Willingness-to-Pay for Specific Genetic Improvements for Aquaculture Species

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Introduction

Whether consumers in the United States know it or not, approximately 30% of their seafood is being raised through aquaculture production (Harvey 2003). Aquaculture in the United Staes primarily consists of production of foodfish, ornamental fish, baitfish, mollusks, crustaceans, aquatic plants, and reptiles such as alligators and turtles (ERS 2003). Rapid growth has occurred within many aquaculture industries since the 1980s, resulting in a quadrupling of U.S. aquaculture production during that time. In 2005 the total value of U.S. aquaculture production was approximately $1.09 billion (2005 U.S. Census of Aquaculture). Foodfish production, which included catfish, trout, salmon, tilapia, hybrid striped bass, sturgeon, yellow perch, and walleye, made up approximately 60% of total sales (2005 U.S. Census of Aquaculture).

Despite the growth in U.S. aquaculture, a variety of challenges have emerged, for example, in production of channel catfish *Ictalurus punctatus* which is an important regional and national market. In 2007, nearly 500 million pounds were processed in the southeastern U.S., and prices paid to farmers ranged from $0.65 to $0.83 per pound (USDA NASS 2008). In the past few years, however, the industry has experienced a catastrophic reduction and continues to face severe challenges. Between 2001 and 2007 the number of fingerlings produced by the four major states (Mississippi, Arkansas, Alabama, and Louisiana) shrank by approximately 22% (USDA NASS 2008), and approximately 40,000 water-acres were taken out of production. The decrease in production is attributable to reduced profit margins from low prices paid to farmers, increased costs of fuel and feed ingredients, and increased foreign competition. Asian countries have become the predominant suppliers in global aquaculture markets, with China alone accounting for over 70% of the total volume of world aquaculture production, and close to 50% of the total world value (FAO 2004). Less expensive labor and an abundance of land suitable for aquaculture production has led to the emergence of global competition. Consequently, a major challenge for U.S. aquaculture is to remain competitive in domestic and global markets. One way to accomplish that is to develop and adopt new technologies and production systems that allow lower production costs. One approach with essentially unexploited potential to increase efficiency is to improve the genetic attributes of fish stocks. Greater control over genetics will allow producers to improve product consistency and lower production costs.

Accordingly, we sought to quantify the awareness and perceived value of the kinds of genetic improvement that could be made available through commercial-scale use of cryopreservation and development of markets for genetic resources within U.S. aquaculture. We employed a choice-based conjoint analysis to determine the importance of genetic improvements to grow-out producers and estimated willingness-to-pay for selected attributes.

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Cryopreservation and Genetics

The ability to selectively breed fish is a proven route to more profitable outcomes. The most obvious potential profits would be from improved fish stocks, resulting from the use of selected males. 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 populations.

The availability of cryopreservation services and frozen germplasm from selected broodstock would enable farmers to more easily access and control improvements in genetic attributes desired in their product line. For instance, if breeders select for broodstock that can survive a fatal disease, the sperm of those fish could be frozen and used for producing disease-resistant offspring. Hatchery operators would have access to and could 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 defined genetic lines, and this process is greatly complicated by the constraints in making necessary crosses and maintaining broodstock populations across years for comparisons. Cryopreservation can increase capabilities for fully crossed breeding designs and allows genetic screening of males by molecular markers for breeding studies. There are inherent, structural differences across aquaculture industries that influence the application of cryopreservation (e.g., Caffey and Tiersch 2000a). For example, presently the species with the most prevalent genetic control is Atlantic salmon *Salmo salar*. Because domesticated broodstocks are used, specific lines are well established and are well suited for application of cryopreservation for genetic improvement. On the other hand, the U.S. hybrid striped bass industry (based on hybrids within the genus *Morone*) has essentially no genetic control because of reliance on wild-caught broodstock each year to artificially spawn within the hatchery. As such, this industry would first rely on cryopreservation simply to ensure that sufficient volumes of sperm were available for annual production of seedstock (i.e., avoiding the potential opportunity costs of collecting too few broodstock).

