Valuing the Willingness-to-pay for Ecosystem Service Benefits from Integrated Multi-trophic and Closed Containment Aquaculture in British Columbia, Canada

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Abstract

Globally, the aquaculture industry is associated with a range of environmental problems. Many of these issues have significance for the conservation of biodiversity and ecosystem services and have stimulated interest in developing more sustainable aquaculture methods. Integrated Mutli-Trophic Aquaculture (IMTA) combines the culturing of fish and extractive aquaculture species at one site to simulate a balanced natural system and reduce some environmental issues of monoculture systems. In contrast, Closed Containment Aquaculture (CCA) separates farming from the natural marine environment by using closed water tanks on land or in water. This paper explores consumer preferences for IMTA and CCA. Two questions are posed: (1) how do salmon consumers in the US Pacific Northwest perceive the products of IMTA and CCA, with or without eco-certification, and in comparison to salmon products from other sources (wild or farmed); and, (2) what are salmon consumers in the US Pacific Northwest willing to pay for salmon produced by IMTA or CCA and is there significant evidence of preference heterogeneity? Results of a Discrete Choice Experiment (DCA) combined with a Latent Class Analysis (LCA) revealed a willingness to pay a price premium of 9.8% and 3.9% for IMTA and CCA, respectively, over conventionally produced Atlantic salmon. Results of the survey also revealed that 44.3% and 16.3% of the respondents preferred the adoption of IMTA and CCA to conventional salmon farming, respectively.

Key words: sustainable aquaculture, salmon farming, non-market valuation, price premium, latent class analysis, discrete choice experiment

Introduction

Globally, the aquaculture industry is associated with a range of environmental problems. Many of these issues have significance for the conservation of biodiversity and ecosystem services. Various alternatives are available to decision-makers responsible for aquaculture development who must grapple with the dilemma of supporting economic development and meeting food production needs while protecting marine and coastal areas. For example, they can simply remove the offending aquaculture operations and find other ways to meet rising food demand, or they can attempt to improve the environmental performance of existing aquaculture operations by adopting more sustainable methods, perhaps recognizing this via eco-certification (Costa-Pierce, 2002). In this paper, we examine the willingness-to-pay of consumers of aquaculture products for the ecosystem benefits that arise from more sustainable aquaculture techniques.

The salmon aquaculture industry in British Columbi (BC), Canada is the fourth largest producer of farmed salmon in the world (Province of British Columbia, 2009). The open-net cage salmon farming method currently used in BC has raised significant public concerns across Canada and the globe because of the associated problems for biodiversity and the provision of ecosystem services.[1] Common issues include threats to wild salmon stocks through potential sea lice and disease transfers, pollution from farm contaminants (such as feed waste and drugs), and escapes of non-native salmon species (Knapp et al., 2007; David Suzuki Foundation, 2009;

[1] In this paper, we will refer the traditional mono-specific, open-net cage aquaculture/farming method as the "conventional method" or "conventional aquaculture". Salmon produced with the conventional method will be called "conventionally farmed/produced salmon".

Allsopp et al., 2008; Greenpeace USA, 2010). Other concerns include the influx of untreated organic and inorganic nutrients and wastes into the marine environment, which can be especially harmful when the local marine system is not nutrient limited. In addition, marine life beneath farm sites can be destroyed and the surrounding marine area may become polluted, which cumulatively affects species in the vicinity of the fish farms (Leggatt, 2001).

While the environmental and social impacts of conventional salmon aquaculture have raised concern amongst the public, the demand for farmed BC salmon has not declined and the aquaculture industry continues to contribute substantially to BC’s economy (Province of British Columbia, 2007; Wild Salmon Supporters, 2010; Coastal Alliance for Aquaculture Reform, 2010; Associated Press, 2010). Nonetheless, addressing environmental issues with salmon aquaculture is a priority for various stakeholders as evidenced by an ongoing attempt to identify sustainable and cost-effective options to produce farmed salmon.

Two potential options available to salmon farmers in BC are the integrated multi-trophic aquaculture (IMTA) and the closed containment aquaculture (CCA). IMTA combines the cultivation of fed aquaculture species (e.g. salmon) with extractive aquaculture species (e.g. mussels/oysters and kelp) to mimic the conditions of a balanced ecosystem in a farm site. IMTA creates natural biological filtration (biomitigation) and thereby reduces the nutrients entering the ocean by enabling both organic and inorganic wastes from the fed salmon to be efficiently absorbed as productive nutrients by the extractive species. In addition to environmental benefits, IMTA also can generate economic and social benefits such as product diversification and partnerships with local indigenous people who are otherwise unwilling to support conventional aquaculture methods (Pacific Sea-Lab Research Society, 2007). On the other hand, CCA separates salmon farming from the natural marine environment by using closed water tanks on land or in the sea to raise salmon and can be developed, with varying degrees of isolation and environmental interactions. CCA can eliminate the industry's impacts on nutrient loading, sea lice outbreaks, fish escapes and disease transfer to wild salmon stock (MMK Consulting Inc., 2007; Living Oceans Society, 2011).

While both systems bring environmental benefits compared to conventional aquaculture, their purposes are different and they have fundamentally different limitations: IMTA does not address species escape and disease transfer to wild salmon stock, while CCA may lead to higher energy consumption and issues related to waste treatment and land-use conflicts. There is a lack of understanding of the salmon consumers' perception and acceptance of the two systems and their products, thus hindering adoption by the salmon aquaculture industry.

