, which was assumed to provide a better product, supply reliability of fingerlings was not an improvement on the current

[55] Only the Cragg results are provided.

Table IV-13. Description Of Variables In The WTP Of Supply Reliability.

Variable	Description
Hatch	1 if the farm participates in spawning activities, 0 otherwise
Bach	1 if the farm manager has Bachelor's degree or higher, 0 otherwise
Multitech	1 if the farm has adopted more than one of the new technologies listed in question 36, 0 otherwise
C2atall	1 if the farm produces any amount of channel catfish, 0 otherwise
B2atall	1 if the farm produces any amount of hybrid striped bass, 0 otherwise
T2atall	1 if the farm produces any amount of rainbow trout, 0 otherwise
Oth4atall	1 if the farm produces any amount of "other" fish, 0 otherwise
Favcrs	1 if the farm was in favor of the practice of cryopreserving sperm, 0 otherwise
Empgr10	1 if the farm has more than 10 full-time employees, 0 otherwise
Great50k	1 if the farm grossed more than $50,000 in sales last year, 0 otherwise

product. A farm manager will pay for this service if the individual farm has a specific need for it. I expected a positive sign associated with "Bach" for the truncated model because I believed the higher educated farm managers would be willing to pay a higher price for supply reliability relative to the less educated managers. The adoption of multiple technologies and a favorable opinion of cryopreservation were expected to have positive signs. Supply reliability should be more easily provided with the use of cryopreservation services. The scale of the operation, represented by the number of employees and the sales variable, should also have a positive effect on WTP. The species-specific variables are characterized as producing some amount of the species. The variable "C2atall" represents producers who grow-out "some amount" of channel catfish. Channel catfish did not have to be the primary product to be included in this variable. Overlap can occur with the variables in this model. This allowed for more observations per species and can attempt to show the effect of having a particular species in an operation, even if it is not the primary product. I expected the catfish variable to be negative. Channel catfish farmers typically use natural spawning, and there is not as much a problem with the supply of this species. I certainly expected to see the bass variable with a positive effect. The hybridization of the species[56], and the need to artificially spawn, makes this species risky with regards to reliability of fingerlings. Rainbow trout were also expected to be positive due to the utilization of artificial spawning. The "Other" category did not have an anticipated sign due to the number of different species included in the variable.

D.2. Cragg Results

D.2.a. Probit Component

A binary probit model was used for the selection, or participation, section of Cragg's model. For this model, the dependent variable was whether or not the farm would be willing to pay for the supply reliability of fingerlings. This was a "Yes" or "No" answer. This model was interpreting the effect of simply paying a premium for reliability.

The results of the model are presented in Table IV-14. The model was significant at the a = 0.05 significance level. The variable "Favcrs," was positive and significant. The "Empgr10" variable had a positive effect on a farm paying a premium for reliability, as expected. The production of at least some channel catfish or rainbow trout had a positive and significant effect. No other variables were significant in this model.

D.2.b. Truncated

The results of the truncated model are presented in Table IV-14. The model was significant at the a = 0.01 significance level. The dependent variable was the actual WTP values

[56] The striped bass and white bass, which are used to produce hybrid striped bass, have unsynchronized spawning periods. There is little overlap between spawning seasons for each species.

reported by producers. All values in this data set were positive, because the values have been truncated at zero. Only respondents who said "Yes" they would pay for supply reliability were evaluated in this model. Results are interpreted as the effect that the independent variables have on the WTP value for supply reliability of fingerlings.

Table IV-14. Results From The Cragg Model For The WTP For Supply Reliability In Fingerlings.

	Probit		Truncated	
	Coefficient (St. Error)	Marginal (St. Error)	Coefficient (St. Error)	Marginal (St. Error)
Hatch	-.842	-.297	-5.828	-5.307
	(.593)	(.195)	(11.716)	(10.692)
Bach	.570	.197	-3.710	-3.392
	(.535)	(.172)	(9.785)	(9.003)
Multitech	.647	.243	17.623**	16.309**
	(.493)	(.186)	(7.765)	(7.242)
C2atall	1.388*	.505**	-13.455	-11.660
	(.708)	(.228)	(11.043)	(9.008)
B2atall	.200	.074	2.963	2.719
	(.589)	(.223)	(9.155)	(8.490)
T2atall	1.198**	.443**	17.173*	16.023*
	(.603)	(.205)	(9.660)	(9.130)
Oth4atall	.194	.071	14.664*	13.334*
	(.500)	(.184)	(8.728)	(7.895)
Favcrs	1.558***	.510***	-25.564*	-24.155*
	(.573)	(.148)	(14.225)	(13.568)
Empgr10	1.841**	.640***	12.494	11.458
	(.711)	(.177)	(10.160)	(9.354)
Great50k	-.204	-.075	34.780***	22.859***
	(.574)	(.217)	(10.979)	(4.541)
Constant	-2.449**		-3.064	
	(.997)		(19.540)	
s			13.392***	
			(2.066)	
Y		.325		18.317
No. of obs.=	55		21	
LR (10)=	20.99**		23.41***	
Pseudo R^2=	.287			

* Statistically significant at the $p < 0.10$ level.
** Statistically significant at the $p < 0.05$ level.
*** Statistically significant at the $p < 0.01$ level.

The results of the truncated, or outcome, equation show that if a farm produced any amount of rainbow trout or "Other" species, there would be a significant positive effect on the WTP values. The presence of channel catfish was not significant in the truncated model. The "Multitech" variable had a positive and significant effect on the WTP value. However, "Multitech" did not have an effect on the decision to pay a premium for reliability[57]. The variable "Favcrs" had a negative and significant effect on WTP values. The "Favcrs" variable was positive in the probit model. The sales variable, "Great50k," was positive and significant in this model. This means that farms with higher gross sales were willing to pay more for supply reliability.

The results of the Cragg model show that there are not only separate sets of variables that make up the decisions to buy and how much to spend, but also that the variables may have opposing effects. Respondents were willing to pay an 18% premium for more reliability in the supply of their fingerling stocks.

E. Choice-based Conjoint Analysis of WTP for Genetic Improvement of Fingerlings

E.1. Choice Task Design

There are numerous ways to set up a stated choice questionnaire. This study elected to utilize the no-purchase alternative (i.e., prefer status quo), to allow producers the same opportunities they would have in a working market. With the inclusion of a "neither" option, respondents had the opportunity to pay a zero price premium since they could choose a non-genetically improved fish stock. Along with the "neither" option, respondents were presented with a pair of alternatives, each with at least one genetically improved attribute. Four attributes with 3 x 3 x 2 x 3 levels respectively, result in 54 possible product combinations. However, this number was thought to be too high to realistically be completed without causing respondent

[57] This is shown in the probit model reported in IV.D.2.a.

fatigue. The software package Bretton-Clark Conjoint Designer was used to formulate 9 orthogonal attribute combinations. Three more product combinations were added to the design in order to have a balanced number of choice tasks[58]. This resulted in twelve genetically improved fish stock alternatives to be evaluated by U.S. grow-out producers. Each choice set included two of the twelve genetically improved fish stocks. The first of the twelve improved stocks was paired with the second improved stock, in order to form the first choice set. The third improved stock was then paired with the fourth to form the second choice set. This process continued until all six choice sets were formed. Because of the length of the overall questionnaire, a split-sample approach was taken. Three versions of the questionnaire were mailed to aquaculture producers in the U.S., with each version having two choice sets to evaluate. Respondents were asked to select their preferred option in each set. An example of a choice task is included in Appendix X and XI.

E.2. Conditional Logit

The results of the conditional logit model and relative importance values are presented in Table IV-15. The overall model was significant at the a = 0.01 significance level with a log likelihood ratio value of 24.71. An alternative-specific constant (ASC) “ab” was created to represent the genetically improved alternatives (options “A” and “B”). This was coded as 0 if the respondent chose the “neither” alternative, and 1 if they chose one of the genetically improved stocks. The purpose of the ASC is to capture the mean effect of the unobserved factors in the error terms of each alternative, which will provide a zero mean for unobserved utility and cause the average probability of each alternative in the sample to be equal to the proportion of respondents actually choosing the alternative (Blamey, Gordon, and Chapman 1999). The price premium variable was recorded as 0, 20%, 40%, or 60% for the available price premium

[58] Even with the addition of three more alternatives, the design maintained its orthogonal distinction.

options[59]. The rest of the variables were effects coded in the data set. Effects coding utilizes a (-1, 0, 1) coding scale, as opposed to the typical (0, 1) dummy coding. Effects codes were used so that base categories

Table IV-15. Conditional Logit, Willingness-To-Pay, And Relative Importance Results From Stated Choice Experiments.

	Conditional Logit		WTP (%)	R.I.[60]
	Coefficient	St. Error		
ab_ASC for Genetic Improvement	1.047**	0.467		
Growth Rate[61]				43.02
10% Increase	0.403*	0.226	14.17	
20% Increase	0.641***	0.207	22.54	
Disease Resistance[62]				13.84
10% Increase	0.136	0.212	4.8	
20% Increase	0.203	0.245	7.14	
Resistance to Lower Dissolved Oxygen Levels	0.005	0.143	0.16	0.26
Price Premium	-0.028**	0.011		42.89

Number of Observations = 360
LR = 24.71***
Pseudo R^2 = .094

* Statistically significant at the p < 0.10 level.
** Statistically significant at the p < 0.05 level.
*** Statistically significant at the p < 0.01 level.

would not be incorporated in the intercept. Instead, the coefficient of the base is equal to the negative sum of the other coefficients related to that variable (Adamowicz et al. 1997). The “neither” option served as the base alternative. Because this option does not include any of the genetic improvements, all variables associated with the “neither” option were coded as (0).

[59] These were defined as a percentage above the producer’s current price for a fingerling stock.
[60] Relative importance of each attribute group.
[61] Relative to the holdout category representing no genetic improvement (Current).
[62] Relative to the holdout category representing no genetic improvement (Current).

A Hausman test of the IIA assumption was performed to ensure that the IIA assumption held for our data. The test failed to reject the null hypothesis of a true IIA (Long and Freese 2003). Therefore, the conditional logit model is an effective model for the data.

Results show that growth rate was the most relatively important attribute to grow-out producers. The two levels of growth rate in the model, the price premium variable, and the ASC for genetically improved stock, were all significant in the model. Disease resistance and resistance to low dissolved oxygen levels were not significant attributes in the purchasing of a fish stock. As expected, respondents were more likely to choose an alternative with 20% increased growth rate than an option offering only a 10% increase. The coefficients were as expected, negative for the price premium and positive for the genetically improved attribute levels (which were relative to their non-genetically improved base levels).

E.3. Relative Importance

The results of the relative importance estimates again showed that growth rate was the most important individual attribute to the grow-out producers in this study[63]. The price premium attribute was also important. Disease resistance and resistance to 10% lower dissolved oxygen levels recorded low relative importance weights.

E.4. Willingness-to-pay

The willingness-to-pay values in this study are interpreted as the percentage increase that producers were willing to pay to obtain the specific genetic attribute. The results are included in Table IV-15. Producers were willing to pay a 14.17% price premium for a fish stock with a 10% increase in the growth rate. This translates into producers being willing to pay about 1.4% more for every 1% increase in growth rate. Results showed that a premium of 22.54% would be paid

[63] Because the ab (ASC) represents a combination of all the genetic attributes, it is not considered as an individual attribute.

to attain a fish stock with a 20% higher growth rate. The results are consistent with economic theory in that both the 20% improvement levels recorded higher willingness-to-pay values than the 10% levels.

F. Choice-based Data with Interaction Terms

F.1. Survey and Data

The data used in this section of results is from the same set of stated-choice questions used in the normal CL model. However, in this model I also utilized individual-specific variables obtained through questions located in the grow-out and demographic sections of the questionnaire.

F.2. Conditional Logit with Interactions

The results of the CLI model and the willingness-to-pay estimates are presented in Table IV-16. The overall model was found to be significant at the a = 0.01 significance level with a log likelihood ratio value of 64.20. The price premium variable was recorded as 0, 20%, 40%, or 60% for the available price premium options. The rest of the variables were effects coded in the data set and the “neither” option again served as the base and was coded as 0 throughout. The alternative-specific constant (ASC) “ab,” which represents the genetically improved alternatives, was held out of this model. This was done to reduce the chance of multicollinearity problems, because all individual-specific variables were interacted with the ASC term. Interactions were included in this model to determine which individual-specific variables significantly affect the selection of a genetically improved alternative.

F.2.a. Genetic Attribute Variables

Most coefficients of the alternative-specific attributes were as expected, negative for the price premium and positive for the genetically improved attribute levels (which were relative to their non-genetically improved base levels). However, the coefficient for resistance to low dissolved oxygen levels was negative[64]. The results reiterated the findings of the normal CL

Table IV-16. Conditional Logit With Interactions And Willingness-To-Pay Results From Stated Choice Experiments.

	Conditional Logit With Interactions		WTP (%)	R.I.[65]
	Coefficient	St. Error		
Growth Rate[66]				40.53
10% Increase	.567**	.283	17.61	
20% Increase	.695***	.242	21.58	
Disease Resistance[67]				17.19
10% Increase	.366	.264	11.35	
20% Increase	.099	.307	3.08	
Resistance to Lower Dissolved Oxygen Levels	-.055	.163	-1.69	2.26
Price premium	-.032**	.013		40.01
Hatch*ab	.291	.286		
Channel Catfish*ab	1.399***	.503		
Tilapia*ab	1.361**	.619		
Rainbow Trout*ab	.632	.432		
Atlantic Salmon*ab	.123	.838		
Hybrid Striped Bass*ab	-.790	.571		
Private*ab	6.209***	2.139		
Bachelor's*ab	.964***	.329		
Multiple*ab	1.385***	.418		
Age[68]				
36-60*ab	-3.144**	1.392		
Over 60*ab	7.215**	3.112		
Favorable*ab	.341	.323		
Sales Greater than 50K*ab	.264	.311		

Number of observations = 324
LR(19) = 64.20***
Pseudo R^2 = .2705

* Statistically significant at the $p < 0.10$ level.
** Statistically significant at the $p < 0.05$ level.
*** Statistically significant at the $p < 0.01$ level.

64 The variable was not found to be significant in the model.
65 Relative importance of each attribute group.
66 Relative to the holdout category representing no genetic improvement (Current).
67 Relative to the holdout category representing no genetic improvement (Current).
68 The holdout category was the youngest group of managers ages 18 to 36.

model which revealed growth rate as the most relatively important genetic attribute to grow-out producers. The two levels of growth rate and the price premium attribute were the only genetic attributes significant in this model[69]. Respondents were more likely to choose an alternative with 20% increased growth rate than an option offering only a 10% increase.

F.2.b. Individual-specific Variables

Individual-specific variables were included as interactions in the model. The individual-specific variables were effects coded (1,-1). All individual-specific variables were interacted with the alternative-specific constant (ab) to analyze the interest for genetic improvement by specific types of farms. For example, the variable "Private*ab" represented privately run grow-out farms that selected either option A or B. The positive significant variable means that private grow-out farms were more likely to choose an alternative that includes some genetic improvement than to select one that has no genetic improvement (the neither option). All species interactions included in this model were positive except for the hybrid striped bass interaction variable. However, only the production of catfish and tilapia had a significant effect on the choosing of a genetically improved stock. This means catfish and tilapia producers were more willing to purchase a genetically improved stock than a stock with no genetic improvement. Producers of "Other" species were held out of this model. This was done because there is the possibility of multicollinearity problems when interacting too many variables (Breffle and Morey 2000). Atlantic salmon, hybrid striped bass, and rainbow trout interactions were not significant in this model.