Genetic Improvement

For genetic improvement to occur through selective breeding there must be a link between the observed attributes a fish displays and its genetics. The attributes a fish displays (phenotype) are determined by environmental influences and genetic influences. One major genetic influence is additive genetic variance (heritability), which refers to the correlation an individual parental phenotype has with phenotypes of offspring, and is measured as the percentage of total phenotypic variation for the trait in question. For genetic improvement to be accomplished using selective breeding, there must be a significant level of heritability associated with a specific trait. 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 faster may not because the environment does not allow for such growth. If the stocking rate is too high or the water quality too low, the stock will not grow beyond what the environment allows.

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). High heritability percentages were shown for weight as well as length in channel catfish (Reagan et al. 1976). Heritability estimates for disease resistance have also been studied. One study found that selective breeding would be practical and effective in Atlantic salmon to increase resistance to furunculosis because heritability for the trait was around 40% (Gjedrem et al. 1991). Selective breeding in Nile tilapia *Oreochromis niloticus* found a relatively high heritability for body weight at 16 wk with an average gain of 12% per generation (Bolivar and Newkirk 2002). The influence of heritability on phenotypic traits varies among species and within a species, but selective breeding is a proven approach to attain genetically improved fish stocks (Lutz 2001), and can be routinely captured and exploited by use of cryopreserved germplasm.

New Products and Technologies and Early Adopters

Opening new approaches to genetically improved fish stocks can be viewed as a new technology adoption problem. Early adopters of a new technology face uncertainty about the effects a new production system, or improved input, will have on costs and profitability. In general, adoption of new technologies entails some investment in equipment or the purchase of more expensive inputs. Hence, cost saving are only possible if the new technology provides greater output per unit of input, or through improved outputs that may be sold at higher prices. Early adopters face uncertainty regarding how effective the new technology will be in lowering costs, as well as whether an improved output will bring a premium price in the market. Studies show that factors influencing whether an operator is an early adopter include the manger's level of education, various firm-specific characteristics, and the manager's knowledge about the new technology (Olmstead and Rhode 1995, Wozniak 1987, Wozniak 1993). Firm-specific characteristics include the level of debt, dependence on off-farm income, and the operational scale of production. Knowledge about the new technology is the amount of information known by the manager regarding the product or service being offered. The ability to apply new technologies depends on the manager's capacity to identify sources of information, and to process and decode relevant information. Studies show that higher levels of education and available information about the product in question reduce the costs and uncertainty of adoption, and therefore increase the likelihood of early adoption. In general producers with larger scales of production are more likely to be early adopters than producers with smaller scales of production.

Little is known about which attributes are preferred by aquaculture grow-out producers in the U.S., or how much producers are willing to pay for them. The genetic attributes examined in this study were growth rate, disease resistance, and resistance to low dissolved oxygen levels. The objective of this study was to measure the willingness of U.S. hatchery and grow-out producers to adopt and pay for genetic improvement in fish stocks. A conditional logit model was used to estimate willingness to pay (WTP) for selected genetic attributes for the selected species. We report results from a national survey of producers of channel catfish (and hybrids with male blue catfish *Ictalurus furcatus*), hybrid striped bass, tilapia, Atlantic salmon and rainbow trout *Oncorhynchus mykiss* in the United States. This study is the first of its kind to evaluate the preferences for genetic attributes from producers. It also is the first known study to evaluate preferences for cryopreservation services by the producers in aquaculture industries.

Methodology

Theory Behind Willingness-to-Pay Determinations for Producers

A producer's willingness to pay (WTP) can be examined in the context of profit maximization subject to a given production technology. Assume that a firm is considering a change from one quality of input to another (i.e., q_0 to q_1). The WTP associated with the change can be modeled as:

$$WTP = \Pi_1(p, w, \mid q_1) - \Pi_0(p, w, \mid q_0)$$

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, $\Pi\ (p, w, \mid q)$, where $\Pi_0(p, w, \mid q_0)$ is the indirect profits given an input quality of q_0. The WTP represents the change in profit the producer expects to receive by acquiring q_1 instead of q_0 (Lusk and Hudson 2004).

In the context of this study, the initial profit $\Pi_0(p, w, \mid q_0)$, consists of input prices (w) that grow-out producers are paying for conventional fingerlings. The adoption of genetically improved fingerlings will affect $\Pi_0(p, w, \mid q_0)$ through improved fingerlings (q_1) that are expected to increase the production efficiency of the operation. This may be through improved growth rate or enhanced disease resistance. Improved efficiency would presumably reduce costs, thereby leading to higher profits and a positive WTP for fingerlings. The difference between Π_1 and Π_0 represents the producers WTP for improved fingerlings.