Previous economic studies of IMTA and CCA have examined the profitability and technical viability of both systems in isolation, with little evidence to indicate how consumers would perceive and value the ecosystem benefits generated by these systems. Results from a capital-budgeting and scenario analysis of salmon-based IMTA in New Brunswick, Canada, showed that the net present value of IMTA was 24% greater than salmon monoculture due to the additional revenues from mussel and kelp sales (Ridler, et al., 2007). Attitudinal studies in New Brunswick and New York found positive attitudes towards IMTA and its products, and a 10% premium for labelled IMTA seafood such as mussels (Ridler et al., 2006; Barrington et al., 2008; Shuve et al., 2009). Results from two surveys using contingent behavior and contingent valuation methods suggested that East Coast Canadian salmon consumers would derive benefits of between CAD $480 to $600 million per year for the first five years of IMTA salmon introduction to the market, while non-consumers would derive benefits of between CAD $42.5 to $93.3 million per year over the same period (Martinez-Espineira, 2011).

On the other hand, economic studies of CCA provide mixed results for profitability, ranging from unprofitable to modestly profitable, with the latter depending on an assumption that consumers are willing-to-pay (WTP) a price premium for CCA products (Liu & Sumaila, 2007; Wright & Arianpoo, 2010). Results of a feasibility study of potential CCA production in BC revealed that only one of the various CCA technologies evaluated was even marginally viable from a financial perspective (DFO, 2010). Further, these evaluations are not supported by any studies of consumers' perception of and WTP for CCA salmon farmed in BC.

Using a web-based survey and discrete choice experiment, we studied the value of reduced damage to the marine environment as expressed by salmon consumers' WTP for salmon products produced from IMTA and CCA rather than conventional farming methods. Specifically, we address two questions: (1) how do salmon consumers in the US Pacific Northwest perceive the products of IMTA and CCA, with or without eco-certification, and in comparison to salmon products from other sources (wild or farmed); and, (2) what are salmon consumers in the US Pacific Northwest willing to pay for salmon produced by IMTA or CCA and is there significant evidence of preference heterogeneity? We used an online survey and choice experiment to compare salmon consumers' perceptions and attitudes towards various sources of salmon products, and to elicit their WTP for salmon supplied using more sustainable technologies. In the following sections we first describe our methods, including the use of a latent class analysis (LCA) designed to test for preference heterogeneity, and then we derive the WTP for salmon products for all-in and individual market segments. We conclude with a discussion of the implications of our findings for improving the environmental performance of salmon aquaculture.

Research Approach and Methods

We used several statistical modelling approaches in our study and these are described in detail below. More technical information on these techniques can be found in the references provided. Then we describe the design of the choice experiment and the online survey used to collect the data.

Statistical modeling approach

In a discrete choice experiment (DCE), different hypothetical products (profiles) that are composed of various levels of decision-influencing factors (attributes) are presented to the respondents. He/she then is asked to choose the profile that they would purchase. Researchers can then quantify and assess the stated choices and estimate the part-worth utility for each attribute level presented (Louviere et al., 2000). DCE is based on random utility theory, and a description of the basic derivation can be found in various sources (McFadden, 1974; Adamowicz et al., 1998). The WTP for a product attribute is the price discrepancy in the consumers' WTP for one unit of a product with the attribute and one unit of a product without the attribute in question. If the production method is an attribute of salmon, where the levels of the attribute are IMTA, CCA and conventional aquaculture, then the WTP for IMTA or CCA salmon is the difference between the consumers' WTP estimates for conventionally grown salmon and IMTA or CCA salmon.

The WTP is calculated as the ratio of two parameter estimates where the numerator is the negative of the coefficient of the attribute of interest ($-\beta_y$) and the denominator is the coefficient of the price attribute (β_P), holding all else constant (Hensher et al. 2005). Thus, the mean WTP for attribute y can be represented as:

$$Mean\ WTP_y = \frac{-\beta_y}{\beta_P} \tag{1}$$

We estimated the mean WTP for IMTA and CCA as alternative levels for a production technology attribute in the DCE.[2] Statistical estimation was carried out using the multinomial logit model (MNL), where we define the probability distribution of choice profile j being chosen by individual i as:

$$Prob\ \{j\ is\ chosen\} = e^{v_{ij}} / \textstyle\sum_k e^{v_{ik}}\ ; for\ all\ k \in C_i \tag{2}$$

The parameter estimates were used to predict the relative probability that an individual will choose a particular profile as described by various combinations of attributes, compared to other profiles with different attribute levels (Hensher et al., 2005).

Latent class analysis (LCA) is an expanded mixed logit form of the MNL and can be used to measure preference heterogeneity within the sample (Train, 2009). The model assumes an overall heterogeneous sample that is made up of a number of relatively homogenous but unobservable classes. The classes are identified initially using differences in preferences across the classes and then they are described by socio-demographic and other attitudinal data (Boxall & Adamowicz, 2002). Homogeneous preferences characterize each class and heterogeneous

2 Median WTP can also be estimated but we chose to use the mean WTP alone.

preferences distinguish the classes from each other (Birol et al., 2006). As opposed to known class models, which derive part-worth utilities based on pre-assigned groups, LCA defines the number of classes endogenously using the survey response data. Using LCA allowed us to estimate different parameters for each class and to examine differences in part-worth utility and WTP among the classes for a given product or attribute level. For further technical information on the LCA model, see Boxall & Adamowicz, (2002).