Having incorporated multiple new technologies in the last 5 years, as well as the manager having a Bachelor's degree had a positive and significant effect on choosing a genetically improved alternative. Two of the three age variables were included in this model. Surprisingly,

[69] Significance levels were 90% or greater for those variables considered significant.

respondents over the age of 60 had a strong positive likelihood of purchasing the genetically improved stocks. However, respondents between the ages of 36 and 60 were less likely to select the improved alternatives. The variable "Favorable*ab" represented a favorable attitude towards cryopreservation by the respondent. It was not significant in the model. Also found not to be significant was the variable "Sales Greater than 50K*ab," which represented farms that grossed more than $50,000 last year. This can be interpreted to mean the scale of an aquaculture farm had no significant effect on the purchasing of a genetically improved stock relative to a non-genetically improved stock.

F.3. Relative Importance

The results of the relative importance estimates again showed that growth rate was the most important individual attribute to the grow-out producers in this study. The price premium attribute was equally as important. Disease resistance and resistance to 10% lower dissolved oxygen levels again recorded low relative importance weights.

F.4. Willingness-to-pay

Willingness-to-pay values were calculated for the alternative-specific genetic attributes. The values were similar to those reported in the normal CL model. Results of this model showed that grow-out producers were willing to pay about a 18% price premium for fish stocks with a 10% increase in growth rate. Producers would pay about 22% more per fingerling for a 20% increase in the growth rate of their stocks.

CHAPTER V: CONCLUSIONS AND FUTURE RESEARCH

A. Introduction

Aquaculture industries are a large part of the U.S. agriculture sector, representing over $1 billion in sales. Economically driven aquaculture studies have focused on reducing costs through altering production practices or adopting new, more efficient, technologies. These studies assume the reduction of costs as a way to increase profits. In this study, I evaluated grow-out producers' willingness-to-pay for a cost-reducing, genetically improved fish stock. Production costs are reduced by using fingerlings that grow faster because the fingerlings will reach market size quicker and incur lower maintenance costs. An alternative approach to increase profits is to increase the revenue received through the sale of the product. If farmers have a stock that is more resistant to disease, the farmers will have more fish to sell in the marketplace. Also, if the fish stocks are consistently larger, the farmers will receive a higher price for the stock.

The genetic improvements that can help farmers increase profits can potentially be accomplished most efficiently with the use of cryopreserved sperm. Cryopreservation has proven its worth for the dairy industry over the last half century. If instituted correctly, aquaculture industries can also expect to see improvements from cryopreservation.

Specifically, the objectives were to: (1) determine which genetic improvements are most important to grow-out producers, specifically for our selected species, (2) estimate how much producers are willing to pay for the opportunity to incorporate genetic improvements into their existing product line, and (3) evaluate the interest in cryopreservation from U.S. aquaculture hatcheries. To accomplish these objectives, survey data was collected from aquaculture farms across the United States. The surveys were divided into three sections. The first section was for farms with spawning operations, the second was for farms with foodfish grow-out operations, and the third was demographic information intended for all farms.

Along with descriptive statistics for every question from all different types of facilities[70], econometric models were also used to analyze specific questions in the survey. An ordered probit model was used to analyze the acceptance for cryopreservation services by hatchery producers. The conditional logit model was used to evaluate the most important genetic attributes presented in the stated choice questions located in the grow-out section of the questionnaire. Willingness-to-pay values for grow-out operators were also computed from this model. A double hurdle regression model was used for contingent valuation type questions also located in the grow-out section of the questionnaire.

B. Results

The results of this study are divided into two sections: hatchery producers and grow-out producers[71]. Results from hatchery respondents include descriptive statistics and an ordered probit regression model. Reported results for the grow-out respondents include descriptive statistics, a conditional logit model, and a double-hurdle model.

An interesting descriptive statistic provided by hatchery respondents[72] was that 31% of hatchery respondents reported that they would pay the costs associated with cryopreservation services. Moreover, 39% of farms with both a hatchery and a grow-out operation indicated a willingness-to-pay for cryopreservation services. In the ordered probit results, I found that producing hybrid striped bass and Atlantic salmon had a positive and significant effect on willingness-to-pay for cryopreservation services, while producing tilapia and rainbow trout had

[70] Facilities with a spawning operation, facilities with a grow-out operation, facilities with both, facilities with only a spawning or grow-out operation, and facilities who only responded to the demographic section.
[71] The Appendix offers a more specific breakdown of results.
[72] This includes farms with only hatchery operations as well as farms with both hatcheries and grow-out facilities.

negative and significant effects. Another variable that showed a positive and significant effect on the decision to pay for cryopreservation services was if the hatchery maintained its broodstock on site throughout the year.

Sixty-five percent of hatchery producers[73] reported that they were in favor of the practice of cryopreserving sperm. However, only 27% of these producers said that they would incorporate cryopreservation services into their existing operation if the services were available. The majority of grow-out producers were not opposed to the genetic improvement of animals. Sixty-four percent were against terminating research regarding the genetic improvement of animals.

The double hurdle model shows that the variables affecting the decision to purchase genetic uniformity and supply reliability, and the variables affecting the decision on how much to pay for the uniformity and reliability, are different. This was shown from the results of both Cragg models estimating the WTP for genetic uniformity and supply reliability.

In the conditional logit model, we found that growth rate was the most important genetic attribute for grow-out respondents. Estimates show that grow-out producers were willing to pay a 22% price premium to obtain fingerlings with a 20% higher growth rate. The variables for the other genetic improvements were not significant in the model. When individual-specific interactions were included in this model, I found that private farms and more educated managers were more likely to select a genetically improved fish stock over a stock with no genetic improvement. The WTP values for a 20% increase in growth rate were again at 22%, reiterating the estimates of the normal CL model.

[73] This includes farms with only hatchery operations as well as farms with both hatchery and grow-out facilities.

C. Implications

This study is the first of its kind in that it evaluates the preferences for genetic attributes from producers. It also is the first known study to evaluate preferences for cryopreservation services in aquaculture industries by the producers. I hope to lay the groundwork for future research that can use the information obtained in this study as a basis to conduct other, more detailed, investigations.

The specific results obtained in this study can provide valuable information to aquaculture farms as well as entrepreneurs who are interested in providing cryopreservation services to the aquaculture industry. The results show that there is an interest in using cryopreserved sperm in a hatchery setting, as well as utilizing the frozen sperm to more efficiently produce genetically improved fish stocks. The WTP values for genetic improvement show a strong interest in fingerlings with an increased growth rate. If cryopreservation can prove to be the most reliable source to produce improved fingerlings, this will ultimately increase the demand, and price, for cryopreservation services. Once the demand increases enough, I expect to see an emergence of firms wanting to provide cryopreservation services to aquaculture industries. These results can also help to identify which aquaculture industries are the most interested in cryopreservation services and also which industries are willing to pay the most for genetic improvement. Specifically I have shown that hybrid striped bass hatchery producers are the most likely to pay for cryopreservation services. I have also shown that the rainbow trout grow-out industry is willing to pay the most for genetic uniformity and supply reliability. Being a private grow-out farm also had a significant effect on the purchasing of genetically improved fingerlings. These findings will help hatcheries as well as potential aquatic cryopreservation firms to better market their products.

Hopefully this research will fuel the interest in cryopreservation and genetic improvement in the aquaculture sector. There is potential for aquaculture industries to continue to gain market share in the seafood market. Individual aquaculture industries need to continue to become more efficient in their production practices so that they can maintain a profitable level of production. Cryopreservation may not be the right answer for every industry, especially right now. However, for the industries that can become more efficient with the use of frozen sperm, they could possibly realize significant gains in their profit levels and in their share of the overall seafood market. Genetic improvements can more efficiently be realized in an aquaculture setting because wild catch harvests are not produced in a controlled environment. Hybrid striped bass or hybrid catfish are not in the wild-caught seafood product base. They are only produced through aquaculture farms. Aquaculture can embrace this advantage and increase the genetically improved product lines.

D. Limitations

One limitation of this research was the mailing list of potential respondents. As previously mentioned, contact information was determined to be inconsistent throughout the list. Other problems included the inability to determine if the potential respondent was an aquaculture farmer. In a consumer study every residential mailing address is a potential valid respondent. For our study, this was not the case. Every mailing address was not necessarily a valid potential respondent. To my knowledge there is no, truly comprehensive, list of aquaculture farmers in the United States. I also had the problem of limiting the list to finfish producers.

Due to the length of the survey, I limited the amount of choice sets in the stated choice section to two. It would have been beneficial to include one more choice set. By including one more set, we could have potentially received 60 more choice set observations to include in the data set[74].

E. Future Research

This study was a first step in a process of determining the future of cryopreservation and genetic improvement in aquaculture industries. The WTP estimates in this study valued the potential end benefits of cryopreservation services in the genetic improvement of foodfish. This research showed that there is an interest in the potential end benefits of cryopreservation services; however, I did not value the specific benefits of the cryopreservation services. While grow-out farmers will realize the benefits of genetic improvement provided by cryopreservation, hatchery producers will realize the benefits that cryopreservation can provide in the efficiency of production practices. Theoretically, the use of cryopreserved sperm will make selective breeding easier, provide a more efficient mechanism to farms that artificially spawn, and provide a greater reliability in the supply of high quality sperm. As of now, the aquaculture industry is not completely sure that cryopreservation will accomplish all of these projections. Aquatic hatcheries have not seen the results of what cryopreservation techniques can bring to the field of aquaculture. When cryopreservation services become an operating market, more extensive research can be done to determine which features, combinations of features, or services, aquaculture hatcheries most desire.

The specific genetic attributes used in the stated choice portion of the questionnaire were growth rate, disease resistance, and resistance to 10% lower dissolved oxygen levels. For future studies, one could possibly evaluate the WTP for genetic attributes such as dress-out percentage,

[74] This approximation is not taking into account any response bias that may be incurred with the addition of one more choice task to complete.

feed conversion ratio, or an increase in seining ability. These are other attributes that foodfish producers could theoretically be willing to pay a price premium for.

A comprehensive partial budget analysis of selected aquaculture industries evaluating the inclusion of cryopreservation services would also be beneficial to the valuation of cryopreservation services as a whole. The use of WTP values for genetically improved foodfish from grow-out producers would improve the estimates of the budget analysis.

The stated choice questions used in this study could also be applied to aquaculture industries other than the foodfish sector. The baitfish, aquarium fish, and shellfish industries would all benefit from genetic improvement as well. It would be interesting to compare the results of this study to the WTP values for any of the other industries.

F. Conclusions

This research was intended to evaluate the interest in cryopreservation services and genetic improvement for specific industries within U.S. aquaculture. This research could encourage dialogue between hatcheries and grow-out producers concerning the utilization of cryopreserved sperm in order to benefit both sectors. I also expect to see more academic studies analyzing cryopreservation services, in the context of commercial operations, for aquaculture industries. Also, I expect more focused studies concerning specific aquaculture industries and their desire for genetic improvement. By analyzing the most desired genetic improvements, hatcheries can provide specific industries with the specific genetic attributes most desired. This is the first step in the process of introducing a new technology into an existing industry.

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APPENDIX I. DESCRIPTIVE STATISTICS FOR ALL RESPONDENTS

Table A1-1. Summary Statistics For All Survey Respondents.

Variable	Number of Respondents	% of Respondents	Mean	St.dev.
Usable Responses by Version				
Version 1	57	39.04%		
Version 2	47	32.19%		
Version 3	42	28.77%		
Total	**146**	**100.00%**		
Breakdown of Respondent's Operations				
Spawning Operations	85	58.22%		
Grow-out Operations	70	47.95%		
Both Spawning & Grow-out	35	23.97%		
Only Spawning	50	34.25%		
Only Grow-out	35	23.97%		
Only Demographic	26	17.81%		
Public or Private Operation				
Public = 0	32	21.92%		
Private = 1	113	77.40%	0.7877	0.4268
Both = 2	1	0.68%		
Total	**146**	**100.00%**		
Employees				
< 10 = 0	121	82.88%		
10 to 50 = 1	23	15.75%		
51 to 150 = 2	2	1.37%	0.1849	0.4235
> 150 = 3	0	0.00%		
Total	**146**	**100.00%**		
Gross Sales				
< $2,500 = 0	11	9.17%		
$2,500-$9,999 = 1	6	5.00%		
$10,000-$49,999 = 2	18	15.00%		
$50,000-$249,999 = 3	35	29.17%		
$250,000-$999,999 = 4	29	24.17%	3.0917	1.5007
$1 million-$4,999,999 = 5	18	15.00%		
$5 million or more = 6	3	2.50%		
Total	**120**	**100.00%**		
Education				
Less than high school = 0	1	0.69%		
High school diploma or GED = 1	20	13.79%		
Some college/technical school = 2	36	24.83%		
Bachelor's degree = 3	57	39.31%	2.6690	0.9864
Advanced degree = 4	31	21.38%		
Total	**145**	**100.00%**		
Age				
18-25 = 0	1	0.70%		
26-35 = 1	13	9.09%		
36-45 = 2	33	23.08%		
46-60 = 3	80	55.94%	2.6783	0.8188
> 60 = 4	16	11.19%		
Total	**143**	**100.00%**		

Table A1-1. (cont.)

Spawning Operations				
Yes = 1	85	58.22%		
No = 0	61	41.78%	0.5822	0.4949
Total	**146**	**100.00%**		
Grow-out Operations				
Yes = 1	70	47.95%		
No = 0	76	52.05%	0.4795	0.5013
Total	**146**	**100.00%**		
Responses by contact method				
1st mail out	58	39.73%		
2nd mail out	67	45.89%		
E-mailed	3	2.05%		
Postcard	18	12.33%		
Total	**146**	**100.00%**		

Table AI-2. Technology Adopted Within The Last Five Years[75].

Variable		Number of Respondents	% of Respondents	Mean	St.dev.
1) Remote monitoring					
	Yes = 1	26	18.44%		
	No = 0	115	81.56%	0.1844	0.3892
	Total	**141**	**100.00%**		
2) PAS					
	Yes = 1	2	1.42%		
	No = 0	139	98.58%	0.0142	0.1187
	Total	**141**	**100.00%**		
3) Internet					
	Yes = 1	94	66.67%		
	No = 0	47	33.33%	0.6667	0.4731
	Total	**141**	**100.00%**		
4) GIS					
	Yes = 1	4	2.84%		
	No = 0	137	97.16%	0.0284	0.1666
	Total	**141**	**100.00%**		
5) Monitering & control					
	Yes = 1	26	18.44%		
	No = 0	115	81.56%	0.1844	0.3892
	Total	**141**	**100.00%**		

[75] Results are from Question 36.

Table AI-3. Ranking Of Potential Benefits Of Cryopreservation Services[76].

Variable		Number of Respondents	% of Respondents	Mean	St.dev.
1) Genetic Control					
	1	28	22.22%		
	2	22	17.46%		
	3	20	15.87%	2.8254	1.2204
	4	56	44.44%		
	Total	**126**	**100.00%**		
2) Production Costs					
	1	62	49.60%		
	2	33	26.40%		
	3	10	8.00%	1.9040	1.1030
	4	20	16.00%		
	Total	**125**	**100.00%**		
3) Production Risks					
	1	22	17.60%		
	2	28	22.40%		
	3	52	41.60%	2.6080	0.9829
	4	23	18.40%		
	Total	**125**	**100.00%**		
4) Improved Product					
	1	34	26.98%		
	2	42	33.33%		
	3	31	24.60%	2.2778	1.0248
	4	19	15.08%		
	Total	**126**	**100.00%**		

[76] Results are from Question 37 of the survey.

