AN ECONOMIC ANALYSIS OF SHELLFISH PRODUCTION ASSOCIATED WITH THE ADOPTION OF INTEGRATED MULTI-TROPHIC AQUACULTURE IN BRITISH COLUMBIA

by

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Abstract

Integrated Multi-Trophic Aquaculture (IMTA) combines fed aquaculture (finfish) with extractive aquaculture (shellfish and seaweeds) at a single site to recycle nutrient waste while producing marketable seafood products. If finfish monoculture operations adopt IMTA widely, it could result in a significant increase in the production of extractive aquaculture products. The study explores the market implications associated with an increase in shellfish aquaculture production from IMTA adoption by finfish monoculture operations in British Columbia (BC), Canada. The study poses three main research questions: (1) on the supply side, by how much could IMTA shellfish production augment existing shellfish production from BC, (2) on the demand side, how might consumers of BC shellfish view the IMTA concept and value IMTA shellfish products, and (3) what could be the potential market implications of IMTA adoption on the west coast for the BC oyster industry? The study considers the possibility of oyster production associated with IMTA adoption by BC salmon farmers to address these research questions. Results of a production scenario analysis demonstrate that IMTA adoption can augment BC oyster production by between 9% and 237%, depending upon the number of BC salmon farms that adopt IMTA and the production quantity per farm. Results of a consumer intercept survey reveal that consumers of BC oysters in San Francisco have a positive perception of IMTA and the majority of respondents would be willing to pay a premium for IMTA oysters. IMTA oyster production in BC could substantially augment the market supply from BC, requiring a reduction in price to increase the quantity demanded or ways would need to be found to increase demand. New market opportunities could be developed in Asian countries, which require substantial enough volumes of production to be viable.

Keywords: Integrated Multi-Trophic Aquaculture; aquaculture economics; British Columbia aquaculture; shellfish aquaculture; willingness to pay; consumer perception

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Chapter 1: Introduction

With declining capture fisheries production and increasing demand for seafood, aquaculture has come to supply a growing percentage of global seafood. However, with the emergence of industrial marine aquaculture have come growing concerns around the environmental impacts of aquaculture practices and processes. In response, sustainable aquaculture techniques have been proposed to mitigate the environmental impacts of conventional aquaculture production (Costa-Pierce, 2002). Integrated Multi-Trophic Aquaculture (IMTA) represents a form of sustainable aquaculture that involves raising a variety of species from different trophic levels at one site as a means of mitigating nutrient loading associated with finfish monoculture. With the addition of other species to a finfish site, there could be increased production of extractive aquaculture production, which will have economic implications for existing industries that must be considered.

1.1 Problem Statement

Integrated Multi-Trophic Aquaculture (IMTA) represents a type of sustainable aquaculture that has the potential to mitigate some of the negative environmental impacts associated with conventional finfish aquaculture. IMTA integrates fed aquaculture (e.g. finfish) with extractive aquaculture (e.g. shellfish and seaweeds) for a more balanced ecosystem approach that reduces the nutrient loading from finfish monoculture operations (Chopin et al., 2008). By growing extractive species from lower trophic levels in close proximity to existing finfish aquaculture pens, the species can consume a portion of the nutrient waste from the finfish, effectively reducing the environmental impact of the finfish operation. Existing finfish operations can adopt

IMTA by retrofitting their operations with the addition of extractive aquaculture production on site.

To the extent that finfish farms adopt an integrated system that involves the production of new products, such as IMTA shellfish and seaweeds, the volume of fish produced need not necessarily change. However, the production of extractive aquaculture products (i.e. shellfish, seaweeds, deposit feeders) on site could increase, depending on the origin of the shellfish component, and lead to an overall increase in the volume of product supplied to market.[1] An increase in production and supply will have implications for the existing markets for those goods as well as the industries supplying those goods. A review of the literature revealed that no study on IMTA to date has considered the potential market implications of extractive aquaculture production associated with IMTA adoption.

To exhaustively consider the potential for, and consequences of, IMTA adoption, the market implications associated with the production of IMTA extractive aquaculture species must be considered. The purpose of the study is to understand the economic and market implications of increased shellfish production associated with the adoption of IMTA by finfish farmers.

1.2 Case Study

This case study addresses the gap in knowledge using the case study of IMTA adoption by salmon farmers in BC, and the associated production of shellfish aquaculture products, specifically Pacific oysters (*Crassostrea gigas)*, hereafter referred to as oysters. British Columbia's west coast is a prime candidate for IMTA adoption, as it possesses existing salmon aquaculture operations, suitable environmental conditions, as well as public pressure for more sustainable aquaculture practices. Additionally, IMTA is currently practiced at one site on the

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[1] The assumption is that all IMTA extractive aquaculture production is incremental. Existing extractive aquaculture operations do not relocate to merge with finfish farms. The prospects for this option are discussed later.

west coast (Kyuquot SEAfoods) and widespread adoption is possible. Pacific oysters were selected as the representative shellfish species because an established oyster aquaculture industry exists in BC with stable distribution channels, standardized farming methods and strong international markets. Additionally, oysters are by far the largest shellfish product in terms of volume and value in BC (DFO, 2010). Economic and market implications associated with increased oyster production resulting from IMTA adoption by salmon farmers are explored to understand the general impact such an event might have. No west coast IMTA market analyses have been conducted to date which represents another knowledge gap that is addressed through this study.