Design of the choice experiment (DCE)

The selection of attributes and levels are critical in a DCE. Therefore, the attributes and levels selected were carefully tested before finalizing the design. The finalized attributes are described below (also see Table 1):

- **Salmon species**: Atlantic, Sockeye and King salmon were included in the study. Atlantic salmon is the primary product of the BC aquaculture industry and Sockeye is the primary wild product available to US salmon consumers. While King salmon is not as widely consumed as the other two species, it was included as it is the only species produced in BC that can be both farmed and wild.
- **Production method**: the conventional farming method, IMTA and CCA farming methods, and the wild production method were presented as levels of the production method attribute.
- **Eco-certification** (represented with a generic label): eco-certification may affect the consumers’ utilities for salmon. While eco-certification for wild salmon exists, eco-certification for farmed salmon is limited and may become more popular as sustainable technologies for salmon farming become available.

- **Country of origin**: the consumers' perception and utility for salmon may change depending on its source, as they may feel that certain countries produce salmon of greater quality than other countries or they may prefer local to foreign products.
- **Price per pound**: the price of salmon was a necessary attribute in the DCE as the estimated coefficients of the price attribute serve as the denominator in the WTP estimation procedure (Equation 1). The average market price of each species was collected during field visits and used as the reference price in the DCE.

These attributes were also selected because they are commonly shown on price tags of fish products sold in the US. However, design of the DCE was made more complicated by conflicts among levels of the different attributes. For instance, Sockeye salmon cannot be farmed; therefore, these two levels across the species and production method attributes cannot be presented together. Additionally, the reference prices are different across each species (e.g. King salmon are much more expensive than Atlantic salmon). We decided to design attribute levels specific to the species, but use an unlabelled DCE so that a species could be presented more than once in a given choice set (Table 2). Furthermore, all wild salmon profiles were presented as "previously-frozen" salmon, while all farmed salmon profiles were presented as "fresh" salmon. "Fresh wild salmon" was not included as it is only available seasonally and is not a year-round substitute for farmed salmon.

Visual images of the salmon were considered and later discarded due to the added complexity and the possible biases it would introduce to the exercise. Respondents were also asked to assume that the cut of the salmon "suit their preferences". The final design displayed three product profiles with a ‘none’ option (Figure 1). The product profiles appeared as price tags similar to what a consumer would see when they purchase salmon at a supermarket.

Information Treatments

We incorporated two treatments to explore impacts on consumer perceptions and WTP from exposure to different descriptions and sequences in the presentation of IMTA and CCA, as indicated below.

- **Sequence of production technologies:** the attitudes toward and WTP for each technology may be affected by the order in which each technology is presented to the respondent. We explored such impacts by partitioning the sample, with half of the respondents presented IMTA first and the other half presented CCA first.
- **Information provided for each production technology**: two options were considered; in the first option, respondents were offered a ‘two-sided’ information treatment that included general descriptions of both the positive and negative environmental impacts of each technology (Depositario et al. 2009). In the second option, the descriptions were presented in a more “favorable” light with only positive environmental impacts.

Presenting either the “balanced” or “favorable” descriptions can influence perceived utility and the final WTP estimate.[3] A lack of studies exploring appropriate information treatments motivated us to partition the sample a second time, so that half of the respondents were presented the “balanced” description, while the other half saw the “favorable” description. To avoid bias,

[3] In a WTP study for golden rice, the mean WTP was higher with positive information > no information > negative information > two-sided information, while a study for biotech foods showed greater WTP bids with positive > two-sided > negative information (Tegene et al., 2003; Depositario et al., 2009)

we segmented the sample such that respondents always saw the same type of description for both technologies.

Survey sample design

The target population consisted of all salmon consumers residing in Seattle, Portland and San Francisco. These cities were chosen as they are the major cities located in the three US states that import most of BC's farmed salmon products. We employed a market research company to recruit and deliver the survey's online link to a representative sample from their respondent database. Those who completed the survey received reward points from the company. Respondents were screened out if they did not live in the targeted cities, if they were not the primary or secondary grocery shoppers in their household, or if they had not consumed salmon at home over the past year. Restaurant consumption of salmon was not included in the study as it represents a different and smaller share of the salmon market. The sample was monitored and controlled for representativeness from each city and for gender proportions to ensure a sufficient number of male respondents. We also eliminated respondents who completed the survey in less than 6 minutes or more than one hour, and those who answered the same option in the DCE more than four times consecutively.

Results and Discussion

A total of 4653 respondents opened the survey and the completion rate was 44.4% (n=2067). Furthermore, 355 respondents were screened out from the 2067 completed responses for the reasons indicated in the previous section to reach a total sample size of 1712 respondents.

The final data used for the analysis were based on a sample of 1631 verified completed responses after further screening for the quality of DCE responses. In the following sections we discuss the responses to our attitudinal questions and then consider the results from the DCE and LCA. We next estimate the WTP values and price premiums derived from our model and finally consider the findings on eco-certification in association with or without more sustainable aquaculture technology.