Review of Related Studies

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 recirculating technology in soft-shelled crab production was studied based on the characteristics of the producer (Caffey and Kazmierczak 1994). Also studied were the production costs incurred by a farm or institution that incorporated cryopreservation into its existing operation (Caffey and Tiersch 2000b). The effects on a particular industry (such as salmon) stemming from government regulations and their influence on market structure have been studied (Tveteras 2002).

Other studies have focused on consumer preferences for seafood attributes (e.g., Holland and Wessells 1998, Anderson 2000). For example, a study of the market for farm-raised hybrid striped bass determined that price and product form were the attributes most important to mid-Atlantic seafood buyers (Halbrendt et al.1991). However, attributes that the consumer values is likely to be different from the attributes that a grow-out farmer would value. Consumers are concerned with features such as price, serving size, product form, how the product was obtained (farmed or wild-caught), color, or presence of ecological labeling (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.

Stated Choice Analysis

Stated choice analysis, also known as discrete choice, contingent-choice, choice experiments, or choice-based conjoint analysis (CA), is a type of analysis in which hypothetical products are evaluated by a subject. 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 et al. 2000). These techniques enable researchers to evaluate market situations that do not yet exist. In a choice-based conjoint experiment, respondents are asked to choose a preferred alternative from a set of alternatives, rather than ranking or rating alternatives, which is a more typical CA format (Adamowicz et al. 1998). Several researchers have found discrete choice methods to be superior relative to the ranking or rating technique (Pinnell 1994).

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, which are typically limited to between two and four. The inclusion of an opt-out, or "neither," option is also common. This serves as an "opt-out" base and is available to all respondents. The stated choice method was chosen for this study 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 specific 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 was no inclusion of an opt-out response. Also, response bias and respondent fatigue increase as the number of alternatives increase (Louviere et al. 2000). The stated choice methods are in line with random utility theory and can be analyzed with random utility models, unlike ranking/rating conjoint methods (Louviere 1994).

Fish Stock Attributes for This Study

Pre-testing of survey design and attribute selection were completed using the assistance of aquaculture extension agents and farm operators. The attributes selected for this 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 minimize respondent fatigue. The four attributes used in the final version of the survey were growth rate, disease resistance, resistance to 10% lower dissolved oxygen levels, and price. All these attributes are important in the production of any species. They also have important economic implications for the grow-out operation. Faster growth rates mean shorter production cycles and improved feed efficiency. If fewer fish die due to disease outbreaks then production efficiency will increase. A higher tolerance to less than desirable oxygen levels means lower costs associated with monitoring and regulating oxygen levels, as well as higher survival rates in low oxygen conditions.

Each attribute was expressed in terms of either two or three levels. Growth rate and disease resistance were expressed as being either at their current level (that is, no change from the operator's current growth rate or disease resistance), or a 10% improvement in growth rate and disease resistance relative to the current level, or a 20% improvement relative to the current levels. If a producer currently averages a loss of 200 fish per production cycle, 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 fingerlings to tolerate 10% lower levels of dissolved oxygen in the water without dying. This attribute was expressed as either a "yes", implying the fingerling possesses an ability to survive in 10% lower oxygen relative to conventional oxygen levels, or "current", which implies the fingerling can survive in conventional oxygen ranges. The price attribute was expressed as a price premium, an amount that producers would be willing to pay above current fingerling price (20%, 40%, and 60%).

Choice Task Design

There are numerous ways to prepare a stated choice questionnaire. This study elected to utilize the no-purchase or "neither" alternative (i.e., prefer status quo). With the inclusion of a "neither" option, respondents had the opportunity to pay a zero price premium because 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. The four attributes chosen (with 3 x 3 x 2 x 3 levels), resulted in 54 possible product combinations. However, this number was too high to realistically be completed without causing respondent fatigue (or a reduction in overall response rate). Therefore the software package Bretton-Clark Conjoint Designer was used to formulate 9 orthogonal attribute combinations. Three more product combinations were added to the design to provide a balanced number of choice tasks. This resulted in twelve alternatives for genetically improved fish stocks to be evaluated by U.S. grow-out producers. Six choice sets were constructed, where each included two of the twelve genetically improved options. The first and second alternatives were paired to form the first choice set, the third and fourth alternatives were paired to form the second choice set, and so on until all six choice sets were formed. Because of the length of the overall questionnaire, a split-sample approach was used. Three versions of the questionnaire were mailed to aquaculture producers, with each version having two choice sets to evaluate. Each version of the questionnaire was randomly assigned to a producer in the mailing list, which included 1,293 U.S. aquaculture farms. Respondents were asked to select their preferred option in each set. An example of a choice task is included in the Appendix.