Table AI-4. Attitudes Towards Cryopreservation And Genetic Improvement[77].

Statement	Strongly Against	Slightly Against	No Position	Slightly In Favor	Strongly In Favor	Total	Mean	St. dev.
The establishment of new genetic lines in aquatic species.	4 2.82%	14 9.86%	40 28.17%	37 26.06%	47 33.10%	142 100.00%	2.7676	1.1023
The adoption of new technology.	1 0.71%	1 0.71%	15 10.64%	41 29.08%	83 58.87%	141 100.00%	3.4468	0.7693
The termination of all research regarding the genetic improvement of animals.	79 56.83%	14 10.07%	37 26.62%	6 4.32%	3 2.16%	139 100.00%	0.8489	1.0896
Government regulations placed on all cryopreserved sperm sales.	46 32.86%	22 15.71%	56 40.00%	12 8.57%	4 2.86%	140 100.00%	1.3286	1.1088
The practice of cryopreserving sperm.	1 0.71%	4 2.84%	62 43.97%	34 24.11%	40 28.37%	141 100.00%	2.7660	0.9230

[77] This is a summation of the responses to Question 38 of the survey.

Table AI-5. Opinions Regarding Cryopreservation[78].

Statement	Strongly Disagree	Somewhat Disagree	No Opinion	Somewhat Agree	Strongly Agree	Total	Mean	St. dev.
Cryopreservation is a form of biotechnology.	3 2.19%	10 7.30%	31 22.63%	43 31.39%	50 36.50%	137 100.00%	2.9270	1.0406
Cryopreservation should be used to preserve the loss of genetic lines, as well as create new ones.	2 1.42%	4 2.84%	35 24.82%	54 38.30%	46 32.62%	141 100.00%	2.9787	0.9061
The freezing of sperm will alter the genetic makeup of the sperm and offspring that are produced.	42 30.00%	25 17.86%	67 47.86%	4 2.86%	2 1.43%	140 100.00%	1.2786	0.9750
Cryopreservation services can help to maintain biodiversity in aquatic species.	2 1.43%	8 5.71%	43 30.71%	46 32.86%	41 29.29%	140 100.00%	2.8286	0.9667
Cryopreservation is an immoral practice.	65 46.43%	25 17.86%	44 31.43%	4 2.86%	2 1.43%	140 100.00%	0.9500	1.0130
Cryopreservation will become an integral part of the overall aquaculture industry within the next five years.	6 4.29%	23 16.43%	63 45.00%	38 27.14%	10 7.14%	140 100.00%	2.1643	0.9339
The ability to store sperm for upcoming years is important to my business.	34 24.46%	22 15.83%	51 36.69%	22 15.83%	10 7.19%	139 100.00%	1.6547	1.2141
I would incorporate cryopreservation services into my existing operation if they were available.	26 18.71%	17 12.23%	68 48.92%	19 13.67%	9 6.47%	139 100.00%	1.7698	1.1054

[78] Results are from Question 39 of the survey.

APPENDIX II. DESCRIPTIVE STATISTICS FOR RESPONDENTS WITH BOTH HATCHERIES AND GROW-OUT OPERATIONS

Table A2-1. Summary Statistics For Respondents With Both Spawning & Grow-out Facilities.

Variable	Number of Respondents	% of Respondents	Mean	St.dev.
Spawning & Grow-out Operations	**35**	**100.00%**		
Maintain on-site throughout the year				
Yes = 1	34	97.14%		
No = 0	1	2.86%	0.9714	0.1690
Total	**35**	**100.00%**		
Methods utilized for on-site maintenance (% of 34)				
Pond	17	50.00%		
Flow-through	11	32.35%		
Net pens/Cages	3	8.82%		
Closed re-circulation	10	29.41%		
Other	0	0.00%		
Collect Broodstock				
Yes = 1	6	17.14%		
No = 0	29	82.86%	0.1714	0.3824
Total	**35**	**100.00%**		
Purchase Broodstock				
Yes = 1	5	14.71%		
No = 0	29	85.29%	0.1471	0.3595
Total	**34**	**100.00%**		
Other methods				
Yes = 1	2	5.71%		
No = 0	33	94.29%	0.0571	0.2355
Total	**35**	**100.00%**		
Spawning Method				
Artificial = 1	14	40.00%		
Natural = 0	18	51.43%		
Both = 2	3	8.57%	0.5714	0.6547
Total	**35**	**100.00%**		
% of eggs fertilized				
<20% = 0	0	0.00%		
21-40% = 1	1	5.88%		
41-60% = 2	4	23.53%		
61-80% = 3	7	41.18%	2.9441	0.8993
81-100% = 4	**5**	29.41%		
Total =	**17**	**100.00%**		
Utilize selective breeding techniques				
Yes = 1	23	67.65%		
No = 0	11	32.35%	0.6765	0.4749
Total	**34**	**100.00%**		
Purchased more than 50% of fingerling stock				
Yes = 1	4	11.43%		
No = 0	31	88.57%	0.1143	0.3228
Total	**35**	**100.00%**		

Table A2-1. (cont.)

Average size of fingerlings purchased				
1-2 inch = 0	2	50.00%	0.5000	
3-4 inch = 1	2	50.00%		
5-6 inch = 2	0	0.00%		
7-9 inch = 3	0	0.00%		
Total =	**4**	100.00%		
Methods utilized for on-site fingerling maintenance (% of 34)				
Pond	20	58.82%		
Flow-through	14	41.18%		
Net pens/Cages	1	2.94%		
Closed re-circulation	7	20.59%		
Other	0	0.00%		
Average weight of foodfish sold				
<1 pound = 0	6	18.75%		
1-2 pounds = 1	22	68.75%		
2-3 pounds = 2	2	6.25%	1.0313	0.8224
3-4 pounds = 3	1	3.13%		
>4 pounds = 4	1	3.13%		
Total =	**32**	**100.00%**		
Willing to pay for genetically uniform fingerlings				
Yes = 1	17	50.00%		
No = 0	17	50.00%	0.5000	0.5075
Total	**34**	**100.00%**		
Mean maximum W.T.P.			15.8824	0.1064
Willing to pay for supply reliability				
Yes = 1	15	44.12%		
No = 0	19	55.88%	0.4412	0.5040
Total	**34**	**100.00%**		
Mean maximum W.T.P.			16.6667	11.1270
Choice set 1				
Option A	16			
Option B	8			
Option C	5			
Choice set 2				
Option A	5			
Option B	17			
Option C	8			
Public or Private Operation				
Public = 0	2	5.71%		
Private = 1	32	91.43%	0.9714	0.2956
Both = 2	1	2.86%		
Total	**35**	**100.00%**		
Employees				
< 10 = 0	21	60.00%		
10 to 50 = 1	12	34.29%		
51 to 150 = 2	2	5.71%	0.4571	0.6108
> 150 = 3	0	0.00%		
Total	**35**	**100.00%**		
Gross Sales				
< $2,500 = 0	1	3.03%		
$2,500-$9,999 = 1	2	6.06%		
$10,000-$49,999 = 2	3	9.09%		
$50,000-$249,999 = 3	4	12.12%		
$250,000-$999,999 = 4	9	27.27%	3.9091	1.5076
$1 million-$4,999,999 = 5	11	33.33%		
$5 million or more = 6	3	9.09%		
Total	**33**	**100.00%**		

Table A2-1. (cont.)

Education				
Less than high school = 0	0	0.00%		
High school diploma or GED = 1	3	8.57%		
Some college/technical school = 2	8	22.86%		
Bachelor's degree = 3	15	42.86%	2.8571	0.9121
Advanced degree = 4	9	25.71%		
Total	**35**	**100.00%**		
Age				
18-25 = 0	1	2.86%		
26-35 = 1	0	0.00%		
36-45 = 2	10	28.57%		
46-60 = 3	20	57.14%	2.7429	0.7800
> 60 = 4	4	11.43%		
Total	**35**	**100.00%**		

Table A2-2. Technology Adopted Within The Last Five Years[79].

Variable		**Number of Respondents**	**% of Respondents**	**Mean**	**St.dev.**
1) Remote monitoring					
	Yes = 1	5	14.71%		
	No = 0	29	85.29%	0.1471	0.3595
	Total	**34**	**100.00%**		
2) PAS					
	Yes = 1	1	2.94%		
	No = 0	33	97.06%	0.0294	0.1715
	Total	**34**	**100.00%**		
3) Internet					
	Yes = 1	23	67.65%		
	No = 0	11	32.35%	0.6765	0.4749
	Total	**34**	**100.00%**		
4) GIS					
	Yes = 1	1	2.94%		
	No = 0	33	97.06%	0.0294	0.1715
	Total	**34**	**100.00%**		
5) Monitering & control					
	Yes = 1	7	20.59%		
	No = 0	27	79.41%	0.2059	0.4104
	Total	**34**	**100.00%**		

[79] Results are from Question 36.

Table A2-3. Ranking Of Potential Benefits Of Cryopreservation Services[80].

Variable		Number of Respondents	% of Respondents	Mean	St.dev.
1) Genetic Control					
	1	7	23.33%		
	2	5	16.67%		
	3	5	16.67%	2.8000	1.2430
	4	13	43.33%		
	Total	**30**	**100.00%**		
2) Production Costs					
	1	20	66.67%		
	2	6	20.00%		
	3	1	3.33%	1.5667	0.9714
	4	3	10.00%		
	Total	**30**	**100.00%**		
3) Production Risks					
	1	6	20.00%		
	2	6	20.00%		
	3	12	40.00%	2.6000	1.0372
	4	6	20.00%		
	Total	**30**	**100.00%**		
4) Improved Product					
	1	8	26.67%		
	2	12	40.00%		
	3	5	16.67%	2.2330	1.0400
	4	5	16.67%		
	Total	**30**	**100.00%**		

[80] Results are from Question 37 of the survey.

Table A2-4. Hatchery & Grow-out Product Distribution For Farms With Both Spawning & Grow-out Operations.

34 respondents reported species totals
% of the 34 respondents

	Hatchery Production			Grow-out Production		
	Primary Product[81]	Single Product Operation[82]	Produce Some[83]	Primary Product[84]	Single Product Operation[85]	Produce Some[86]
Channel Catfish	11	7	13	12	9	13
	32.35%	20.59%	38.24%	35.29%	26.47%	38.24%
Hybrid Striped Bass	2	1	2	2	0	2
	5.88%	2.94%	5.88%	5.88%	0.00%	5.88%
Tilapia	5	5	7	5	5	6
	14.71%	14.71%	20.59%	14.71%	14.71%	17.65%
Atlantic Salmon	2	2	2	2	2	2
	5.88%	5.88%	5.88%	5.88%	5.88%	5.88%
Rainbow Trout	5	2	5	6	2	6
	14.71%	5.88%	14.71%	17.65%	5.88%	17.65%
Other	9	7	17	7	7	16
	26.47%	20.59%	50.00%	20.59%	20.59%	47.06%

Percent of farms with only one product = 70.59%
Percent of farms with multiple products = 29.41%

Percent of farms with only one product = 0.00%
Percent of farms with multiple products = 26.47%

[81] Primary product refers to species that represent the highest percentage of reported sales.
[82] Single product operation refers to species that represent 100% of reported sales.
[83] Produce some refers to species that represent some percentage of reported sales (1% to 100%).
[84] Primary product refers to species that represent the highest percentage of reported sales.
[85] Single product operation refers to species that represent 100% of reported sales.
[86] Produce some refers to species that represent some percentage of reported sales (1% to 100%).

Table A2-5. Hatchery Producers' Opinions Regarding Cryopreservation Services[87].

Question	Definitely	Maybe	Not Sure	Probably Not	Definitely Not	Total	Mean	St. dev.
Would you be willing to utilize a service that meant you only had tocollect, or maintain, male broodstock once every five years?	5 14.29%	10 28.57%	8 22.86%	10 28.57%	2 5.71%	35 100.00%	2.1714	1.1754
If you produce non-hybrids, would you be willing to try a new cost-effective way to produce hybrids or crossbreeds? (Bass, catfish, etc.) (Please skip to next question if you produce only hybrids)	9 26.47%	9 26.47%	7 20.59%	5 14.71%	4 11.76%	34 100.00%	2.4118	1.351
Would you be willing to pay for a service that meant you could selectively breed your product by using the sperm from the best males of a particular species?	5 14.29%	18 51.43%	7 20.00%	3 8.57%	2 5.71%	35 100.00%	2.6	1.0347
Assume there was a service that would freeze the sperm of your fish, store it until you were ready to fertilize your eggs, and then transport it to you. Would you be willing to pay the storage and processing costs that are required to maintain this service throughout the year?	3 8.57%	10 28.57%	11 31.43%	8 22.86%	3 8.57%	35 100.00%	2.0571	1.1099

[87] Results are from Question 9 of the survey.

Table A2-6. Knowledge Regarding Cryopreservation[88].

Statement	Yes	No	Don't Know	Total	Mean	St. dev.
Cryopreservation allows sperm to be frozen, stored indefinitely, and later used for fertilization of fresh eggs.	22 62.86%	1 2.86%	12 34.29%	35 100.00%	1.6000	0.5531
Use of cryopreserved sperm totally eliminates the need for male broodstock.	4 11.43%	21 60.00%	10 28.57%	35 100.00%	0.5143	0.7017
Cryopreservation is an integral part of the dairy industry.	18 51.43%	1 2.86%	16 45.71%	35 100.00%	1.4857	0.5621
Cryopreservation techniques are currently being commercially utilized within aquaculture industries.	14 40.00%	3 8.57%	18 51.43%	35 100.00%	1.3143	0.6311
Cryopreservation will help to establish genetic lines within aquatic species.	22 62.86%	2 5.71%	11 31.43%	35 100.00%	1.5714	0.6081
Cryopreservation is a new technique, developed in the last five years, and there is little known about its benefits.	7 20.00%	17 48.57%	11 31.43%	35 100.00%	0.7143	0.7886
Genetic improvement can be accomplished through cryopreservation of sperm.	17 48.57%	4 11.43%	14 40.00%	35 100.00%	1.3714	0.6897
The cryopreservation of sperm increases the risk of an invasive species entering an area.	4 11.76%	18 52.94%	12 35.29%	34 100.00%	0.5882	0.7014

[88] Results are from Question 10 of the survey.

Table A2-7. Attitudes Towards Cryopreservation And Genetic Improvement[89].

Statement	Strongly Against	Slightly Against	No Position	Slightly In Favor	Strongly In Favor	Total	Mean	St. dev.
The establishment of new genetic lines in aquatic species.	0 0.00%	0 0.00%	6 17.65%	13 38.24%	15 44.12%	34 100.00%	3.2647	0.7511
The adoption of new technology.	0 0.00%	0 0.00%	2 5.88%	7 20.59%	25 73.53%	34 100.00%	3.6765	0.5888
The termination of all research regarding the genetic improvement of animals.	19 55.88%	5 14.71%	7 20.59%	2 5.88%	1 2.94%	34 100.00%	0.8529	1.1317
Government regulations placed on all cryopreserved sperm sales.	16 47.06%	10 29.41%	5 14.71%	3 8.82%	0 0.00%	34 100.00%	0.8529	0.9888
The practice of cryopreserving sperm.	0 0.00%	0 0.00%	12 35.29%	9 26.47%	13 38.24%	34 100.00%	3.0294	0.8699

[89] This is a summation of the responses to Question 38 of the survey.