Responses to attitudinal questions

When asked about their preferences for either wild or farmed salmon, 64.6% of the respondents indicated that they prefer wild over farmed salmon, 4.2% preferred farmed over wild salmon, 28.9% had no strong preference, and 2.3% indicated “don’t know”. The respondents who preferred wild salmon believed that wild salmon were more natural, healthy, eco-friendly and tasted better than farmed salmon, while respondents who preferred farmed salmon believed that farmed salmon was more available, tastes better and is cheaper. Moreover, respondents could also specify their own reasons; those who specified a preference for wild salmon were concerned about salmon farming’s environmental problems, while those who specified a preference for farmed salmon believed that the consumption of wild salmon leads to wild stock depletion and overfishing.

We asked respondents if they were aware of the environmental concerns of conventional salmon aquaculture presented in common media. While 45.2% of the respondents said they knew about the environmental concerns of salmon aquaculture, more than half of the respondents (51.9%) indicated that they were not aware, while the remainder (2.9%) were not sure if they knew about the environmental concerns. The awareness of IMTA and CCA were both low, but substantively more respondents had heard of CCA (20.2%) than IMTA (7.0%).

Since the sample was partitioned in two ways, first to allow for a differing sequence of technology descriptions (IMTA first or CCA first), and second to offer different descriptions of the technologies (favorable or balanced), we analyzed the sample aggregately and then compared the results across the four segments. Respondents were asked to express their attitudes toward IMTA and CCA immediately after each technology was presented. The responses were coded on a scale of 1 to 5, where 1 was "Very negative", 5 was "Very positive" and "Don't know" was coded as a missing response. Results of the paired sample *t*-test showed that the total sample felt significantly more positive towards IMTA ($M = 3.68$, $SD = 0.965$) than CCA ($M = 3.15$, $SD = 1.109$), with $t\ (1350) = 16.753$ ($p < 0.05$, $d = 0.46$). Thus, our sample in aggregate felt more positively toward IMTA than CCA (Table 3).

Overall, the comparisons of the attitudes toward both technologies across the four segments revealed that the differing sequences of the technology presentation affected the sample's attitude toward CCA but not IMTA, while the different types of description for both technologies led to different attitudinal results. Specifically, individuals who saw the favorable descriptions had a more positive attitude toward both technologies than those who saw the balanced descriptions. Finally, all segments had more positive attitudes toward IMTA than CCA, which corresponded to a more positive attitude toward IMTA than CCA in the aggregate sample.

Results from the latent class analysis (LCA)

The DCE data were analyzed with the software package Latent Gold, allowing us to explore the data using known class analysis and latent class analysis. None of the known class analyses yielded encouraging results, so we focused on the latent class analysis (LCA) using information from the latter to estimate the WTP for each latent class in addition to the aggregate sample. Below we discuss the part-worth utility results from the LCA model, followed by the descriptions of the latent classes and conclude with the WTP estimates for production technologies and eco-certification.

Results of the LCA for 1 to 5 classes confirmed the presence of heterogeneous preferences in the sample.[4] The 3-class model was determined to be the best-fit model for the data as it had the lowest BIC, AIC, and AIC3 statistics amongst the stable models (**Error! Reference source not found.**). The $R^2(0)$ and R^2 confirmed the goodness-of-fit for the 3-class model, as estimates between 0.2 and 0.4 are indicative of a good model fit (Louviere et al. 2000). In the 3-class model, 45% (n=727) of the respondents belonged to the first class, 29% (n=472) to the second class, and 26% (n=432) to the third class. The estimated coefficients of all attributes were significant at the 5% level, while significant differences among latent classes were found with the coefficients of the following attributes: salmon species, the production methods of Atlantic and King salmon, eco-certification for Sockeye salmon, the origin of Sockeye and King salmon, and the prices of all three species (Table 5).

[4] Interaction effects were explored in the LCA but minimal benefits to explanatory power was found. I concluded that the linear 3-class without interaction model was the best fit model in my analysis.

The characteristics of each latent class based on the results of the LCA and the covariate analysis are discussed below:

- ***Class 1: Wild Salmon Lovers:*** Members of class 1 were labelled as the “wild salmon lovers” because of their strong preferences for Sockeye salmon and wild King salmon. In the case of farmed Atlantic salmon, the wild salmon lovers preferred IMTA over the other production methods. Their preference toward IMTA salmon can be explained by their more positive attitude toward IMTA (M=3.41) than CCA (M=2.84).
- ***Class 2: Price-Sensitive Consumers:*** Class 2 was the most price-sensitive class among the three classes and, therefore, was labelled the “price-sensitive consumers”. The price-sensitive consumers also preferred IMTA for both King and Atlantic salmon, which was explained by their more positive attitude toward IMTA (M=3.84) than CCA (M=3.29).
- ***Class 3: Sustainably Farmed Salmon Supporters:*** Class 3 found greater utility in farmed salmon than wild salmon, which was opposite to that of the wild salmon lovers, who preferred Sockeye and wild King salmon. Further, class 3 was the only class to prefer eco-certification for all three species. Some respondents believed that the consumption of wild salmon contributes to wild stock depletion, which is a possible reason for this class’s preference for farmed salmon. In general, members of this group preferred IMTA (M=3.93) to CCA (M=3.48). They also felt significantly more positive toward IMTA and CCA compared to the other classes.