Survey and Data

The survey was administered during the summer of 2005. Usable responses were returned from 11.8% of the total surveys mailed. In addition to the previously described choice task, the survey also elicited information regarding preferences, beliefs, and opinions of aquaculture producers across the U.S. about topics such as cryopreservation, genetic improvement, and the future of aquaculture. These responses could be used to determine which issues were most important to the various groups and segments of aquaculture producers. Questions concerning prior knowledge about cryopreserved sperm were included in the questionnaire to determine whether that firm was a potential early adopter. Firm-specific questions such as farm size and gross sales, individual-specific questions (i.e., education level of the farm manager), as well as questions specifically asking managers about their history and potential likelihood of adopting a new technology were also included in the survey. The survey was divided into three sections. The first applied only to farms that participated in spawning activities. The second, applied only to farms with grow-out operations. The third section applied to all aquaculture farms and included mostly demographic information. The stated choice questions were included only in the grow-out section of the questionnaire.

Model Formulation

Choice-based modeling is derived from random utility theory, which assumes that consumers maximize their utility with the choices that they make (Louviere et al. 2000). In the present study, we assume that maximizing profits for their operation is analogous to maximizing the operator's utility with respect to factors that affect firm level profits. 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 (ε_{ij}) (McFadden 1974, Louviere et al. 2000, Heiss 2002). The resulting utility equation is:

$$U_{ij} = V_{ij} + \varepsilon_{ij}$$

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 for all k in the choice set not equal to j is:

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

The conditional logit (CL), multinomial logit (MNL), and nested logit (NL) models are common methods used to analyze discrete choice variables. The nested logit 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. The MNL utilizes individual specific explanatory variables, whereas the CL model focuses on the characteristics of the alternatives for each individual and uses them as explanatory variables. The difference between the two models is shown in the following equations:

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

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

where X_i is the individual specific characteristics of individual i, β and α 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 probability of the CL model 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, and allows analysis of the attributes in the alternatives as opposed to analyzing the attributes of the individual selecting the alternative (Jepsen and Jepsen 2002).

The conditional logit model with interactions (CLI), or mixed logit model, is a hybrid of the MNL and CL models. The CLI model 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 et al. 2005). It is reasonable to assume that the characteristics of the operator, as well as the operation, will have a significant impact on the preferences for selecting fish stock alternatives. The individual-specific (or operator-specific) characteristics may include socioeconomic characteristics as well as variables representing the respondent's attitude towards a certain subject.

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 as follows:

$$\text{CLI:} \qquad P_{ij} = \sum_{k=1}^{J} \exp\left(X_i\beta_j + Z_{ij}\beta\right) / \exp\left(X_i\beta_k + Z_{ik}\alpha\right)$$

where X_i is the individual specific characteristics of individual i, β and α 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 identification of 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 maintains the assumption of independent and identically distributed (i.i.d.) error terms. There is a precedent for this in previous studies. For example, analysis of the attributes contributing to the utility of a moose hunting trip included the addition of interaction terms to the normal CL model to evaluate the impact of being from an urban area on the choice selection of a hunting site (Adamowicz et al. 1998). Another study evaluated the socioeconomic impacts on the selection of a forest design (Hanleyet al. 1998). In a study that evaluated the attributes associated with a wetland management program, interaction effects were measured for various individual-specific variables (Birol, et al. 2005). The practice of using interaction terms can allow results to be individual specific.