Table A2-8. Opinions Regarding Cryopreservation[90].

Statement	Strongly Disagree	Somewhat Disagree	No Opinion	Somewhat Agree	Strongly Agree	Total	Mean	St. dev.
Cryopreservation is a form of biotechnology.	3 8.82%	0 0.00%	8 23.53%	9 26.47%	14 41.18%	34 100.00%	2.9118	1.2152
Cryopreservation should be used to preserve the loss of genetic lines, as well as create new ones.	0 0.00%	0 0.00%	9 26.47%	11 32.35%	14 41.18%	34 100.00%	3.1471	0.8214
The freezing of sperm will alter the genetic makeup of the sperm and offspring that are produced.	13 38.24%	5 14.71%	15 44.12%	1 2.94%	0 0.00%	34 100.00%	1.1176	0.9775
Cryopreservation services can help to maintain biodiversity in aquatic species.	1 2.94%	1 2.94%	11 32.35%	8 23.53%	13 38.24%	34 100.00%	2.9118	1.0551
Cryopreservation is an immoral practice.	18 52.94%	5 14.71%	10 29.41%	0 0.00%	1 2.94%	34 100.00%	0.8529	1.0483
Cryopreservation will become an integral part of the overall aquaculture industry within the next five years.	2 5.88%	5 14.71%	12 35.29%	11 32.35%	4 11.76%	34 100.00%	2.2941	1.0597
The ability to store sperm for upcoming years is important to my business.	10 29.41%	3 8.82%	9 26.47%	7 20.59%	5 14.71%	34 100.00%	1.8235	1.4454
I would incorporate cryopreservation services into my existing operation if they were available.	6 17.65%	2 5.88%	13 38.24%	8 23.53%	5 14.71%	34 100.00%	2.1176	1.2736

[90] Results are from Question 39 of the survey.

APPENDIX III. DESCRIPTIVE STATISTICS FOR RESPONDENTS WITH HATCHERIES

Table A3-1. Summary Statistics For Respondents With Spawning Operations.

Variable	Number of Respondents	% of Respondents	Mean	St.dev.
Spawning Operations	**85**	**100.00%**		
Maintain on-site throughout the year				
Yes = 1	72	85.71%		
No = 0	12	14.29%	0.8571	0.3520
Total	**84**	**100.00%**		
Methods utilized for on-site maintenance (% of 72)				
Pond	42	58.33%		
Flow-through	25	34.72%		
Net pens/Cages	4	5.56%		
Closed re-circulation	14	19.44%		
Other	0	0.00%		
Collect Broodstock				
Yes = 1	27	32.14%		
No = 0	57	67.86%	0.3214	0.4698
Total	**84**	**100.00%**		
Purchase Broodstock				
Yes = 1	10	12.05%		
No = 0	73	87.95%	0.1205	0.3275
Total	**83**	**100.00%**		
Other methods				
Yes = 1	4	4.76%		
No = 0	80	95.24%	0.0476	0.2142
Total	**84**	**100.00%**		
Spawning Method				
Artificial = 1	38	45.78%		
Natural = 0	36	43.37%		
Both = 2	9	10.84%	0.6745	0.6646
Total	**83**	**100.00%**		
% of eggs fertilized				
<20% = 0	1	2.00%		
21-40% = 1	2	4.00%		
41-60% = 2	6	12.00%		
61-80% = 3	19	38.00%	3.1800	0.9409
81-100% = 4	**22**	44.00%		
Total =	**50**	**100.00%**		
Utilize selective breeding techniques				
Yes = 1	46	55.42%		
No = 0	37	44.58%	0.5542	0.5001
Total	**83**	**100.00%**		
Grow-out Operations				
Yes = 1	36	42.35%		
No = 0	49	57.65%	0.4235	0.4971
Total	**85**	**100.00%**		

Table A3-1. (cont.)

Purchased more than 50% of fingerling stock last year				
Yes = 1	4	11.43%		
No = 0	31	88.57%	0.1143	0.3228
Total	**35**	**100.00%**		
Average size of fingerlings purchased				
1-2 inch = 0	3	50.00%		
3-4 inch = 1	2	33.33%		
5-6 inch = 2	0	0.00%	0.8333	1.1690
7-9 inch = 3	1	16.67%		
Total =	**6**	100.00%		
Methods utilized for on-site fingerling maintenance (% of 34)				
Pond	20	58.82%		
Flow-through	14	41.18%		
Net pens/Cages	1	2.94%		
Closed re-circulation	7	20.59%		
Other	0	0.00%		
Average weight of foodfish sold				
<1 pound = 0	6	18.75%		
1-2 pounds = 1	22	68.75%		
2-3 pounds = 2	2	6.25%	1.0313	0.8224
3-4 pounds = 3	1	3.13%		
>4 pounds = 4	1	3.13%		
Total =	**32**	**100.00%**		
Willing to pay for genetically uniform fingerlings				
Yes = 1	17	50.00%		
No = 0	17	50.00%	0.5000	0.5075
Total	**34**	**100.00%**		
Mean maximum W.T.P.			15.8824	0.1064
Willing to pay for supply reliability				
Yes = 1	15	44.12%		
No = 0	19	55.88%	0.4412	0.5040
Total	**34**	**100.00%**		
Mean maximum W.T.P.			16.6667	11.1270
Choice set 1				
Option A	16			
Option B	8			
Option C	5			
Choice set 2				
Option A	5			
Option B	17			
Option C	8			
Public or Private Operation				
Public = 0	23	27.06%		
Private = 1	61	71.76%	0.7412	0.4668
Both = 2	1	1.18%		
Total	**85**	**100.00%**		

Table A3-1. (cont.)

Employees				
< 10 = 0	62	72.94%		
10 to 50 = 1	21	24.71%		
51 to 150 = 2	2	2.35%	0.2941	0.5076
> 150 = 3	0	0.00%		
Total	**85**	**100.00%**		
Gross Sales				
< $2,500 = 0	6	8.96%		
$2,500-$9,999 = 1	4	5.97%		
$10,000-$49,999 = 2	7	10.45%		
$50,000-$249,999 = 3	17	25.37%		
$250,000-$999,999 = 4	13	19.40%	3.3433	1.6381
$1 million-$4,999,999 = 5	17	25.37%		
$5 million or more = 6	3	4.48%		
Total	**67**	**100.00%**		
Education				
Less than high school = 0	0	0.00%		
High school diploma or GED = 1	8	9.52%		
Some college/technical school = 2	17	20.24%		
Bachelor’s degree = 3	37	44.05%	2.8690	0.9155
Advanced degree = 4	22	26.19%		
Total	**84**	**100.00%**		
Age				
18-25 = 0	1	1.20%		
26-35 = 1	7	8.43%		
36-45 = 2	18	21.69%		
46-60 = 3	48	57.83%	2.6867	0.8253
> 60 = 4	9	10.84%		
Total	**83**	**100.00%**		

Table A3-2. Technology Adopted Within The Last Five Years[91].

Variable		Number of Respondents	% of Respondents	Mean	St.dev.
1) Remote monitoring					
	Yes = 1	18	21.69%		
	No = 0	65	78.31%	0.2169	0.4146
	Total	**83**	**100.00%**		
2) PAS					
	Yes = 1	2	2.41%		
	No = 0	81	97.59%	0.0241	0.1543
	Total	**83**	**100.00%**		
3) Internet					
	Yes = 1	59	71.08%		
	No = 0	24	28.92%	0.7108	0.4561
	Total	**83**	**100.00%**		
4) GIS					
	Yes = 1	4	4.82%		
	No = 0	79	95.18%	0.0482	0.2155
	Total	**83**	**100.00%**		
5) Monitering & control					
	Yes = 1	16	19.28%		
	No = 0	67	80.72%	0.1928	0.3969
	Total	**83**	**100.00%**		

[91] Results are from Question 36.

Table A3-3. Ranking Of Potential Benefits Of Cryopreservation Services[92].

Variable		Number of Respondents	% of Respondents	Mean	St.dev.
1) Genetic Control					
	1	23	31.08%		
	2	14	18.92%		
	3	10	13.51%	2.5541	1.2729
	4	27	36.49%		
	Total	**74**	**100.00%**		
2) Production Costs					
	1	36	49.32%		
	2	12	16.44%		
	3	8	10.96%	2.0822	1.2445
	4	17	23.29%		
	Total	**73**	**100.00%**		
3) Production Risks					
	1	8	10.96%		
	2	13	17.81%		
	3	35	47.95%	2.8356	0.9131
	4	17	23.29%		
	Total	**73**	**100.00%**		
4) Improved Product					
	1	20	27.03%		
	2	34	45.95%		
	3	12	16.22%	2.1081	0.9230
	4	8	10.81%		
	Total	**74**	**100.00%**		

[92] Results are from Question 37 of the survey.

Table A3-4. Hatchery Product Distribution For Farms With Hatcheries.

74 respondents reported species totals
% of the 74 respondents

	Primary Product[93]	Single Product Operation[94]	Produce Some[95]
Channel Catfish	14	7	21
	18.92%	9.46%	28.38%
Hybrid Striped Bass	3	1	6
	4.05%	1.35%	8.11%
Tilapia	5	5	8
	6.76%	6.76%	10.81%
Atlantic Salmon	2	2	2
	2.70%	2.70%	2.70%
Rainbow Trout	13	5	14
	17.57%	6.76%	18.92%
Other	37	26	52
	50.00%	35.14%	70.27%
Percent of farms with only one product =		***62.16%***	
Percent of farms with multiple products =		***37.84%***	

[93] Primary product refers to species that represent the highest percentage of reported sales.
[94] Single product operation refers to species that represent 100% of reported sales.
[95] Produce some refers to species that represent some percentage of reported sales (1% to 100%).

Table A3-5. Hatchery Producers' Opinions Regarding Cryopreservation Services[96].

Question	Definitely	Maybe	Not Sure	Probably Not	Definitely Not	Total	Mean	St. dev.
Would you be willing to utilize a service that meant you only had tocollect, or maintain, male broodstock once every five years?	8 9.76%	22 26.83%	14 17.07%	27 32.93%	11 13.41%	82 100.00%	1.8659	1.235
If you produce non-hybrids, would you be willing to try a new cost-effective way to produce hybrids or crossbreeds? (Bass, catfish, etc.) (Please skip to next question if you produce only hybrids)	12 16.44%	19 26.03%	13 17.81%	14 19.18%	15 20.55%	73 100.00%	1.9863	1.3993
Would you be willing to pay for a service that meant you could selectively breed your product by using the sperm from the best males of a particular species?	9 11.11%	29 35.80%	15 18.52%	14 17.28%	14 17.28%	81 100.00%	2.0617	1.2976
Assume there was a service that would freeze the sperm of your fish, store it until you were ready to fertilize your eggs, and then transport it to you. Would you be willing to pay the storage and processing costs that are required to maintain this service throughout the year?	5 6.02%	21 25.30%	20 24.10%	19 22.89%	18 21.69%	83 100.00%	1.7108	1.235

[96] Results are from Question 9 of the survey.

Table A3-6. Knowledge Regarding Cryopreservation[97].

Statement	Yes	No	Don't Know	Total	Mean	St. dev.
Cryopreservation allows sperm to be frozen, stored indefinitely, and later used for fertilization of fresh eggs.	54 64.29%	3 3.57%	27 32.14%	84 100.00%	1.6071	0.5601
Use of cryopreserved sperm totally eliminates the need for male broodstock.	7 8.33%	55 65.48%	22 26.19%	84 100.00%	0.4286	0.6454
Cryopreservation is an integral part of the dairy industry.	46 54.76%	3 3.57%	35 41.67%	84 100.00%	1.5119	0.5702
Cryopreservation techniques are currently being commercially utilized within aquaculture industries.	30 36.14%	5 6.02%	48 57.83%	83 100.00%	1.3012	0.5788
Cryopreservation will help to establish genetic lines within aquatic species.	49 58.33%	3 3.57%	32 38.10%	84 100.00%	1.5476	0.5683
Cryopreservation is a new technique, developed in the last five years, and there is little known about its benefits.	9 10.84%	39 46.99%	35 42.17%	83 100.00%	0.6386	0.6731
Genetic improvement can be accomplished through cryopreservation of sperm.	43 51.19%	8 9.52%	33 39.29%	84 100.00%	1.4167	0.6624
The cryopreservation of sperm increases the risk of an invasive species entering an area.	10 12.05%	43 51.81%	30 36.14%	83 100.00%	0.6024	0.6974

[97] Results are from Question 10 of the survey.

Table A3-7. Attitudes Towards Cryopreservation And Genetic Improvement[98].

Statement	Strongly Against	Slightly Against	No Position	Slightly In Favor	Strongly In Favor	Total	Mean	St. dev.
The establishment of new genetic lines in aquatic species.	1 1.20%	8 9.64%	22 26.51%	22 26.51%	30 36.14%	83 100.00%	2.8675	1.0566
The adoption of new technology.	0 0.00%	0 0.00%	6 7.23%	20 24.10%	57 68.67%	83 100.00%	3.6145	0.6214
The termination of all research regarding the genetic improvement of animals.	54 65.85%	8 9.76%	16 19.51%	2 2.44%	2 2.44%	82 100.00%	0.6585	1.0330
Government regulations placed on all cryopreserved sperm sales.	30 36.14%	14 16.87%	28 33.73%	9 10.84%	2 2.41%	83 100.00%	1.2651	1.1379
The practice of cryopreserving sperm.	1 1.20%	0 0.00%	28 33.73%	25 30.12%	29 34.94%	83 100.00%	2.9759	0.8968

[98] This is a summation of the responses to Question 38 of the survey.

Table A3-8. Opinions Regarding Cryopreservation[99].

Statement	Strongly Disagree	Somewhat Disagree	No Opinion	Somewhat Agree	Strongly Agree	Total	Mean	St. dev.
Cryopreservation is a form of biotechnology.	3 3.70%	4 4.94%	15 18.52%	22 27.16%	37 45.68%	81 100.00%	3.0617	1.0880
Cryopreservation should be used to preserve the loss of genetic lines, as well as create new ones.	0 0.00%	1 1.20%	19 22.89%	31 37.35%	32 38.55%	83 100.00%	3.1325	0.8081
The freezing of sperm will alter the genetic makeup of the sperm and offspring that are produced.	31 37.35%	14 16.87%	36 43.37%	1 1.20%	1 1.20%	83 100.00%	1.1205	0.9803
Cryopreservation services can help to maintain biodiversity in aquatic species.	2 2.41%	5 6.02%	24 28.92%	24 28.92%	28 33.73%	83 100.00%	2.8554	1.0375
Cryopreservation is an immoral practice.	44 53.01%	12 14.46%	23 27.71%	2 2.41%	2 2.41%	83 100.00%	0.8675	1.0566
Cryopreservation will become an integral part of the overall aquaculture industry within the next five years.	3 3.61%	16 19.28%	32 38.55%	25 30.12%	7 8.43%	83 100.00%	2.2048	0.9723
The ability to store sperm for upcoming years is important to my business.	22 26.83%	12 14.63%	26 31.71%	13 15.85%	9 10.98%	82 100.00%	1.6951	1.3211
I would incorporate cryopreservation services into my existing operation if they were available.	19 22.89%	10 12.05%	32 38.55%	13 15.66%	9 10.84%	83 100.00%	1.7952	1.2664

[99] Results are from Question 39 of the survey.