All three classes preferred IMTA over CCA and conventional methods for Atlantic salmon. These results mirror the more positive attitude toward IMTA than CCA seen in the attitudinal question responses, as well as the overwhelming preference for IMTA when respondents were asked to choose between the two technologies (Table 6).[5] The wild salmon lovers and sustainably farmed salmon supporters both experienced greater utility from salmon originating from the US, indicating that they preferred to buy local salmon. On the other hand, the origin was not as important for the price-sensitive consumers, as they did not have a strong preference for either Canada or US as the origin for their Sockeye and King salmon.

Finally, we explored the influences in part-worth utility from the sample partitioning exercises using a known class analysis. No significant differences were found between the known classes in each of the treatments. While the type of technology description (favorable or balanced) affected the initial perception of the technologies, the difference in attitudes did not translate into differences in choice, part-worth utility or WTP for the product attributes across classes.

WTP Estimates and Price Premiums for IMTA and CCA salmon

Tthe price attributes approximated negative, linear relationships between utilities and prices among all species and latent classes, meaning that utility decreases as the price of salmon increases and confirming the theoretical validity of our DCE results. We calculated the price premiums that the respondents were willing to pay for one pound of Atlantic salmon produced by IMTA or CCA, relative to the price they were willing to pay for one pound of conventionally produced Atlantic salmon (Table 7). We focused on the results for Atlantic salmon as it is the primary product of the BC aquaculture industry. The results of the 1-class analysis revealed that the sample, as a whole, was willing to pay a premium of USD $1.07/lb for IMTA salmon and a

[5] 722 respondents (44.3%) chose IMTA while only 265 respondents (16.2%) chose CCA when asked to choose one method to replace conventional aquaculture.

premium of USD $0.43/lb for CCA salmon in comparison to conventionally farmed salmon. These estimates can be expressed as price premiums of 9.8% and 3.9% for IMTA and CCA Atlantic salmon, respectively, using USD $10.99/lb as the reference price for conventionally produced Atlantic salmon.

The 3-class model results revealed price premium differences among the three latent classes. Most notably, the wild salmon lovers were willing to pay 41.7% more for IMTA salmon at USD $4.58/lb. CCA, on the other hand, did not enjoy the same premium over conventional salmon. The price premiums for CCA Atlantic salmon were not much higher than zero in the 3-class latent class model. Moreover, the sustainably farmed salmon supporters were not willing to pay a positive price premium for CCA salmon. These results indicate that while members in this class were concerned about the environmental problems of salmon production and desired eco-certification for all species, they did not think CCA was significantly more environmentally friendly than conventional aquaculture. The pronounced heterogeneity among salmon consumers in the 3-class LCA model indicates that the salmon aquaculture industry needs to target consumer segments when marketing their products.

Not surprisingly, a comparison of the WTP estimates also revealed a higher price premium for IMTA compared to CCA. All three classes identified in the latent class model were willing to pay a higher price premium for Atlantic salmon produced with IMTA than for Atlantic salmon produced with CCA. The limited premium for CCA Atlantic salmon revealed a conservative consumer attitude toward CCA. Moreover, the absence of a WTP a price premium for CCA suggested that any added operating costs associated with this technology might not be recouped by charging a higher price to consumers.

In addition, we compared our WTP results to other WTP studies related to IMTA and CCA. Barrington et al. (2008) found that participants in focus groups were willing to pay a 10% premium for labelled IMTA seafood products.[6] An attitudinal study in New York revealed that 38% of the respondents were willing to pay 10% more for IMTA mussels compared to conventionally produced mussels (Shuve et al., 2009). Using a payment card method, Kitchen (2011) revealed a willingness to pay for a 24% to 36% premium for IMTA oysters compared to conventionally produced oysters from oyster consumers in San Francisco. While WTP studies for CCA salmon has not been found, a feasibility study of closed containment options for the BC salmon aquaculture industry suggested that salmon produced by a version of closed-containment system may generate a premium of CAD $0.33/kg (CAD $0.73/lb) compared to conventionally produced salmon (DFO, 2010).[7] These results were very similar to and provided strong support for the WTP premiums we found for IMTA and CCA salmon.

The results of the known class analyses also revealed that information treatments did not alter stated WTP, but favorable descriptions led to slightly more positive attitudes toward both IMTA and CCA. We were very explicit when describing the limitations of each technology in the "balanced descriptions", stating that "IMTA does not address escapes by farmed salmon and may not significantly reduce the infestation of wild salmon by sea lice" and that "CCA requires a significant amount of energy and could face issues related to land use and waste disposal". Yet, the minimal WTP impacts from the description treatment suggested that revealing the methods' environmental limitations will not affect the perceived utility of consumers as reflected by

[6] Participants of their focus group came from several segments of the population, including restaurateurs, residents of communities near aquaculture facilities, and the general population from New Brunswick, Canada (Barrington et al, 2008).
[7] The suggested premium for CCA salmon was based on suggestions of "subject matter experts" ranging from independent consultants and individuals from consulting firms, environmental advocacies, research groups, and salmon farming associations (DFO, 2010).

insignificant results in the *a priori* analysis with the information treatment variables. Given these results, marketers can expect a positive reaction and a WTP a price premium for IMTA salmon (and to a lesser extent CCA, at least in some market segments), even when the systems' limitations are explained.

