Willingness-to-Pay for Genetic Attributes in Aquaculture Industries

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Abstract:
The genetic make-up of fish stocks is an important factor in aquaculture production. Choice-based conjoint analysis is used to determine importance of genetic improvements to grow-out producers and an estimated willingness-to-pay for selected attributes. Results from a national survey of aquaculture producers, reveal growth rate as the most important attribute.

Keywords: Aquaculture, Stated Choice, Conditional Logit, Willingness-to-pay

Introduction:

United States aquaculture industries contributed 200 to 300 million pounds of edible weight to the total U.S. seafood supply in 2001 (Selock 2001). The contribution of aquaculture industries to the American consumed seafood supply has increased in recent years. This trend has amplified the competition between farmed fish and wild-catch segments (Harvey 2003). In 1998, U.S. farm-level sales by aquacultural industries were $978 million, with an estimated 4,028 farms (table 1) (LASS 2000). The Southern region, which includes Mississippi, Louisiana, Alabama, Arkansas, Florida, etc., contains about 68% of the aquaculture farms in the U.S. and is responsible for 65% of total U.S. sales. Mississippi alone accounted for over $290 million in sales in 1998 (NASS 2004). Aquaculture is one of the fastest growing segments in agriculture. Expectations are that aquaculture's contribution to the seafood market will continue to increase, relative to wild-harvested products. Aquaculture provides a means for consumers to consistently and reliably have access to the seafood of their choice.

Despite the growth in U.S. aquaculture, foreign imports, primarily from the Asian markets, are very competitive with U.S. aquaculture. China, and other Asian countries, dominate global aquaculture production. For instance, China is responsible for over 70% of the total volume of world aquaculture production, and close to 50% of the total world value. 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 (FAO 2004).

Two major challenges facing U.S. aquaculture are to:

1. continue to gain market share within the total seafood market; and,

2. become more competitive in domestic and world markets with the Asian products.

One way to overcome these challenges is to increase the efficiency of U.S. aquaculture. By improving certain genetic attributes aquaculture farms may reduce production costs, thereby increasing efficiency. Selective breeding is one answer to increased genetic control. Selective breeding is a key way to improve the productivity of plant and animal species (Kerr 1984). Hatcheries and grow-out producers can benefit economically by controlling the genetics of the products that they produce. Greater control over the genetics of fish stocks will allow farmers to produce a better and more consistent product. An improved and more consistent product may allow farmers to demand a premium price, and also lower production costs.

Little is known about which attributes are preferred by aquaculture grow-out producers, or how much producers are willing to pay for those attributes. The objective of this paper is to measure the relative importance of genetic attributes and determine how much producers are willing to pay for fish stocks with selected attributes. The genetic attributes examined in this study are growth rate, disease resistance, and resistance to low dissolved oxygen levels.

Literature Review

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). A relatively new topic is the production costs endured by a farm that incorporates cryopreservation techniques into its existing operation (Caffey and Tiersch 2000). The impacts on a particular industry, like salmon, stemming from government regulations can influence the market structure of that industry (Tveteras 2002). Therefore, many different policy implications have been researched.

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 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 concerning consumer preferences for seafood attributes includes studies by Halbrendt, Worth, and Vaughn (1991), Holland and Wessells (1998), and Anderson (2000). 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. The attributes used in this study were seafood inspection, production method, and price. They want to find out if seafood inspection is an important attribute in the selection of salmon. The identity of the company doing the inspection is 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. They 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. Johnston et al. (2001) observed the propensity to purchase an ecolabeled product based on country, species, certifying agency, and consumer group. In another ecolabel study, they 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).

Stated Choice Analysis

Stated choice techniques are a type of conjoint analysis, where 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 (Adamowicz et al. 1998). 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.

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 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).

Model

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). 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:

$$U_{ij} = V_{ij} + e_{ij}$$

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:

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

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 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 and the CL models are very 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 them as explanatory variables. The difference between the two models is shown in the following equations:

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

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

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 us to analyze the attributes in the alternatives as opposed to analyzing the attributes of the individual selecting the alternative (Jepsen and Jepsen 2002).

This paper utilizes the CL model to analyze the data in our 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 is interested in determining the relative importance of the selected attributes, as well as the willingness-to-pay for those attributes. The CL model will allow for the estimation of both.

Methodology

Fish Stock Attributes

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 needed to 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 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 is associated with two or three levels. Growth rate and disease resistance are 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%[1].

Choice Task Design

There are many different ways to set up a stated choice questionnaire. This study elected to utilize the no-purchase alternative (i.e., prefer status quo), as 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 chose 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

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

high to realistically be completed without causing respondent fatigue. The software package, Bretton-Clark Conjoint Designer, was used to formulate the attribute combinations available in the choice task scenarios. The program generated 9 orthogonal combinations. Three more product combinations were added to the design in order to have a balanced number of choice tasks[2]. This resulted in twelve genetically improved fish stock alternatives to be evaluated by the 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 the appendix.

Survey and Data

The results of this study are from a nationwide survey sent out on June 16, 2005, to 1,293 aquaculture farms[3]. A usable response rate of 11.8% was returned. 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 could then be used to determine which issues are most important to the various groups and segments of the aquaculture industry. The survey was divided into three sections. The

[2] Even with the addition of three more alternatives, the design maintained its orthogonal distinction.
[3] The focus of this study was foodfish production, so an effort was made to restrict the mailing list to farms with at least some foodfish revenue.

first section 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.