APPENDIX IV. DESCRIPTIVE STATISTICS FOR RESPONDENTS WITH GROW-OUT OPERATIONS

Table A4-1. Summary Statistics For Respondents With Grow-out Operations.

Variable	Number of Respondents	% of Respondents	Mean	St.dev.
Spawning Operations	**35**	**100.00%**		
Maintain on-site throughout the year				
Yes = 1	34	97.14%		
No = 0	1	2.86%	0.9714	0.1690
Total	**35**	**100.00%**		
Methods utilized for on-site maintenance (% of 34)				
Pond	17	50.00%		
Flow-through	11	32.35%		
Net pens/Cages	3	8.82%		
Closed re-circulation	10	29.41%		
Other	0	0.00%		
Collect Broodstock				
Yes = 1	6	17.14%		
No = 0	29	82.86%	0.1714	0.3824
Total	**35**	**100.00%**		
Purchase Broodstock				
Yes = 1	5	14.71%		
No = 0	29	85.29%	0.1471	0.3595
Total	**34**	**100.00%**		
Other methods				
Yes = 1	2	5.71%		
No = 0	33	94.29%	0.0571	0.2355
Total	**35**	**100.00%**		
Spawning Method				
Artificial = 1	14	40.00%		
Natural = 0	18	51.43%		
Both = 2	3	8.57%	0.5714	0.6547
Total	**35**	**100.00%**		
% of eggs fertilized				
<20% = 0	0	0.00%		
21-40% = 1	1	5.88%		
41-60% = 2	4	23.53%		
61-80% = 3	7	41.18%	2.9412	0.8993
81-100% = 4	5	29.41%		
Total =	**17**	**100.00%**		
Utilize selective breeding techniques				
Yes = 1	23	67.65%		
No = 0	11	32.35%	0.6765	0.4749
Total	**34**	**100.00%**		
Grow-out Operations				
Yes = 1	70	100.00%		
No = 0	0	0.00%	1.0000	0.0000
Total	**70**	**100.00%**		

Table A4-1. (cont.)

Purchased more than 50% of fingerling stock last year				
Yes = 1	24	34.29%		
No = 0	46	65.71%	0.3429	0.4781
Total	**70**	**100.00%**		
Average size of fingerlings purchased				
1-2 inch = 0	7	26.92%		
3-4 inch = 1	11	42.31%		
5-6 inch = 2	6	23.08%	1.1154	0.9089
7-9 inch = 3	2	7.69%		
Total =	**26**	100.00%		
Methods utilized for on-site fingerling maintenance (% of 70)				
Pond	36	51.43%		
Flow-through	29	41.43%		
Net pens/Cages	3	4.29%		
Closed re-circulation	14	20.00%		
Other	0	0.00%		
Average weight of foodfish sold				
<1 pound = 0	14	21.88%		
1-2 pounds = 1	37	57.81%		
2-3 pounds = 2	9	14.06%	1.0625	0.8333
3-4 pounds = 3	3	4.69%		
>4 pounds = 4	1	1.56%		
Total =	**64**	**100.00%**		
Willing to pay for genetically uniform fingerlings				
Yes = 1	36	52.94%		
No = 0	32	47.06%	0.5294	0.5028
Total	**68**	**100.00%**		
Mean maximum W.T.P.			19.7222	17.3182
Willing to pay for supply reliability				
Yes = 1	25	37.88%		
No = 0	41	62.12%	0.3788	0.4888
Total	**66**	**100.00%**		
Mean maximum W.T.P.			21.2000	18.7794
Choice set 1				
Option A	26			
Option B	16			
Option C	17			
Choice set 2				
Option A	11			
Option B	26			
Option C	24			
Public or Private Operation				
Public = 0	5	7.14%		
Private = 1	64	91.43%	0.9429	0.2892
Both = 2	1	1.43%		
Total	**70**	**100.00%**		

Table A4-1. (cont.)

Employees				
< 10 = 0	55	78.57%		
10 to 50 = 1	13	18.57%		
51 to 150 = 2	2	2.86%	0.2429	0.4945
> 150 = 3	0	0.00%		
Total Gross Sales	**70**	**100.00%**		
< $2,500 = 0	3	4.69%		
$2,500-$9,999 = 1	3	4.69%		
$10,000-$49,999 = 2	8	12.50%		
$50,000-$249,999 = 3	15	23.44%		
$250,000-$999,999 = 4	21	32.81%	3.4531	1.4134
$1 million-$4,999,999 = 5	11	17.19%		
$5 million or more = 6	3	4.69%		
Total	**64**	**100.00%**		
Education				
Less than high school = 0	1	1.43%		
High school diploma or GED = 1	8	11.43%		
Some college/technical school = 2	19	27.14%		
Bachelor’s degree = 3	25	35.71%	2.7000	1.0122
Advanced degree = 4	17	24.29%		
Total	**70**	**100.00%**		
Age				
18-25 = 0	1	1.45%		
26-35 = 1	5	7.25%		
36-45 = 2	18	26.09%		
46-60 = 3	38	55.07%	2.6522	0.8194
> 60 = 4	7	10.14%		
Total	**69**	**100.00%**		

Table A4-2. Technology Adopted Within The Last Five Years[100].

Variable		Number of Respondents	% of Respondents	Mean	St.dev.
1) Remote monitoring					
	Yes = 1	12	18.18%		
	No = 0	54	81.82%	0.1818	0.3887
	Total	**66**	**100.00%**		
2) PAS					
	Yes = 1	1	1.52%		
	No = 0	65	98.48%	0.0152	0.1231
	Total	**66**	**100.00%**		
3) Internet					
	Yes = 1	42	63.64%		
	No = 0	24	36.36%	0.6364	0.4847
	Total	**66**	**100.00%**		
4) GIS					
	Yes = 1	1	1.52%		
	No = 0	65	98.48%	0.0152	0.1231
	Total	**66**	**100.00%**		
5) Monitering & control					
	Yes = 1	15	22.73%		
	No = 0	51	77.27%	0.2273	0.4223
	Total	**66**	**100.00%**		

[100] Results are from Question 36.

Table A4-3. Ranking Of Potential Benefits Of Cryopreservation Services[101].

Variable		Number of Respondents	% of Respondents	Mean	St.dev.
1) Genetic Control					
	1	7	11.48%		
	2	12	19.67%		
	3	11	18.03%	3.0820	1.0847
	4	31	50.82%		
	Total	**61**	**100.00%**		
2) Production Costs					
	1	35	57.38%		
	2	19	31.15%		
	3	2	3.28%	1.6230	0.8975
	4	5	8.20%		
	Total	**61**	**100.00%**		
3) Production Risks					
	1	17	27.87%		
	2	16	26.23%		
	3	20	32.79%	2.3115	1.0254
	4	8	13.11%		
	Total	**61**	**100.00%**		
4) Improved Product					
	1	14	22.95%		
	2	15	24.59%		
	3	19	31.15%	2.5082	1.0743
	4	13	21.31%		
	Total	**61**	**100.00%**		

[101] Results are from Question 37 of the survey.

Table A4-4. Grow-out Product Distribution For Farms With Grow-out Operations.

69 respondents reported species totals
% of the 69 respondents

	Primary Product[102]	Single Product Operation[103]	Produce Some[104]
Channel Catfish	22	18	24
	31.88%	26.09%	34.78%
Hybrid Striped Bass	8	2	10
	11.59%	2.90%	14.49%
Tilapia	7	7	10
	10.14%	10.14%	14.49%
Atlantic Salmon	2	2	2
	2.90%	2.90%	2.90%
Rainbow Trout	20	13	21
	28.99%	18.84%	30.43%
Other	10	9	22
	14.49%	13.04%	31.88%
Percent of farms with only one product =		***73.91%***	
Percent of farms with multiple products =		***26.09%***	

[102] Primary product refers to species that represent the highest percentage of reported sales.
[103] Single product operation refers to species that represent 100% of reported sales.
[104] Produce some refers to species that represent some percentage of reported sales (1% to 100%).

Table A4-5. Attitudes Towards Cryopreservation And Genetic Improvement[105].

Statement	Strongly Against	Slightly Against	No Position	Slightly In Favor	Strongly In Favor	Total	Mean	St. dev.
The establishment of new genetic lines in aquatic species.	0 0.00%	3 4.48%	17 25.37%	20 29.85%	27 40.30%	67 100.00%	3.0597	0.9192
The adoption of new technology.	0 0.00%	0 0.00%	5 7.58%	21 31.82%	40 60.61%	66 100.00%	3.5303	0.6378
The termination of all research regarding the genetic improvement of animals.	37 56.92%	5 7.69%	18 27.69%	4 6.15%	1 1.54%	65 100.00%	0.8769	1.1111
Government regulations placed on all cryopreserved sperm sales.	29 44.62%	15 23.08%	16 24.62%	4 6.15%	1 1.54%	65 100.00%	0.9692	1.0454
The practice of cryopreserving sperm.	0 0.00%	2 3.03%	30 45.45%	16 24.24%	18 27.27%	66 100.00%	2.7576	0.8955

[105] This is a summation of the responses to Question 38 of the survey.

Table A4-6. Opinions Regarding Cryopreservation[106].

Statement	Strongly Disagree	Somewhat Disagree	No Opinion	Somewhat Agree	Strongly Agree	Total	Mean	St. dev.
Cryopreservation is a form of biotechnology.	3 4.55%	4 6.06%	14 21.21%	22 33.33%	23 34.85%	66 100.00%	2.8788	1.1027
Cryopreservation should be used to preserve the loss of genetic lines, as well as create new ones.	0 0.00%	2 3.03%	16 24.24%	24 36.36%	24 36.36%	66 100.00%	3.0606	0.8572
The freezing of sperm will alter the genetic makeup of the sperm and offspring that are produced.	20 30.30%	11 16.67%	30 45.45%	4 6.06%	1 1.52%	66 100.00%	1.3181	1.0252
Cryopreservation services can help to maintain biodiversity in aquatic species.	1 1.52%	3 4.55%	20 30.30%	21 31.82%	21 31.82%	66 100.00%	2.8788	0.9690
Cryopreservation is an immoral practice.	31 46.97%	14 21.21%	20 30.30%	0 0.00%	1 1.52%	66 100.00%	0.8788	0.9530
Cryopreservation will become an integral part of the overall aquaculture industry within the next five years.	2 3.03%	9 13.64%	30 45.45%	19 28.79%	6 9.09%	66 100.00%	2.2727	0.9206
The ability to store sperm for upcoming years is important to my business.	15 22.73%	9 13.64%	22 33.33%	15 22.73%	5 7.58%	66 100.00%	1.7879	1.2467
I would incorporate cryopreservation services into my existing operation if they were available.	9 13.64%	5 7.58%	34 51.52%	13 19.70%	5 7.58%	66 100.00%	2.0000	1.0670

[106] Results are from Question 39 of the survey.

APPENDIX V. DESCRIPTIVE STATISTICS FOR RESPONDENTS WITH ONLY HATCHERY OPERATIONS

Table A5-1. Summary Statistics For Respondents With Only Spawning Operations.

Variable	Number of Respondents	% of Respondents	Mean	St.dev.
Spawning Operations	**50**	**100.00%**		
Maintain on-site throughout the year				
Yes = 1	38	77.55%		
No = 0	11	22.45%	0.7755	0.4216
Total	**49**	**100.00%**		
Methods utilized for on-site maintenance (% of 38)				
Pond	25	34.72%		
Flow-through	14	19.44%		
Net pens/Cages	1	1.39%		
Closed re-circulation	4	5.56%		
Other	0	0.00%		
Collect Broodstock				
Yes = 1	21	42.86%		
No = 0	28	57.14%	0.4286	0.5000
Total	**49**	**100.00%**		
Purchase Broodstock				
Yes = 1	5	10.20%		
No = 0	44	89.80%	0.1020	0.3058
Total	**49**	**100.00%**		
Other methods				
Yes = 1	2	4.08%		
No = 0	47	95.92%	0.0408	0.1999
Total	**49**	**100.00%**		
Spawning Method				
Artificial = 1	26	52.00%		
Natural = 0	18	36.00%		
Both = 2	6	12.00%	0.7600	0.6565
Total	**50**	**100.00%**		
% of eggs fertilized				
<20% = 0	1	3.03%		
21-40% = 1	1	3.03%		
41-60% = 2	2	6.06%		
61-80% = 3	12	36.36%	3.3030	0.9515
81-100% = 4	**17**	51.52%		
Total =	**33**	**100.00%**		
Utilize selective breeding techniques				
Yes = 1	23	46.94%		
No = 0	26	53.06%	0.4694	0.5042
Total	**49**	**100.00%**		

Table A5-1. (cont.)

Grow-out Operations				
Yes = 1	0	0.00%		
No = 0	50	100.00%	0.0000	0.0000
Total	**50**	**100.00%**		
Public or Private Operation				
Public = 0	21	42.00%		
Private = 1	29	58.00%	0.5800	0.4986
Both = 2	0	0.00%		
Total	**50**	**100.00%**		
Employees				
< 10 = 0	41	82.00%		
10 to 50 = 1	9	18.00%		
51 to 150 = 2	0	0.00%	0.1800	0.3881
> 150 = 3	0	0.00%		
Total	**50**	**100.00%**		
Gross Sales				
< $2,500 = 0	5	14.71%		
$2,500-$9,999 = 1	2	5.88%		
$10,000-$49,999 = 2	4	11.76%		
$50,000-$249,999 = 3	13	38.24%		
$250,000-$999,999 = 4	4	11.76%	2.7941	1.5913
$1 million-$4,999,999 = 5	6	17.65%		
$5 million or more = 6	0	0.00%		
Total	**34**	**100.00%**		
Education				
Less than high school = 0	0	0.00%		
High school diploma or GED = 1	5	10.20%		
Some college/technical school = 2	9	18.37%		
Bachelor's degree = 3	22	44.90%	2.8776	0.9272
Advanced degree = 4	13	26.53%		
Total	**49**	**100.00%**		
Age				
18-25 = 0	0	0.00%		
26-35 = 1	7	14.58%		
36-45 = 2	8	16.67%		
46-60 = 3	28	58.33%	2.6458	0.8627
> 60 = 4	5	10.42%		
Total	**48**	**100.00%**		

Table A5-2. Technology Adopted Within The Last Five Years[107].

Variable		Number of Respondents	% of Respondents	Mean	St.dev.
1) Remote monitoring					
	Yes = 1	13	26.53%		
	No = 0	36	73.47%	0.2653	0.4461
	Total	**49**	**100.00%**		
2) PAS					
	Yes = 1	1	2.04%		
	No = 0	48	97.96%	0.0204	0.1423
	Total	**49**	**100.00%**		
3) Internet					
	Yes = 1	36	73.47%		
	No = 0	13	26.53%	0.7347	0.4461
	Total	**49**	**100.00%**		
4) GIS					
	Yes = 1	3	6.12%		
	No = 0	46	93.88%	0.0612	0.2422
	Total	**49**	**100.00%**		
5) Monitering & control					
	Yes = 1	9	18.37%		
	No = 0	40	81.63%	0.1837	0.3912
	Total	**49**	**100.00%**		

[107] Results are from Question 36.

Table A5-3. Ranking Of Potential Benefits Of Cryopreservation Services[108].