Our study assumed that IMTA and CCA salmon will be labelled explicitly so that consumers can differentiate between the production methods, much like how wild and farmed salmon are distinguished currently at the time of sale. The potential demand and estimated premiums associated with IMTA salmon cannot be realized without appropriate labelling and marketing by the industry. As discussed by Wessells et al. (1999), educating the public about the environmental issues of aquaculture and the need for sustainable seafood consumption was identified as a priority for the industry and policy makers if they want to realize the market potential for IMTA salmon. Furthermore, with the introduction of IMTA and CCA salmon, 38.4% of the respondents indicated they would buy farmed salmon more frequently. Those who would buy more often would do so, on average, 5.87 times more per year (median = 4). These results suggest that the presence of IMTA and CCA would have a non-trivial but limited impact on consumer demand for salmon.

Finally, we should be mindful that charging a premium to the consumers does not guarantee additional funds to producers in Canada. Knapp et al. (2007) found that industry operators were paid only $0.59 per pound of salmon when consumers paid $15.99 per pound. Markups are charged by many participants in the U.S. salmon distribution system, including primary processors, importers, secondary distributors, brokers, traders, and many different kinds of retail and food service companies (Knapp et al., 2007). Therefore, ensuring a substantive share of any price premium flows to producers will help encourage sustainable aquaculture technology adoption in the BC salmon industry.

WTP Estimates and Price Premiums for Eco-certification

We also calculated the premiums that the full sample and individual latent classes were willing to pay for eco-certification of each species (Table 8). The 1-class analysis revealed that the sample as a whole was willing to pay premiums for eco-certification of all three species. The premiums for eco-certification of Atlantic, Sockeye, and King salmon were USD $0.51/lb (4.6%), USD $0.12/lb (1.0%), and USD $0.36/lb (2.3%), respectively.[8]

Each class enjoyed greater utility when the least preferred salmon species was certified and, therefore, was more willing to pay a higher premium for eco-certification of the species they favoured the least. Specifically, the wild salmon lovers were willing to pay a premium of USD $2.39/lb for eco-certification of Atlantic salmon, the price-sensitive consumers were willing to pay a premium of USD $0.35/lb for eco-certification of King salmon, and the sustainably farmed salmon supporters were willing to pay a premium of USD $3.04/lb for eco-certification of Sockeye salmon. The significant premiums estimated for the wild salmon lovers and the sustainably farmed salmon supporters indicated greater concerns about the environmental issues related to farmed Atlantic and wild Sockeye salmon, respectively.[9] The low premiums for the price-sensitive consumers, on the other hand, could be expected as this group was much more price-sensitive than the other classes. Finally, the price-sensitive consumers were unwilling to

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8 The percentage premiums were calculated as the percentage increase from the reference prices for each species: Atlantic at $10.99/lb, Sockeye at $11.99/lb, and King at $15.99/lb.

9 The sustainably farmed salmon supporters may believe that eating wild salmon contributes to the depletion of wild salmon stock, which is also a belief known to be common to some individuals in society (Grescoe, 2008).

pay a premium for eco-certification of Sockeye salmon, which indicated that they had very few concerns about the environmental impacts of wild salmon production.

Our results confirmed other study findings of increases in utility from eco-labels in sustainable foods (Wessells et al., 1999; Onyango et al., 2005; Olesen et al., 2010). Canadian salmon exporters and policy makers should consider the development of an eco-certification program to differentiate and increase the attractiveness of sustainable products. The price premiums identified can be used to analyze whether or not the costs of future eco-certification program will be covered by consumers, and whether or not monetary subsidies are needed to encourage sustainable aquaculture development.

Conclusion

We study addressed a gap in the literature relating to the attitudes, preference and WTP for Integrated Multi-Trophic Aquaculture (IMTA) and Closed Containment Aquaculture (CCA), the two sustainable salmon farming methods under discussion by Canadian policy makers and the salmon farming industry. Two research questions were posed: (1) how do salmon consumers in the US Pacific Northwest perceive the products of IMTA and CCA, with or without eco-certification, and in comparison to salmon products from other sources (wild or farmed); and, (2) what are salmon consumers in the US Pacific Northwest willing to pay for salmon produced by IMTA or CCA and is there significant evidence of preference heterogeneity? We surveyed salmon consumers in the Pacific Northwest region of the US and used a discrete choice experiment (DCE) and latent class analysis (LCA) to elicit their preferences and estimate their WTP for the methods presented.

We found that consumers had a more positive perception towards IMTA compared to CCA. Information differences did not alter their relatively more positive preference for IMTA compared to CCA. While the respondents perceived both methods as environmentally friendly, 70% of the respondents who chose IMTA felt that it was more natural than CCA. Moreover, our results revealed that consumers from the traditional markets for BC farmed salmon in the US Pacific Northwest were willing to pay a 9.8% premium for IMTA over conventionally produced Atlantic salmon. On the other hand, the sample was only willing to pay a 3.9% premium for CCA over conventionally produced Atlantic salmon. A closer look at the latent class results identified price premiums ranging from 3.5% to 41.6% for IMTA over conventionally produced Atlantic salmon. CCA enjoyed only modest price premiums and a 1.0% compensation (or price reduction) was needed for the sustainably farmed salmon supporters to accept Atlantic salmon produced with CCA.

Finally, our study revealed that the majority of salmon consumers were aware of the environmental concerns surrounding conventional salmon farming and 63.5% of them were supportive of adopting a more sustainable salmon farming method even if it is more expensive. Most importantly, the majority of salmon consumers are willing to pay a premium for reduced impacts from the aquaculture industry on ecosystem services provided by the marine environment. While IMTA and CCA both have environmental advantages and limitations, IMTA was a much more preferred option over CCA when both were presented and evaluated by salmon consumers at the same time. Such results may indicate that consumers believe IMTA is more effective in reducing environmental impacts than CCA. Lastly, IMTA and CCA products need to be labelled and the methods need to be communicated explicitly to the consumers for the industry to realize a price premium. Hopefully, our results will contribute to further financial feasibility analysis and the overall business case for adoption of more sustainable salmon farming methods.