Seventy respondents reported that they conducted grow-out operations on their farm[4]. As you can see in table 2, the majority of respondents reported channel catfish and rainbow trout as their major product[5]. A quarter of the farms reported production of more than one species. An overwhelming majority of grow-out farms reported that they were a private company and that they employed less than 10 people (table 3). Over 90% of respondents reported that they used ponds and/or flow-through systems for their stock maintenance. This is expected due to the high number of catfish and trout farmers that responded to the questionnaire. Catfish farming is primarily done utilizing ponds, while tank systems are the principal methods for trout production.

Results

Conditional Logit

The results of the conditional logit model and the willingness-to-pay estimates are presented in table 4. The overall model was found to be significant at the 1% 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 zero if the respondent chose the "neither" alternative, and one if they chose one of the genetically improved stocks. The price premium variable was recorded as 0,

[4] Sixty-nine of the 70 respondents reported the specific species farmed at their operation.
[5] Major product is defined as the product with the highest reported percentage of sales.

20%, 40%, or 60% for the available price premium options[6]. 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 the "neither" option could serve as the base. Since this option does not include any of the genetic improvements, all variables associated with the "neither" option were coded as (-1).

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. Therefore, the conditional logit model is an effective model for our 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, price premium, and the ASC for genetically improved stock, were the only significant variables for our model. Significance levels were 90% or greater for those significant variables. Disease resistance and resistance to low dissolved oxygen levels did not prove to be 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).

Relative importance weights were also calculated for each attribute group. In order to do this, the utility range for each attribute group was determined. These ranges were then divided by the sum of all the utility ranges. The results of these estimates again show that growth rate is the most important individual attribute to the grow-out

[6] These were defined as a percentage above the producer's current price for a fingerling stock.

producers in this study[7]. The price premium attribute was also very important. Disease resistance and resistance to 10% lower dissolved oxygen levels recorded low relative importance weights.

Willingness-to-pay

The willingness-to-pay for attribute *i* is calculated as the negative ratio of the coefficient for attribute *i* and the price premium coefficient. It can be calculated as:

$$WTP_i = -\frac{b_i}{a}$$

where $ß_i$ is the coefficient of attribute *i* and *a* is the price premium coefficient. The willingness-to-pay values in this study are interpreted as the percentage increase that producers are willing to pay to obtain the specific genetic attribute. The results are included in table 4. Producers are willing to pay a 14.17% price premium for a fish stock with a 10% increase in the growth rate. This translates into producers willing to pay about 1.4% more for every one percent increase in growth rate. A premium of 22.54% would be paid to attain a fish stock with a 20% higher growth rate. Grow-out producers were willing to pay over 36% more to acquire a stock that included some combination of genetic improvements. The results are consistent with economic theory in that both the 20% improvement levels recorded higher willingness-to-pay values than the 10% levels.

Conclusions

A nationwide survey of aquaculture producers was sent out to elicit information about their production techniques, their opinions about the industry, and their preferences for certain attributes. This paper analyzes the responses of the grow-out

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

producers regarding their preferences for specific genetic attributes. The attributes used in this 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. Respondents were asked to complete two choice tasks with three alternatives in each task. Two alternatives were genetically improved fish stocks. The third alternative was to purchase neither. A conditional logit model was used to analyze the responses, and then willingness-to-pay estimates were derived from those results. Growth rate was the most significant attribute available to the grow-out producers. Responses suggest grow-out producers would pay 22.54% more to acquire a fish stock with a 20% increase in growth. The results also show a strong positive attitude towards the purchasing of genetically improved fish stocks. Producers were willing to pay almost 37% more to buy fish stocks with some combination of genetic improvements. This study may also benefit hatchery producers, by showing them which attributes they should be breeding for in order to sell their products at the highest price.

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Table 1: Southern Aquaculture Production

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

Table 2: Grow-out Product Distribution for Farms with Grow-out operations[8]

	Major Product[9]	Only Product[10]	Produce any at all[11]
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%
Atlantis 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%

[8] Percentages are of the 69 respondents who reported the species that they produced.
[9] Indicates that the species represents the highest percentage of gross sales.
[10] Indicates that the species makes up a farm's entire sales revenue.
[11] Indicates that the species represents at least some part of gross sales.

Table 3: Summary Statistics for Respondents with Grow-out Operations

Variable		Number of Respondents	% of Respondents	Mean	Standard Deviation
Methods utilized for on-site fingerling maintenance			**(% of 70)**		
	Pond	36	51.43%	0.5217	0.5032
	Flow-through	29	41.43%	0.4203	0.4972
	Net pens/Cages	3	4.29%	0.0435	0.2054
	Closed re-circulation	14	20.00%	0.2029	0.4051
	Other	0	0.00%	0.0000	0.0000
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%**		
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 4: Conditional Logit, Willingness-to-pay, and Relative Importance Results from Stated Choice Experiments

	Conditional Logit		**WTP (%)**	**R.I.**[12]
	Coefficient	St. Error		
ab_ASC for Genetic Improvement	1.047**	0.467	36.82	34.84
Growth Rate				28.03
10% increase	0.403*	0.226	14.17	
20% increase	0.641***	0.207	22.54	
Disease Resistance				9.02
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	0.17
Price Premium	-0.028**	0.011		27.95

Number of Observations = 360
LR = 24.71***

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

[12] Relative importance of each attribute group.

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** ☐