Variable		Number of Respondents	% of Respondents	Mean	St.dev.
1) Genetic Control					
	1	16	36.36%		
	2	9	20.45%		
	3	5	11.36%	2.3864	1.2798
	4	14	31.82%		
	Total	**44**	**100.00%**		
2) Production Costs					
	1	16	37.21%		
	2	6	13.95%		
	3	7	16.28%	2.4419	1.2966
	4	14	32.56%		
	Total	**43**	**100.00%**		
3) Production Risks					
	1	2	4.65%		
	2	7	16.28%		
	3	23	53.49%	3.0000	0.7868
	4	11	25.58%		
	Total	**43**	**100.00%**		
4) Improved Product					
	1	12	27.27%		
	2	22	50.00%		
	3	7	15.91%	2.0227	0.8488
	4	3	6.82%		
	Total	**44**	**100.00%**		

[108] Results are from Question 37 of the survey.

Table A5-4. Hatchery Product Distribution For Farms With Only Hatcheries.

39 respondents reported species totals
% of the 39 respondents

	Primary Product[109]	Single Product Operation[110]	Produce Some[111]
Channel Catfish	3	0	8
	7.69%	0.00%	20.51%
Hybrid Striped Bass	1	0	4
	2.56%	0.00%	10.26%
Tilapia	0	0	1
	0.00%	0.00%	2.56%
Atlantic Salmon	0	0	0
	0.00%	0.00%	0.00%
Rainbow Trout	7	3	8
	17.95%	7.69%	20.51%
Other	28	19	35
	71.79%	48.72%	89.74%
Percent of farms with only one product =		***56.41%***	
Percent of farms with multiple products =		***43.59%***	

[109] Primary product refers to species that represent the highest percentage of reported sales.
[110] Single product operation refers to species that represent 100% of reported sales.
[111] Produce some refers to species that represent some percentage of reported sales (1% to 100%).

Table A5-5. Hatchery Producers' Opinions Regarding Cryopreservation Services[112].

Question	Definitely	Maybe	Not Sure	Probably Not	Definitely Not	Total	Mean	St. dev.
Would you be willing to utilize a service that meant you only had tocollect, or maintain, male broodstock once every five years?	3 6.38%	12 25.53%	6 12.77%	17 36.17%	9 19.15%	47 100.00%	1.6383	1.2411
If you produce non-hybrids, would you be willing to try a new cost-effective way to produce hybrids or crossbreeds? (Bass, catfish, etc.) (Please skip to next question if you produce only hybrids)	3 7.69%	10 25.64%	6 15.38%	9 23.08%	11 28.21%	39 100.00%	1.6154	1.3498
Would you be willing to pay for a service that meant you could selectively breed your product by using the sperm from the best males of a particular species?	4 8.70%	11 23.91%	8 17.39%	11 23.91%	12 26.09%	46 100.00%	1.6522	1.337
Assume there was a service that would freeze the sperm of your fish, store it until you were ready to fertilize your eggs, and then transport it to you. Would you be willing to pay the storage and processing costs that are required to maintain this service throughout the year?	2 4.17%	11 22.92%	9 18.75%	11 22.92%	15 31.25%	48 100.00%	1.4583	1.2709

[112] Results are from Question 9 of the survey.

Table A5-6. Knowledge Regarding Cryopreservation[113].

Statement	Yes	No	Don't Know	Total	Mean	St. dev.
Cryopreservation allows sperm to be frozen, stored indefinitely, and later used for fertilization of fresh eggs.	32 65.31%	2 4.08%	15 30.61%	49 100.00%	1.6122	0.5707
Use of cryopreserved sperm totally eliminates the need for male broodstock.	3 6.12%	34 69.39%	12 24.49%	49 100.00%	0.3673	0.6019
Cryopreservation is an integral part of the dairy industry.	28 57.14%	2 4.08%	19 38.78%	49 100.00%	1.5306	0.5810
Cryopreservation techniques are currently being commercially utilized within aquaculture industries.	16 33.33%	2 4.17%	30 62.50%	48 100.00%	1.2917	0.5442
Cryopreservation will help to establish genetic lines within aquatic species.	27 55.10%	1 2.04%	21 42.86%	49 100.00%	1.5306	0.5440
Cryopreservation is a new technique, developed in the last five years, and there is little known about its benefits.	2 4.17%	22 45.83%	24 50.00%	48 100.00%	0.5833	0.5774
Genetic improvement can be accomplished through cryopreservation of sperm.	26 53.06%	4 8.16%	19 38.78%	49 100.00%	1.4490	0.6475
The cryopreservation of sperm increases the risk of an invasive species entering an area.	6 12.24%	25 51.02%	18 36.73%	49 100.00%	0.6122	0.7017

[113] Results are from Question 10 of the survey.

Table A5-7. Attitudes Towards Cryopreservation And Genetic Improvement[114].

Statement	Strongly Against	Slightly Against	No Position	Slightly In Favor	Strongly In Favor	Total	Mean	St. dev.
The establishment of new genetic lines in aquatic species.	1 2.04%	8 16.33%	16 32.65%	9 18.37%	15 30.61%	49 100.00%	2.5918	1.1532
The adoption of new technology.	0 0.00%	0 0.00%	4 8.16%	13 26.53%	32 65.31%	49 100.00%	3.5714	0.6455
The termination of all research regarding the genetic improvement of animals.	35 72.92%	3 6.25%	9 18.75%	0 0.00%	1 2.08%	48 100.00%	0.5208	0.9451
Government regulations placed on all cryopreserved sperm sales.	14 28.57%	4 8.16%	23 46.94%	6 12.24%	2 4.08%	49 100.00%	1.5510	1.1558
The practice of cryopreserving sperm.	1 2.04%	0 0.00%	16 32.65%	16 32.65%	16 32.65%	49 100.00%	2.9388	0.9221

[114] This is a summation of the responses to Question 38 of the survey.

Table A5-8. Opinions Regarding Cryopreservation[115].

Statement	Strongly Disagree	Somewhat Disagree	No Opinion	Somewhat Agree	Strongly Agree	Total	Mean	St. dev.
Cryopreservation is a form of biotechnology.	0 0.00%	4 8.51%	7 14.89%	13 27.66%	23 48.94%	47 100.00%	3.1702	0.9851
Cryopreservation should be used to preserve the loss of genetic lines, as well as create new ones.	0 0.00%	1 2.04%	10 20.41%	20 40.82%	18 36.73%	49 100.00%	3.1224	0.8071
The freezing of sperm will alter the genetic makeup of the sperm and offspring that are produced.	18 36.73%	9 18.37%	21 42.86%	0 0.00%	1 2.04%	49 100.00%	1.1224	0.9923
Cryopreservation services can help to maintain biodiversity in aquatic species.	1 2.04%	4 8.16%	13 26.53%	16 32.65%	15 30.61%	49 100.00%	2.8163	1.0342
Cryopreservation is an immoral practice.	26 53.06%	7 14.29%	13 26.53%	2 4.08%	1 2.04%	49 100.00%	0.8776	1.0730
Cryopreservation will become an integral part of the overall aquaculture industry within the next five years.	1 2.04%	11 22.45%	20 40.82%	14 28.57%	3 6.12%	49 100.00%	2.1429	0.9129
The ability to store sperm for upcoming years is important to my business.	12 25.00%	9 18.75%	17 35.42%	6 12.50%	4 8.33%	48 100.00%	1.6042	1.2332
I would incorporate cryopreservation services into my existing operation if they were available.	13 26.53%	8 16.33%	19 38.78%	5 10.20%	4 8.16%	49 100.00%	1.5714	1.2247

[115] Results are from Question 39 of the survey.

APPENDIX VI. DESCRIPTIVE STATISTICS FOR RESPONDENTS WITH ONLY GROW-OUT OPERATIONS

Table A6-1. Summary Statistics For Respondents With Only Grow-out Operations.

Variable	Number of Respondents	% of Respondents	Mean	St.dev.
Grow-out Operations				
Yes = 1	35	100.00%		
No = 0	0	0.00%	1.0000	0.0000
Total	**35**	**100.00%**		
Purchased more than 50% of fingerling stock last year				
Yes = 1	20	57.14%		
No = 0	15	42.86%	0.5714	0.5021
Total	**35**	**100.00%**		
Average size of fingerlings purchased				
1-2 inch = 0	4	20.00%		
3-4 inch = 1	9	45.00%		
5-6 inch = 2	6	30.00%	1.2000	0.8335
7-9 inch = 3	1	5.00%		
Total =	**20**	100.00%		
Methods utilized for on-site fingerling maintenance (% of 35)				
Pond	16	45.71%		
Flow-through	15	42.86%		
Net pens/Cages	2	5.71%		
Closed re-circulation	7	20.00%		
Other	0	0.00%		
Average weight of foodfish sold				
<1 pound = 0	8	25.00%		
1-2 pounds = 1	15	46.88%		
2-3 pounds = 2	7	21.88%	1.0934	0.8561
3-4 pounds = 3	2	6.25%		
>4 pounds = 4	0	0.00%		
Total =	**32**	**100.00%**		
Willing to pay for genetically uniform fingerlings				
Yes = 1	20	58.82%		
No = 0	14	41.18%	0.5882	0.4996
Total	**34**	**100.00%**		
Mean maximum W.T.P.			23.1579	21.3574
Willing to pay for supply reliability				
Yes = 1	10	31.25%		
No = 0	22	68.75%	0.3125	0.4709
Total	**32**	**100.00%**		
Mean maximum W.T.P.			28.0000	25.7337

Table A6-1. (cont.)

Choice set 1				
Option A	10			
Option B	8			
Option C	12			
Choice set 2				
Option A	6			
Option B	9			
Option C	16			
Public or Private Operation				
Public = 0	3	8.57%		
Private = 1	32	91.43%	0.9143	0.2840
Both = 2	0	0.00%		
Total	**35**	**100.00%**		
Employees				
< 10 = 0	34	97.14%		
10 to 50 = 1	1	2.86%		
51 to 150 = 2	0	0.00%	0.0286	0.1690
> 150 = 3	0	0.00%		
Total	**35**	**100.00%**		
# of Years				
			0.2079	0.1869
Gross Sales				
< $2,500 = 0	2	6.45%		
$2,500-$9,999 = 1	1	3.23%		
$10,000-$49,999 = 2	5	16.13%		
$50,000-$249,999 = 3	11	35.48%		
$250,000-$999,999 = 4	12	38.71%	2.9677	1.1397
$1 million-$4,999,999 = 5	0	0.00%		
$5 million or more = 6	0	0.00%		
Total	**31**	**100.00%**		
Education				
Less than high school = 0	1	2.86%		
High school diploma or GED = 1	5	14.29%		
Some college/technical school = 2	11	31.43%		
Bachelor’s degree = 3	10	28.57%	2.5429	1.0939
Advanced degree = 4	8	22.86%		
Total	**35**	**100.00%**		
Age				
18-25 = 0	0	0.00%		
26-35 = 1	5	14.71%		
36-45 = 2	8	23.53%		
46-60 = 3	18	52.94%	2.5588	0.8596
> 60 = 4	3	8.82%		
Total	**34**	**100.00%**		

Table A6-2. Technology Adopted Within The Last Five Years[116].

Variable		Number of Respondents	% of Respondents	Mean	St.dev.
1) Remote monitoring					
	Yes = 1	7	21.88%		
	No = 0	25	78.13%	0.2188	0.4200
	Total	**32**	**100.00%**		
2) PAS					
	Yes = 1	0	0.00%		
	No = 0	32	100.00%	0.0000	0.0000
	Total	**32**	**100.00%**		
3) Internet					
	Yes = 1	19	59.38%		
	No = 0	13	40.63%	0.5938	0.4990
	Total	**32**	**100.00%**		
4) GIS					
	Yes = 1	0	0.00%		
	No = 0	32	100.00%	0.0000	0.0000
	Total	**32**	**100.00%**		
5) Monitering & control					
	Yes = 1	8	25.00%		
	No = 0	24	75.00%	0.2500	0.4399
	Total	**32**	**100.00%**		

[116] Results are from Question 36.

Table A6-3. Ranking Of Potential Benefits Of Cryopreservation Services[117].

Variable		Number of Respondents	% of Respondents	Mean	St.dev.
1) Genetic Control					
	1	0	0.00%		
	2	7	22.58%		
	3	6	19.35%	3.3548	0.8386
	4	18	58.06%		
	Total	**31**	**100.00%**		
2) Production Costs					
	1	15	48.39%		
	2	13	41.94%		
	3	1	3.23%	1.6774	0.8321
	4	2	6.45%		
	Total	**31**	**100.00%**		
3) Production Risks					
	1	11	35.48%		
	2	10	32.26%		
	3	8	25.81%	2.0322	0.9481
	4	2	6.45%		
	Total	**31**	**100.00%**		
4) Improved Product					
	1	6	19.35%		
	2	3	9.68%		
	3	14	45.16%	2.7742	1.0555
	4	8	25.81%		
	Total	**31**	**100.00%**		

[117] Results are from Question 37 of the survey.

Table A6-4. Grow-out Product Distribution For Farms With Only Grow-out Operations.

35 respondents reported species totals
% of the 35 respondents

	Primary Product[118]	Single Product Operation[119]	Produce Some[120]
Channel Catfish	10	9	11
	28.57%	25.71%	31.43%
Hybrid Striped Bass	6	2	8
	17.14%	5.71%	22.86%
Tilapia	2	2	4
	5.71%	5.71%	11.43%
Atlantic Salmon	0	0	0
	0.00%	0.00%	0.00%
Rainbow Trout	14	11	15
	40.00%	31.43%	42.86%
Other	3	2	6
	8.57%	5.71%	17.14%
Percent of farms with only one product =		***74.29%***	
Percent of farms with multiple products =		***25.71%***	

118 Primary product refers to species that represent the highest percentage of reported sales.
119 Single product operation refers to species that represent 100% of reported sales.
120 Produce some refers to species that represent some percentage of reported sales (1% to 100%).

Table A6-5. Attitudes Towards Cryopreservation And Genetic Improvement[121].

Statement	Strongly Against	Slightly Against	No Position	Slightly In Favor	Strongly In Favor	Total	Mean	St. dev.
The establishment of new genetic lines in aquatic species.	0 0.00%	3 9.09%	11 33.33%	7 21.21%	12 36.36%	33 100.00%	2.8485	1.0344
The adoption of new technology.	0 0.00%	0 0.00%	3 9.38%	14 43.75%	15 46.88%	32 100.00%	3.3750	0.6599
The termination of all research regarding the genetic improvement of animals.	18 58.06%	0 0.00%	11 35.48%	2 6.45%	0 0.00%	31 100.00%	0.9032	1.1062
Government regulations placed on all cryopreserved sperm sales.	13 41.94%	5 16.13%	11 35.48%	1 3.23%	1 3.23%	31 100.00%	1.0968	1.1062
The practice of cryopreserving sperm.	0 0.00%	2 6.25%	18 56.25%	7 21.88%	5 15.63%	32 100.00%	2.4688	0.8418

[121] This is a summation of the responses to Question 38 of the survey.

Table A6-6. Opinions Regarding Cryopreservation[122].