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Table 1. DCE Attributes and Levels

Attribute	Levels
Species	Atlantic Salmon; Sockeye Salmon; King Salmon
Production Method	Conventionally Farmed; Farmed in IMTA; Farmed in CCA; Caught wild
Country of Origin	Canada; USA; Chile; Norway
Eco-Certification	Yes; No
Price	Reference price; Reference – 30%; Reference + 30%; Reference + 60%

Table 2. DCE Attributes and Levels by Species

	Atlantic Salmon	Sockeye Salmon	King Salmon
Production Method	• Conventionally Farmed • Farmed in IMTA • Farmed in CCA	• Wild	• Conventionally Farmed • Farmed in IMTA • Farmed in CCA • Wild
Country of Origin	• Canada • USA • Chile • Norway	• Canada • USA	• Canada • USA
Certification	• Yes • No	• Yes • No	• Yes • No
Price / lb	• $7.99 • $10.99 • $14.99 • $17.99	• $8.99 • $11.99 • $15.99 • $19.99	• $11.99 • $15.99 • $20.99 • $25.99

Note: The reference price was the average market price selected based on a review of the observed prices of salmon sold in supermarkets and available data of farm gate prices. The final price levels of our survey were tested rigorously to ensure that the DCE was realistic and that the respondents were responsive to the prices set in the DCE through pretests.

Table 3. Attitudes toward IMTA and CCA of the Full Sample and Segments based on a Rating Scale of 1 (Very negative) to 5 (Very positive)

	Total Sample	Segment 1 IMTA first Favorable n = 397 (A)	Segment 2 IMTA first Balanced n = 417 (B)	Segment 3 CCA first Favorable n = 406 (C)	Segment 4 CCA first Balanced n = 411 (D)	Sig. Level
Attitudes toward IMTA	3.68 (3.63 - 3.73) n = 1421	3.86 (3.77 - 3.95) n = 344 **B D**	3.59 (3.50 - 3.69) n = 361 **D**	3.88 (3.78 - 3.98) n = 361 **B D**	3.40 (3.29 - 3.50) n = 355	<0.001
Attitudes toward CCA	3.15 (3.09 - 3.21) n = 1428	3.14 (3.02 - 3.25) n = 352 **B**	2.88 (2.77 - 3.00) n = 364	3.50 (3.39 - 3.60) n = 358 **A B D**	3.09 (2.97 - 3.21) n = 354	<0.001

*Sample sizes for each segment and total sample were different due to missing responses.
Results of the comparison of column means are based on the one-way between subjects analysis of variance (ANOVA) test. The Tukey's post hoc procedure assuming equal variances (0.05 significance level) was used for attitudes toward CCA. The Brown-Forsythe test and Dunnett's T3 post hoc procedure were used for attitudes toward IMTA, as the Levene's test indicated that the variable's variances were not equal. For each significant pair, the key of the smaller category (A, B, C or D) appears under the category with the larger mean.

Table 4. Results of the Goodness-of-Fit Tests for the Latent Class Analysis based on the 1 to 5 Class Models

	LL	BIC(LL)	AIC(LL)	AIC3(LL)	$R^2(0)$	R^2
1-class	-15338.31	30817.1671	30714.6250	30733.6250	0.1467	0.1311
2-class	-13678.25	27689.3704	27446.5077	27491.5077	0.3118	0.2988
3-class	-13224.30	26973.7896	26590.6063	26661.6063	0.3631	0.3511
4-class	-12876.57	26470.6353	25947.1313	26044.1313	0.3940	0.3826
5-class	-12630.75	26171.3331	25507.5084	25630.5084	0.4256	0.4148

Table 5. Part-Worth Utility Estimates based for the Latent Class Model (3-Class Solution) for the latent classes by Salmon Species