Results

Seventy respondents from the survey reported that they conducted grow-out operations (Table 1). Twenty two respondents (32%) indicated that channel catfish is their primary product and 20 (29%) of respondents indicated that rainbow trout is their primary product. Fifty one of the respondents (74%) reported that they grow only one species; with the remaining 19 (26%) indicating they produce multiple products. Hybrid strip bass producers accounted for 12% of the respondents, followed by producers of tilapia, which accounted for 10% of the total. Atlantic salmon producers represented only 3% of the total.

Table 1. Species distribution of grow-out operations.

	Primary Product [a]	Percent	Only Product [b]	Percent
Channel catfish	22	32	18	35
Hybrid striped bass	8	12	2	4
Tilapia	7	10	7	14
Atlantic salmon	2	3	2	4
Rainbow trout	20	29	13	25
Other	10	14	9	18
Totals	70	100	51	100
Percent of farms with only one product = 74%				
Percent of farms with multiple products = 26%				

a. Primary product is defined as the species with the highest reported percentage of sales.
b. Respondents who reported the species is the only one they produce.

An overwhelming majority of grow-out farms reported they are privately held company and employ less than 10 workers (Table 2, next page). More than 50% of the respondents reported that they used ponds as there production system. This is expected due to the high number of catfish farmers. Over 40% used flow-through systems, which is attributed to the trout farmers. The highest category for sales is $250,000 to $1 million. Only 4.7% of the respondents generated more that $5 million in sales. Most of the respondents had some college education or graduated from college with a bachelor’s degree or an advanced degree. More than 60% of the respondents were 46 yr of age or older.

Table 2: Summary statistics for respondents with grow-out operations

Production Method	#	%	*Ownership*	#	%
Pond	36	51.4	Public	5	7.1
Flow-through	29	41.4	Private	64	91.4
Net pens/cages	3	4.3	Both	1	1.4
Closed recirculation	14	20.0	Total	70	100
Total	70	100			

Employees	#	%	*Sales (x $1,000)*	#	%
Less than 10	55	78.6	Less than 2.5	3	4.7
10 to 50	13	18.6	2.5 to 9.999	3	4.7
51 to 150	2	2.9	10 to 49.999	8	12.5
More than 150	0	0	50 to 249.999	15	23.4
Total	70		250 to 999.999	21	32.8
			1,000 to 4,999.999	11	17.2
			More than 5,000	3	4.7
			Total	64	

Education	#	%	*Age (yr)*	#	%
Less than high school	1	1.4	18 to 24	1	1.5
High School graduate	8	11.4	26 to 35	5	7.3
Some college	19	27.1	36 to 45	18	26.1
Bachelor's degree	25	35.7	46 to 60	38	55.1
Advanced degree	17	24.3	Older than 60	7	10.1
Total	70	100	Total	69	100

Conditional Logit with Interactions

Results for the mixed logit model are presented in Table 3 (next page). The overall model was found to be significant at the $\alpha = 0.01$ significance level with a log likelihood ratio value of 64.20. The price premium variable was coded as 0, 20%, 40%, or 60% for the available price premiums above current fingerling prices. The rest of the variables were effects coded in the data set and the "neither" option served as the base and was coded as 0 throughout. The alternative-specific constant (ASC) "ab," which represented the genetically improved alternatives, was held out of this model. This was done to reduce the chance of multicollinearity, because all individual-specific variables were interacted with the ASC term. Interactions were included in this model to determine which individual-specific variables significantly affected the selection of a genetically improved alternative.

The signs of most of the alternative-specific coefficients were as expected, negative for the price premium and positive for genetically improved attribute levels. The coefficient

Table 3. Conditional logit with interactions, payment and Willingness-to-Pay (WTP) estimates

	Coefficient	St. Error	WTP	R.I.[a]
Growth Rate Attribute				40.53
10% Increase	.567**	.283	17.61	
20% Increase	.695***	.242	21.58	
Disease Resistance				17.19
10% Increase	.366	.264	11.35	
20% Increase	.099	.307	3.08	
Tolerance to Low Dissolved Oxygen	-.055	.163	-1.69	2.26
Price premium	-.032**	.013		40.01
Firm- Specific Interactions				
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		
Sales greater than 50K*ab	.264	.311		
Operator-Specific Interactions				
Bachelor's degree*ab	.964***	.329		
Multiple new technologies in last 5 yr*ab	1.385***	.418		
36-60 yr of age*ab	-3.144**	1.392		
Over 60 yr of age*ab	7.215**	3.112		
Favorable toward Cryo*ab	.341	.323		