Statement	Strongly Disagree	Somewhat Disagree	No Opinion	Somewhat Agree	Strongly Agree	Total	Mean	St. dev.
Cryopreservation is a form of biotechnology.	0 0.00%	4 12.50%	6 18.75%	13 40.63%	9 28.13%	32 100.00%	2.8438	0.9873
Cryopreservation should be used to preserve the loss of genetic lines, as well as create new ones.	0 0.00%	2 6.45%	7 22.58%	12 38.71%	10 32.26%	31 100.00%	2.9677	0.9123
The freezing of sperm will alter the genetic makeup of the sperm and offspring that are produced.	7 21.88%	6 18.75%	15 46.88%	3 9.38%	1 3.13%	32 100.00%	1.5313	1.0468
Cryopreservation services can help to maintain biodiversity in aquatic species.	0 0.00%	2 6.25%	9 28.13%	13 40.63%	8 25.00%	32 100.00%	2.8438	0.8839
Cryopreservation is an immoral practice.	13 40.63%	9 28.13%	10 31.25%	0 0.00%	0 0.00%	32 100.00%	0.9063	0.8561
Cryopreservation will become an integral part of the overall aquaculture industry within the next five years.	0 0.00%	4 12.50%	18 56.25%	8 25.00%	2 6.25%	32 100.00%	2.2500	0.7620
The ability to store sperm for upcoming years is important to my business.	5 15.63%	6 18.75%	13 40.63%	8 25.00%	0 0.00%	32 100.00%	1.7500	1.0160
I would incorporate cryopreservation services into my existing operation if they were available.	3 9.38%	3 9.38%	21 65.63%	5 15.63%	0 0.00%	32 100.00%	1.8750	0.7931

[122] Results are from Question 39 of the survey.

APPENDIX VII. DESCRIPTIVE STATISTICS FOR RESPONDENTS WITH ONLY DEMOGRAPHIC INFORMATION

Table A7-1. Summary Statistics For Respondents With Only Demographic Information.

Variable		Number of Respondents	% of Respondents	Mean	St.dev.
Total Number of Respondents		**26**	**100.00%**		
Public or Private Operation					
	Public = 0	6	23.08%		
	Private = 1	20	76.92%	0.7692	0.4297
	Both = 2	0	0.00%		
	Total	**26**	**100.00%**		
Employees					
	< 10 = 0	25	96.15%		
	10 to 50 = 1	1	3.85%		
	51 to 150 = 2	0	0.00%	0.0385	0.1961
	> 150 = 3	0	0.00%		
	Total	**26**	**100.00%**		
# of Years					
				27.1600	15.4021
Gross Sales					
	< $2,500 = 0	3	13.64%		
	$2,500-$9,999 = 1	1	4.55%		
	$10,000-$49,999 = 2	6	27.27%		
	$50,000-$249,999 = 3	7	31.82%		
	$250,000-$999,999 = 4	4	18.18%	2.5000	1.3715
	$1 million-$4,999,999 = 5	1	4.55%		
	$5 million or more = 6	0	0.00%		
	Total	**22**	**100.00%**		
Education					
	Less than high school = 0	0	0.00%		
	High school diploma or GED = 1	7	26.92%		
	Some college/technical school = 2	8	30.77%		
	Bachelor's degree = 3	10	38.46%	2.1923	0.8953
	Advanced degree = 4	1	3.85%		
	Total	**26**	**100.00%**		
Age					
	18-25 = 0	0	0.00%		
	26-35 = 1	1	3.85%		
	36-45 = 2	7	26.92%		
	46-60 = 3	14	53.85%	2.8077	0.7494
	> 60 = 4	4	15.38%		
	Total	**26**	**100.00%**		

Table A7-2. Technology Adopted Within The Last Five Years[123].

Variable		Number of Respondents	% of Respondents	Mean	St.dev.
1) Remote monitoring					
	Yes = 1	1	3.85%		
	No = 0	25	96.15%	0.0385	0.1961
	Total	**26**	**100.00%**		
2) PAS					
	Yes = 1	0	0.00%		
	No = 0	26	100.00%	0.0000	0.0000
	Total	**26**	**100.00%**		
3) Internet					
	Yes = 1	16	61.54%		
	No = 0	10	38.46%	0.6154	0.4961
	Total	**26**	**100.00%**		
4) GIS					
	Yes = 1	0	0.00%		
	No = 0	26	100.00%	0.0000	0.0000
	Total	**26**	**100.00%**		
5) Monitering & control					
	Yes = 1	2	7.69%		
	No = 0	24	92.31%	0.0769	0.2717
	Total	**26**	**100.00%**		

[123] Results are from Question 36.

Table A7-3. Ranking Of Potential Benefits Of Cryopreservation Services[124].

Variable		Number of Respondents	% of Respondents	mean	St.dev.
1) Genetic Control					
	1	5	23.81%		
	2	1	4.76%		
	3	4	19.05%	3.0000	1.2649
	4	11	52.38%		
	Total	**21**	**100.00%**		
2) Production Costs					
	1	11	52.38%		
	2	8	38.10%		
	3	1	4.76%	1.6190	0.8047
	4	1	4.76%		
	Total	**21**	**100.00%**		
3) Production Risks					
	1	3	14.29%		
	2	5	23.81%		
	3	9	42.86%	2.6667	0.9661
	4	4	19.05%		
	Total	**21**	**100.00%**		
4) Improved Product					
	1	8	38.10%		
	2	5	23.81%		
	3	5	23.81%	2.1429	1.1084
	4	3	14.29%		
	Total	**21**	**100.00%**		

[124] Results are from Question 37 of the survey.

Table A7-4. Attitudes Towards Cryopreservation And Genetic Improvement[125].

Statement	Strongly Against	Slightly Against	No Position	Slightly In Favor	Strongly In Favor	Total	Mean	St. dev.
The establishment of new genetic lines in aquatic species.	3 11.54%	3 11.54%	7 26.92%	8 30.77%	5 19.23%	26 100.00%	2.3462	1.2631
The adoption of new technology.	1 3.85%	1 3.85%	6 23.08%	7 26.92%	11 42.31%	26 100.00%	3.0000	1.0954
The termination of all research regarding the genetic improvement of animals.	7 26.92%	6 23.08%	10 38.46%	2 7.69%	1 3.85%	26 100.00%	1.3846	1.0983
Government regulations placed on all cryopreserved sperm sales.	3 11.54%	3 11.54%	17 65.38%	2 7.69%	1 3.85%	26 100.00%	1.8077	0.8953
The practice of cryopreserving sperm.	0 0.00%	2 7.69%	16 61.54%	2 7.69%	6 23.08%	26 100.00%	2.4615	0.9479

[125] This is a summation of the responses to Question 38 of the survey.

Table A7-5. Opinions Regarding Cryopreservation[126].

Statement	Strongly Disagree	Somewhat Disagree	No Opinion	Somewhat Agree	Strongly Agree	Total	Mean	St. dev.
Cryopreservation is a form of biotechnology.	0 0.00%	2 8.33%	10 41.67%	8 33.33%	4 16.67%	24 100.00%	2.5833	0.8805
Cryopreservation should be used to preserve the loss of genetic lines, as well as create new ones.	2 7.69%	1 3.85%	9 34.62%	10 38.46%	4 15.38%	26 100.00%	2.5000	1.0677
The freezing of sperm will alter the genetic makeup of the sperm and offspring that are produced.	4 16.00%	5 20.00%	16 64.00%	0 0.00%	0 0.00%	25 100.00%	1.4800	0.7703
Cryopreservation services can help to maintain biodiversity in aquatic species.	0 0.00%	1 4.00%	10 40.00%	9 36.00%	5 20.00%	25 100.00%	2.7200	0.8426
Cryopreservation is an immoral practice.	8 32.00%	4 16.00%	11 44.00%	2 8.00%	0 0.00%	25 100.00%	1.2800	1.0214
Cryopreservation will become an integral part of the overall aquaculture industry within the next five years.	3 12.00%	3 12.00%	13 52.00%	5 20.00%	1 4.00%	25 100.00%	1.9200	0.9967
The ability to store sperm for upcoming years is important to my business.	7 28.00%	4 16.00%	12 48.00%	1 4.00%	1 4.00%	25 100.00%	1.4000	1.0801
I would incorporate cryopreservation services into my existing operation if they were available.	4 16.67%	4 16.67%	15 62.50%	1 4.17%	0 0.00%	24 100.00%	1.5417	0.8330

[126] Results are from Question 39 of the survey.

APPENDIX VIII. SURVEY COVER LETTERS

Department of Agricultural Economics and Agribusiness
101 Agricultural Administration Building
Louisiana State University
Baton Rouge, LA 70803-5604
(225) 578-3282
(225) 578-2716

June 15, 2005

Dear Aquaculture Producer:

The Louisiana State University Agricultural Center is conducting a study to identify potential markets for a sperm cryopreservation service for aquaculture industries. The cryopreservation service has the potential to improve the genetic make-up of fingerlings, which will benefit grow-out operations, as well as improve the efficiency of hatchery operations. The service would freeze sperm from your brood fish, store it until you are ready to fertilize your eggs, transport it to you, and provide technical support regarding artificial spawning using the frozen sperm. As an important stakeholder in the U.S. aquaculture industry, we need your help for our study to be successful.

We would appreciate it if the general manager of your operation could please take a few minutes to complete the enclosed questionnaire and return it in the postage-paid envelope. All of the responses are **completely confidential** and names of specific companies will not be recorded.

The results of our study will enable hatcheries to provide grow-out producers with products that have the most desired genetic traits, such as an increased growth rate, an increased resistance to disease, and others. If you have any questions or comments regarding this survey, or simply require more information, please feel free to call or e-mail either of the contacts below.

Thank you for your help with this important study.

Sincerely,

Dr. R. Wes Harrison
Associate Professor
(225) 578-2727
wharrison@agctr.lsu.edu

Brian Boever
Graduate Research Assistant
(225) 578-8579
bboeve1@lsu.edu

Department of Agricultural Economics and Agribusiness
101 Agricultural Administration Building
Louisiana State University
Baton Rouge, LA 70803-5604
(225) 578-3282
(225) 578-2716

July 8, 2005

Dear Aquaculture Producer:

About three weeks ago, a questionnaire seeking information about a sperm cryopreservation service for aquaculture industries was sent to you. The Louisiana State University Agricultural Center is conducting this study in order to identify the potential markets for these services. Cryopreservation techniques have the potential to improve the genetic make-up of fingerlings, which will benefit grow-out operations, as well as improve the efficiency of hatchery operations. The service would freeze sperm from your brood fish, store it until you are ready to fertilize your eggs, transport it to you, and provide technical support regarding artificial spawning using the frozen sperm.

As of today, we have not yet received your completed questionnaire. Your participation, as an important stakeholder in the U.S. aquaculture industry, is extremely important for our study to be successful.

If you have recently completed and returned the survey, we thank you for your participation. If not, we have enclosed another copy for your convenience. We would appreciate it if the general manager of your operation could please take a few minutes to complete the questionnaire and return it in the postage-paid envelope. All of the responses are **completely confidential** and names of specific companies will not be recorded.

If you have any questions or comments regarding this survey please call or e-mail either of the contacts below.

Thank you for your help with this important study.

Sincerely,

Dr. R. Wes Harrison
Associate Professor
(225) 578-2727
wharrison@agctr.lsu.edu

Brian Boever
Graduate Research Assistant
(225) 578-8579
bboeve1@lsu.edu

Department of Agricultural Economics and Agribusiness
101 Agricultural Administration Building
Louisiana State University
Baton Rouge, LA 70803-5604
Phone: (225) 578-3282
Fax: (225) 578-2716

August 15, 2005

Dear Aquaculture Producer:

About four weeks ago, a questionnaire seeking information about a sperm cryopreservation service for aquaculture industries was sent to you. As of today, we have not yet received your completed questionnaire. Therefore we are requesting one final time for your participation. **We have enclosed a copy of the questionnaire in Microsoft Word format as an attachment to this e-mail so that you can complete electronically or print out and complete by hand.** The electronic questionnaire is completely interactive and we would appreciate it if the general manager of your operation could please take a few minutes to complete and return it to us.

To complete electronically: Simply open the attached file, fill it out by clicking the desired boxes, save the file, and "Reply" to this e-mail with the completed questionnaire as an attachment.

To complete by hand: Print the Word file, complete the questionnaire, and either fax or mail it to Wes Harrison at the address in the letter head.

Your participation, as an important stakeholder in the U.S. aquaculture industry, is extremely important for our study to be successful. If you have recently completed and returned the survey, we thank you for your participation. All of the responses are **completely confidential** and names of specific companies will not be recorded.

The Louisiana State University Agricultural Center is conducting this study in order to identify the potential markets for these services. Cryopreservation techniques have the potential to improve the genetic make-up of fingerlings, which will benefit grow-out operations, as well as improve the efficiency of hatchery operations.

If you have any questions or comments regarding this survey please call or e-mail either of the contacts below.

Thank you for your help with this important study.

Sincerely,

Dr. R. Wes Harrison
Associate Professor
(225) 578-2727
wharrison@agctr.lsu.edu

Brian Boever
Graduate Research Assistant
(225) 578-8579
bboeve1@lsu.edu

Dear Aquaculture Producer:

About four weeks ago, a questionnaire regarding a sperm cryopreservation service for aquaculture industries was sent to you. As of today, we have not yet received your completed questionnaire.

It is extremely important that you participate in the study so that our results are a true representation of the aquaculture industry. Therefore we are asking one final time for your help. Please complete and return your questionnaire today.

If by some chance you did not receive the questionnaire, or it has been misplaced, please call or e-mail us and another will be sent to you immediately. We would also be pleased to send you an electronic copy of the questionnaire. Please e-mail either of us and we will send you an electronic copy immediately.

Sincerely,

Dr. R. Wes Harrison
Associate Professor
(225) 578-2727
wharrison@agctr.lsu.edu

Brian Boever
Graduate Research Assistant
(225) 578-8579
bboeve1@lsu.edu

APPENDIX IX. SPECIES COMBINATIONS

Table AIX-1. Farms With Species Combinations for Hatchery Production[127].

	Channel catfish	HSB	Tilapia	Atlantic salmon	Rainbow trout	Other
Channel catfish	.	1	1	0	1	13
Hybrid striped bass	1	.	1	0	0	5
Tilapia	1	1	.	0	0	3
Atlantic salmon	0	0	0	.	0	0
Rainbow trout	1	0	0	0	.	8
Other	13	5	3	0	8	.

Table AIX-2. Farms With Species Combinations for Grow-out Production[128].

	Channel catfish	HSB	Tilapia	Atlantic salmon	Rainbow trout	Other
Channel catfish	.	2	0	0	1	4
Hybrid striped bass	2	.	3	0	1	3
Tilapia	0	3	.	0	0	1
Atlantic salmon	0	0	0	.	0	0
Rainbow trout	1	1	0	0	.	7
Other	4	3	1	0	7	.

[127] Numbers based on a farm producing any amount at all of the species.
[128] Based on a farm producing any amount at all of the species.

APPENDIX X. SURVEY VERSION 1

A Survey of Aquaculture Producer Preferences For Sperm Cryopreservation and Genetic Improvement

Louisiana State University

Department of Agricultural Economics and Agribusiness
and
Aquaculture Research Station[1]

Your answers are completely confidential. Please do not write the name of your company on the questionnaire.

Thank you for your time.

1. Does your farm have spawning operations? (Please mark the appropriate box)

☐ Yes **(If yes, please go to question 2)** ☐ No **(If no, please skip to question 11 on page 2)**

Section 1 - Spawning Operations
Questions 2 – 11

2. Please indicate the percentage of gross sales that each species contributes to your total spawning operation. (Total should sum to 100%)

Channel catfish ______ Hybrid striped bass ______ Tilapia _____

Atlantic salmon ______ Rainbow trout ______ Other _____

If other, please specify type(s) ____

Please base answers for questions 3 - 9 on the species you assigned the highest percentage in question 2.