	Wild salmon lovers n=727	Price-sensitive consumers n=472	Sustainably farmed salmon supporters n=432	Wald p-value	Wald(=) p-value
Atlantic Salmon	-1.8985 (0.0883)*	0.3364 (0.0829)*	0.6079 (0.0478)*	<0.001	<0.001
Production Method					
Conventional	-0.4502 (0.1556)*	-0.284 (0.0799)*	-0.0345 (0.0637)	<0.001	<0.001
IMTA	0.8572 (0.1272)*	0.3004 (0.0676)*	0.1138 (0.0538)**		
CCA	-0.407 (0.1672)**	-0.0163 (0.0868)	-0.0792 (0.0617)		
Eco-certification					
No	-0.342 (0.0864)*	-0.1106 (0.0545)**	-0.1987 (0.0409)*	<0.001	0.087
Yes	0.342 (0.0864)*	0.1106 (0.0545)**	0.1987 (0.0409)*		
Origin					
Canada	0.1705 (0.1323)	0.3706 (0.0847)*	0.1043 (0.0693)		
USA	0.8915 (0.1213)*	0.4688 (0.0927)*	0.7942 (0.0696)*	<0.001	0.110
Chile	-0.9074 (0.1717)*	-0.5297 (0.0851)*	-0.6401 (0.0768)*		
Norway	-0.1545 (0.1769)	-0.3097 (0.0964)*	-0.2585 (0.071)*		
Price	-0.2857 (0.0899)*	-1.1638 (0.0756)*	-0.3907 (0.0469)*	<0.001	<0.001
Sockeye Salmon	2.0518 (0.0602)*	0.8409 (0.0679)*	-0.9071 (0.063)*	<0.001	<0.001
Eco-certification					
No	-0.0297 (0.0311)	0.1677 (0.0485)*	-0.3016 (0.0721)*	<0.001	<0.001
Yes	0.0297 (0.0311)	-0.1677 (0.0485)*	0.3016 (0.0721)*		
Origin					
Canada	-0.245 (0.0307)*	0.1341 (0.0487)*	-0.2023 (0.0708)*	<0.001	<0.001
USA	0.245 (0.0307)*	-0.1341 (0.0487)*	0.2023 (0.0708)*		
Price	-0.5233 (0.0318)*	-1.0302 (0.058)*	-0.1987 (0.0674)*	<0.001	<0.001
King Salmon	-0.1534 (0.0519)*	-1.1773 (0.105)*	0.2992 (0.0467)*	<0.001	<0.001
Production Method					
Wild	1.9777 (0.0786)*	-0.0535 (0.1669)	-1.0207 (0.1004)*		
Conventional	-0.9367 (0.1043)*	-0.0317 (0.1604)	0.3112 (0.0748)*	<0.001	<0.001
IMTA	0.0844 (0.0745)	0.2172 (0.1442)	0.363 (0.0729)*		
CCA	-1.1254 (0.1002)*	-0.132 (0.1717)	0.3464 (0.0723)*		
Eco-certification					
No	-0.1027 (0.0424)**	-0.2345 (0.0741)*	-0.0978 (0.0431)**	<0.001	0.270
Yes	0.1027 (0.0424)**	0.2345 (0.0741)*	0.0978 (0.0431)**		
Origin					
Canada	-0.2789 (0.049)*	0.1256 (0.1163)	-0.2536 (0.0446)*	<0.001	<0.001
USA	0.2789 (0.049)*	-0.1256 (0.1163)	0.2536 (0.0446)*		
Price	-0.523 (0.0374)*	-1.3511 (0.0917)*	-0.5239 (0.0374)*	<0.001	<0.001
Intercept	-0.0664 (0.0734)	0.2223 (0.1689)	0.1524 (0.0819) ***	<0.001	<0.001

* Significantly different from a parameter estimate of 0 at the 1% level
** Significantly different from a parameter estimate of 0 at the 5% level
*** Significantly different from a parameter estimate of 0 at the 10% level
( ) represents standard error; significance of coefficients are explained by the Wald p-value, while significance between classes are explained by the Wald(=) p-value; Note: the model has been estimated as an alternative specific model by salmon species: Atlantic, Sockeye and King Salmon, estimates are organized accordingly.

Table 6. Preference toward IMTA or CCA for the Full Sample and Segments based on a Rating Scale of -2 (Much more prefer CCA) to 2 (Much more prefer IMTA)

	Total Sample n = 1426	Segment 1 IMTA first Favorable n = 353 (A)	Segment 2 IMTA first Balanced n = 365 (B)	Segment 3 CCA first Favorable n = 358 (C)	Segment 4 CCA first Balanced n = 350 (D)	Sig. Level
Technology Preference	0.45 (0.39 - 0.50)	0.57 (0.46 - 0.68) **D**	0.43 (0.32 - 0.54)	0.47 (0.36 - 0.57)	0.32 (0.21 - 0.43)	0.016

*Responses based on scale of -2 to 2; -2 = Much more prefer CCA, -1 = Somewhat prefer CCA, 0 = Indifferent, 1 = Somewhat prefer IMTA, 2 = Much more prefer IMTA; Don't knows are coded as missing.
Figures in parentheses are the lower and upper bounds based on a 95% confidence interval for the mean.
Results of the comparison of column means were based on the one-way between subjects analysis of variance (ANOVA) test. The Tukey's post hoc procedure assuming equal variances (0.05 significance level) was used. For each significant pair, the key of the smaller category (A, B, C or D) appears under the category with the larger mean.

Table 7. WTP Price Premiums for IMTA and CCA Produced Atlantic Salmon versus Conventionally Produced Atlantic Salmon: 1-Class and 3-Class (LCA) Model Results

Production Methods	1-Class model	3-Class model		
		Wild salmon lovers	Price-sensitive consumers	Sustainably farmed salmon supporters
IMTA	$1.07	$4.58	$0.50	$0.38
CCA	$0.43	$0.15	$0.23	-$0.11

Note: All prices expressed in USD dollar per lb of salmon

Table 8. WTP Premiums for Eco-certification of Atlantic, Sockeye, and King Salmon: 1-Class and 3-Class (LCA) Model Results

Eco-certification for Species	1-class model	3-class model		
		Wild salmon lovers	Price-sensitive consumers	Sustainably farmed salmon supporters
Atlantic	$0.51	$2.39	$0.19	$1.02
Sockeye	$0.12	$0.11	-$0.33	$3.04
King	$0.36	$0.39	$0.35	$0.37

Note: All prices are n USD/lb

Figure 1. Sample Choice Set from the DCE Presented to Respondents