N = 324 ; LR(19) = 64.20***; Pseudo R^2 = .2705.
*, **, ***. Denotes Significance levels at α= .10, .05, and .01 percent, respectively.
a. Relative importance (RI) measures the percentage of the selected attribute's part-worth range to the sum of part-worth ranges for all attributes.

associated with resistance to low dissolved oxygen levels was negative but not statistically significant. The results show that growth rate and price premium were the most important genetic attributes for grow-out producers, tied with relative importance factors of 40%. The levels of growth-rate and the price premium were the only significant genetic attributes in model. Moreover, producers were more likely to choose an alternative with 20% increased growth rate than an option offering only a 10% increase.

Firm-specific variables were included as interactions in the model. The firm-specific variables were effects coded (1,-1). All firm-specific variables were placed in interaction with the alternative-specific constant (ab) to analyze the interest for genetic improvement by specific types of farms. For example, the variable "Private*ab" represents privately run grow-out farms that selected either of the two genetically improved options. The positive and significant coefficient associated with variable indicating private grow-out farms (Private*ab) implied that private farms are more likely to adopt genetically improved fish stocks relative to publically managed operations. All species interactions were positive except for the hybrid striped bass interaction variable. However, only the variable indicating the operation produced predominantly catfish and tilapia was statistically significant, which implied that catfish and tilapia producers were more likely to adopt genetically improved stock relative to producers of other species.

Atlantic salmon, hybrid striped bass, and rainbow trout interactions were not significant in this model.

Operators-specific variables were also included as interactions in the model, and were coded using conventional 0,1 dummy variable coding. Respondents having incorporated multiple new technologies in the last 5 yr, as well as managers having a Bachelor's degree, each had a positive and significant effect on choosing a genetically improved alternative. Two of the three age variables were included in this model. Surprisingly, respondents over the age of 60 yr had a strong positive and significant coefficient, indicating a higher likelihood of adopting a genetically improved fingerling relative to the omitted category of 18 to 36 yr. However, operators between the ages of 36 and 60 years of age were less likely to select the improved alternatives relative to the youngest operator category. The variable "Favorable toward Cryo*ab" represents the operator's attitude toward cryopreservation, but 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 in the previous year. This meant the relative size of the operation had no significant effect on the willingness to adopt a genetically improved fish stock.

The 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:

$$WTP_i = -\frac{\beta_i}{\alpha}$$

where β_i is the coefficient of attribute *i* and α is the price premium coefficient. The willingness-to-pay values are interpreted as the percentage premium above current prices that producers are willing to pay to obtain a fingerling with the specific genetic attribute. Results of this model showed that grow-out producers were willing to pay approximately 18% more 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.

Conclusions

A nationwide survey of aquaculture producers was administered to elicit information about grower production techniques, grower opinions about the industry, and grower preferences for genetically improved fish stocks. Data from the survey were used to estimate a conditional mixed logit model to analyze grow-out producer preferences for selected genetic attributes. The attributes analyzed in the study were growth rate, disease resistance, and resistance to 10% lower dissolved oxygen levels. A price premium attribute was also included in the available alternatives. A conditional logit with interactions model was estimated and willingness-to-pay estimates were derived from the results. Improved growth rate was the most significant genetic attribute desired by grow-out producers. Willingness-to-pay estimates indicated that grow-out producers would pay 22% more relative to the current price of fingerlings to acquire a fish stock with a 20% increase in growth. Disease resistance and tolerance of low oxygen levels were not significant in the model. This implies that grow-out producers in the United States are more likely to adopt fish stocks with improved growth rates rather than those with disease resistance, or tolerance for low oxygen levels. The results also showed that the channel catfish and tilapia industries were more likely to adopt genetically improved fish stocks relative to other species. Future research that focuses on improved growth rates for these species are more likely to be adopted by United States aquaculture industries.

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Appendix: An Example of the Choice Task from Survey Version #3

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	20% better	Current
Disease resistance	Current	20% increase
Resistance to 10% lower dissolved oxygen levels	Current	Yes
Price premium	40%	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	20% better
Disease resistance	10% increase	20% increase
Resistance to 10% lower dissolved oxygen levels	Yes	Current
Price premium	20%	60%

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** ☐