3. How do you obtain your broodstock? (Please mark all that apply)

☐ Maintain on site throughout the year

a. Which type of facility do you use to maintain your broodstock? (Please mark all boxes that apply)

☐ Ponds ☐ Flow-through systems ☐ Net pens or cages ☐ Closed re-circulation tanks

If other, please specify ____

☐ Collect from the wild

a. How many days are typically involved in collecting broodstock each season? __________

☐ Purchase

☐ Other (Please specify) ____

4. Which type of spawning method do you use? (Please mark appropriate box)

☐ Natural **(Please skip to question 7)**

☐ Artificial **(Please go to question 5)**

5. Approximately how many total labor hours are needed for the handling and transportation of fish during the artificial spawning process? __________

6. What percent of eggs are typically fertilized during artificial spawning? (Please mark only one box)

☐ = 20% ☐ 21 – 40% ☐ 41 – 60% ☐ 61 – 80% ☐ 81 – 100%

7. How many fry/fingerlings did you produce last year? (Approximate number of fish) __________

8. Are you currently utilizing selective breeding techniques? (Select one)

☐ Yes ☐ No

9. Please read the following questions and select the answer that most closely represents your **opinion**. (Please check ✓ appropriate box)

Question	**Definitely**	**Maybe**	**Not Sure**	**Probably Not**	**Definitely Not**
Would you be willing to utilize a service that meant you only had to collect, or maintain, male broodstock once every five years?					
If you produce non-hybrids, would you be willing to try a new cost-effective way to produce hybrids or crossbreeds? (Bass, catfish, etc.) (Please skip to next question if you produce only hybrids)					
Would you be willing to pay for a service that meant you could selectively breed your product by using the sperm from the best males of a particular species?					
Assume there was a service that would freeze the sperm of your fish, store it until you were ready to fertilize your eggs, and then transport it to you. Would you be willing to pay the storage and processing costs that are required to maintain this service throughout the year?					

10. Please indicate whether or not you **agree** with the following statements. (Please check ✓ appropriate box)

Statement	**Yes**	**No**	**Don't Know**
Cryopreservation allows sperm to be frozen, stored indefinitely, and later used for fertilization of fresh eggs.			
Use of cryopreserved sperm totally eliminates the need for male broodstock.			
Cryopreservation is an integral part of the dairy industry.			
Cryopreservation techniques are currently being commercially utilized within aquaculture industries.			
Cryopreservation will help to establish genetic lines within aquatic species.			
Cryopreservation is a new technique, developed in the last five years, and there is little known about its benefits.			
Genetic improvement can be accomplished through cryopreservation of sperm.			
The cryopreservation of sperm increases the risk of an invasive species entering an area.			

11. Does your farm have foodfish grow-out operations?

☐ Yes **(If yes, please go to question 12)**

☐ No **(If no, please skip to question 30 on page 6)**

Section 2 - Foodfish Grow-out Operations
Questions 12 – 29

12. Please indicate the percentage of gross sales that each species contributes to your total foodfish grow-out operation. (Total should sum to 100%)

Channel catfish ______ Hybrid striped bass ______ Tilapia _____

Atlantic salmon ______ Rainbow trout ______ Other _____

If other, please specify type(s) ____

Please base answers for questions 13 - 29 on the species you assigned the highest percentage in question 12.

13. Did you purchase more than 50% of your fingerling stock last year?

☐ Yes **(If yes, please go to question 14)**
☐ No **(If no, please skip to question 17)**

14. Approximately how many fingerlings did you purchase last year? ___________

15. What size fingerlings, on average, did you purchase last year? (Select one)

☐ 1-2 inch ☐ 3-4 inch ☐ 5-6 inch ☐ 7-9 inch

16. How much, on average, did you pay per fingerling last year? $___________

17. How much did you spend last year on feed for your foodfish? $___________

18. In which type of facility are your fingerlings stocked? (Please mark all boxes that apply)

☐ Ponds ☐ Flow-through systems ☐ Net pens or cages ☐ Closed re-circulation tanks

If other, please specify ____

19. What was the average individual weight of the foodfish you sold last season? (Select one)

☐ < 1 pound ☐ 1-2 pounds ☐ 2-3 pounds ☐ 3-4 pounds ☐ > 4 pounds

Willingness to Pay

The following section contains questions about genetic uniformity and supply reliability. Genetic uniformity refers to stocks that are uniform in their genetic makeup. Supply reliability refers to lower probabilities of supply shortages for desired fish stocks.

Assume that you could purchase fingerlings that are more uniform in their **genetic** makeup. That is, variations in size, color, and yield would be minimized across fish. This means a more reliable and consistent product when the time comes to sell your foodfish to processors.

20. Would you be willing to pay a premium for **genetically uniform** fingerlings?

☐ Yes **(If yes, please go to question 21)**
☐ No **(If no, please skip to question 24)**

21. What is the maximum amount, above your current price, that you would be willing to pay, per fingerling, for **genetically uniform** fingerlings? (Select one)

☐ 10%	☐ 30%	☐ 50%	☐ 70%	☐ 90%
☐ 20%	☐ 40%	☐ 60%	☐ 80%	☐ 100%

22. On a scale of 1 to 10 (where 1 represents being 10% sure and 10 represents being 100% sure), how certain are you that you would pay the price you stated above? (Circle one)

1 2 3 4 5 6 7 8 9 10

Less certain ———————————— Very certain

23. If you selected a number less than 8 in question 22, please write in the maximum percentage increase above your current price that you would be at least 80% certain of paying. ____________

Assume that each year you could **reliably** obtain your supply of fingerlings throughout the female spawning season, therefore, the **uncertainty** of not being able to purchase, or produce, your desired amount of fingerlings would be greatly reduced.

24. Would you be willing to pay a premium for greater **reliability** in the supply of fingerlings?

☐ Yes **(If yes, please go to question 25)**

☐ No **(If no, please skip to "*Grower Preferences*" at the bottom of this page)**

25. What is the maximum amount, above your current price, that you would be willing to pay, per fingerling, for this **supply reliability**? (Select one)

☐ 10%	☐ 30%	☐ 50%	☐ 70%	☐ 90%
☐ 20%	☐ 40%	☐ 60%	☐ 80%	☐ 100%

26. On a scale of 1 to 10 (where 1 represents being 10% sure and 10 represents being 100% sure), how certain are you that you would pay the price you stated above? (Circle one)

1 2 3 4 5 6 7 8 9 10

Less certain ———————————— Very certain

27. If you selected a number less than 8 in question 26, please write in the maximum percentage increase above your current price that you would be at least 80% certain of paying. ____________

Grower Preferences

For questions 28 & 29, please review each table. Each table consists of two options, each of which contains a set of specific genetic attributes for a hypothetical fish stock. The genetic attributes vary based on growth rate, disease resistance, resistance to lower dissolved oxygen levels, and price. The attributes are defined as follows:

*"Growth rate" is expressed as being at your **current** level, **10% better** than your current level, or **20% better** than your current level.*

*"Disease resistance," which refers to the ability of the fish stock to defend against deaths related to disease outbreaks, is expressed as being at the **current** level, a **10% increase**, or a **20% increase** to the current level.*

*The attribute "Resistance to 10% lower dissolved oxygen levels" refers to the ability of the fish stock to tolerate 10% lower levels of dissolved oxygen within the water supply without dying. This attribute is either present (**Yes**) in the fish stock, or it is not present (**Current**).*

*The "Price premium" attribute is expressed as the price that you would pay above your current fingerling price – the levels are **20%**, **40%**, and **60%.***

Options "A" and "B" represent hypothetical fingerling stocks which are made up of the specific genetic characteristics listed below them. Please check the letter that indicates your **preferred option in each set**. If neither option is preferable, or if you prefer your current fish stock to either options "A" or "B," then select the "Neither" option under the table.

Choice Set 1

Attribute	Option A	Option B
Growth rate	10% better	Current
Disease resistance	Current	10% increase
Resistance to 10% lower dissolved oxygen levels	Yes	Yes
Price premium	20%	40%

28. Please indicate the option that you would select if these products were made available to you in the marketplace. (Select one)

Option A ☐ **Option B** ☐ **Neither** ☐

Choice Set 2

Attribute	Option A	Option B
Growth rate	Current	20% better
Disease resistance	20% increase	20% increase
Resistance to 10% lower dissolved oxygen levels	Current	Yes
Price premium	20%	60%

29. Please indicate the option that you would select if these products were made available to you in the marketplace. (Select one)

Option A ☐ **Option B** ☐ **Neither** ☐

Please continue to question 30.

Section 3 – Demographic Information
Questions 30 – 39

Questions 30 – 39 apply to all aquaculture operations:

30. Is your operation a public (state or federal) organization or a privately owned commercial operation? (Select one)

☐ Public ☐ Private

31. How many people are **employed** full time by your operation? (Select one)

☐ < 10 ☐ 10 – 50 ☐ 51 – 150 ☐ > 150

32. Please indicate the number of **years** that your current operation has been in business. __________

33. What were the **total gross sales** of your entire operation last year? (Select one)

☐ < $2,500 ☐ $2,500 - $9,999 ☐ $10,000 - $49,999
☐ $50,000 - $249,999 ☐ $250,000 - $999,999 ☐ $1 million - $4,999,999
☐ $5 million or more

34. Please select the highest level of **education** achieved by the general manager. (Select one)

☐ Less than high school ☐ High school diploma or GED ☐ Some college/technical school
☐ Bachelor's degree ☐ Advanced degree (Master's, Ph.D, JD, M.D., etc.)

35. Please indicate the **age** of your general manager.

☐ 18 – 25 ☐ 26 – 35 ☐ 36 – 45 ☐ 46 – 60 ☐ > 60

36. Has your company incorporated any of the following technologies within the last **5** years? (Select all that apply)

☐ Remote monitoring ☐ Partitioned Aquaculture System (PAS)
☐ Internet usage ☐ Geographic Information Systems (GIS) based precision agriculture
☐ Automated monitoring and control systems

Opinions

37. The following is a list of potential benefits to aquaculture industries that can be achieved through the integration of cryopreservation services. Please rank them on a scale of 1 to 4 with 1 representing the most important benefit and 4 representing the least important.

____Increased genetic control ____Decreased production costs

____Decreased production risks ____Improved product

38. Please indicate your **attitude** concerning the following activities. (Please check ✓ appropriate box)

Statement	**Strongly In Favor**	**Slightly In Favor**	**No Position**	**Slightly Against**	**Strongly Against**
The establishment of new genetic lines in aquatic species.					
The adoption of new technology.					
The termination of all research regarding the genetic improvement of animals.					
Government regulations placed on all cryopreserved sperm sales.					
The practice of cryopreserving sperm.					

39. Please read the following statements and select the category that most closely represents your **opinion**. (Please check ✓ appropriate box)

Statement	**Strongly Agree**	**Somewhat Agree**	**No Opinion**	**Somewhat Disagree**	**Strongly Disagree**
Cryopreservation is a form of biotechnology.					
Cryopreservation should be used to preserve the loss of genetic lines, as well as create new ones.					
The freezing of sperm will alter the genetic makeup of the sperm and offspring that are produced.					
Cryopreservation services can help to maintain biodiversity in aquatic species.					
Cryopreservation is an immoral practice.					
Cryopreservation will become an integral part of the overall aquaculture industry within the next five years.					
The ability to store sperm for upcoming years is important to my business.					
I would incorporate cryopreservation services into my existing operation if they were available.					

Any additional comments may be made at the bottom of this page. Results will be made available upon your request.

Thank you for your time.

APPENDIX XI. CHOICE SETS FOR VERSION 2 & VERSION 3

Version 2

Choice Set 1

Attribute	Option A	Option B
Growth rate	10% better	20% better
Disease resistance	20% increase	10% increase
Resistance to 10% lower dissolved oxygen levels	Yes	Yes
Price premium	40%	20%

40. Please indicate the option that you would select if these products were made available to you in the marketplace. (Select one)

Option A ☐ **Option B** ☐ **Neither** ☐

Choice Set 2

Attribute	Option A	Option B
Growth rate	Current	10% better
Disease resistance	Current	10% increase
Resistance to 10% lower dissolved oxygen levels	Yes	Current
Price premium	60%	60%

41. Please indicate the option that you would select if these products were made available to you in the marketplace. (Select one)

Option A ☐ **Option B** ☐ **Neither** ☐

Version 3

Choice Set 1

Attribute	Option A	Option B
Growth rate	20% better	Current
Disease resistance	Current	20% increase
Resistance to 10% lower dissolved oxygen levels	Current	Yes
Price premium	40%	40%

42. Please indicate the option that you would select if these products were made available to you in the marketplace. (Select one)

Option A ☐ **Option B** ☐ **Neither** ☐

Choice Set 2

Attribute	Option A	Option B
Growth rate	Current	20% better
Disease resistance	10% increase	20% increase
Resistance to 10% lower dissolved oxygen levels	Yes	Current
Price premium	20%	60%

43. Please indicate the option that you would select if these products were made available to you in the marketplace. (Select one)

Option A ☐ **Option B** ☐ **Neither** ☐

APPENDIX XII. SCIENTIFIC NAMES OF SPECIES SPECIFIED IN THESIS

Table A12-1. Comparisons Of Scientific and Common Names For Species Cited In Thesis.

Common Name	**Scientific Name**
Channel catfish	*Ictalurus punctatus*
Blue catfish	*Ictalurus furcatus*
Hybrid catfish	*Ictalurus*
White bass	*Morone chrysops*
Striped bass	*Morone saxatilis*
Largemouth bass	*Micropterus salmoides*
Hybrid striped bass	*Morone*
Bluegill	*Lepomis macrochirus*
Rainbow trout	*Oncorhynchus mykiss*
Brown trout	*Salmo trutta*
Brook trout	*Salvelinus fontinalis*
Atlantic salmon	*Salmo salar*
Pacific salmon	*Oncorhynchus*
Coho salmon	*Oncorhynchus kisutch*
Nile tilapia	*Oreochromis niloticus*
Tilapia	*Oreochromis, Sarotherodon, and Tilapia*
Crawfish	*Procambarus clarkii*
Sturgeon	*Acipenser*
Yellow perch	*Perca flavescens*

Table A12-1. (cont.)

Walleye	*Sander vitreus*
Carp	*Cyprinus*
European eel	*Anguila anguila*
Soft-shelled crab	*Callinectes sapidus*
Abalone	*Haliotis*
Red drum	*Sciaenops ocellatus*
Whit Amur (Grass carp)	*Ctenopharyngodon idella*

VITA

Brian Boever was born January 6, 1981, in New Orleans, Louisiana. As he grew up, Brian played many sports and made some great friends. He completed his high school education in New Orleans. Brian attended Louisiana State University in the Fall of 1999. He completed his bachelor's degree in agricultural business in the Spring of 2003. Throughout his high school and undergraduate years, Brian worked at a sno-ball stand in New Orleans where he learned many skills, not the least of which was hard work.

At the completion of Brian's undergraduate degree, he applied for a research assistantship in the Department of Agricultural Economics and Agribusiness at Louisiana State University, which would allow him to work towards a master's degree in agricultural economics. Brian is completing this degree and expects to graduate in the Summer of 2006.