1.3 Research Questions

The study investigates the potential market implications associated with increased oyster production from IMTA adoption by salmon monoculture operations. The three research questions are:

Research Question #1: On the supply side, how could IMTA adoption augment oyster production in BC?

Research Question #2: On the demand side, how might consumers of BC shellfish view the IMTA concept and value IMTA shellfish products?

Research Question #3: What could be the potential market implications of IMTA adoption on the west coast for the BC oyster industry?

1.4 Research Objectives and Approach

To answer these questions, the research objectives and approach are as follows:

Objective #1: Estimate the potential increase in production of BC oysters as a result of the IMTA adoption by BC salmon farmers.

I develop a production scenario analysis to determine how IMTA oyster production could augment current BC oyster production. A representative IMTA oyster component is designed to estimate IMTA oyster production volume per site. Data sources include literature on BC oyster production as well as information and parameters supplied by interviewees. The production volume of IMTA oysters will depend on a number of variables including the production volume per IMTA farm and the number of salmon farms that adopt IMTA. These variables are considered in the analysis and a range of outcomes are presented as part of a sensitivity analysis.

Objective #2: Understand the consumer perception of the IMTA concept and IMTA oysters.

I determine how consumers perceive the IMTA concept and value IMTA oysters through a survey of oyster consumers in a major BC oyster export market (San Francisco).

Objective #3: Understand and draw conclusions about the potential market implications of IMTA adoption on the west coast for the BC oyster industry.

I aim to integrate the findings from the literature review, interviews with stakeholders, the production scenario analysis, and the consumer survey to draw conclusions about the market implications of IMTA oyster production in BC associated with IMTA adoption.

1.5 Scope of the Study

The market implications will be different for each extractive aquaculture species due to different market and industry characteristics. The scope of the study presented here is limited to the case study of IMTA adoption at BC salmon farm sites and consequent increased production of IMTA oysters. However, general insights can be gathered from this analysis and applied to other IMTA extractive aquaculture products.

1.6 Organization of the Study

In Chapter 2, I review the existing literature on sustainable aquaculture, integrated aquaculture systems, IMTA and specifically the economics of IMTA. In Chapter 3, I provide background for the study including a description of IMTA and the BC aquaculture industry (specifically salmon and oyster industries). In Chapter 4, I present the methodology used for the production scenario analysis and consumer survey. In Chapter 5, I present the results of the supply side analysis (production scenario analysis) and the results of the demand side analysis (oyster consumer perception survey). In Chapter 6, I integrate the findings from the study and discuss potential market implications of increased oyster production associated with IMTA adoption in BC. In Chapter 7, I conclude the study with a summary of the key research findings and final thoughts.

Chapter 2: Literature Review

The literature review addresses the emergence of sustainable aquaculture and integrated aquaculture systems as an alternative to conventional single species aquaculture. IMTA is discussed as a form of integrated aquaculture with a focus on research to date on the economics of IMTA. The review highlights the knowledge gap related to the economic and market implications of extractive aquaculture production associated with the IMTA adoption. Additionally, the review reveals that no west coast IMTA market analyses have been conducted to date which represents another contribution of this study to the literature.

2.1 Sustainable Aquaculture

While aquaculture can provide significant benefits to society, the negative environmental impacts of conventional marine aquaculture have received considerable attention in the literature. In response to the criticisms directed towards conventional marine aquaculture, the idea of sustainable aquaculture has emerged. Recognizing the importance of aquaculture as well as the environmental impact of some forms of aquaculture, a substantial amount of literature has highlighted sustainable alternatives to address the issues associated with marine aquaculture (Chopin et al., 2008; Soto et al., 2008; Neori et al., 2007; White, O'Neill, & Tzankova, 2004; Neori et al., 2004; Frankic & Hershner, 2003; Costa-Pierce, 2002; Naylor et al., 2000; Wurts, 2000).

Sustainable aquaculture does not have one simple definition; rather it is a complex concept with numerous facets. However, Muir (2005) argues that most definitions of sustainability consider three core issues; intergenerational equity, intragenerational equity, and the need for a greater emphasis on the environment. When considering the concept of sustainability as it relates to aquaculture, the literature has presented a number of interpretations. Barry Costa-Pierce has proposed the idea of 'ecological aquaculture.' He defines ecological aquaculture as:

> "an alternative model of aquaculture research and development that brings the technical aspects of ecological principles and ecosystems thinking to aquaculture, and incorporates – at the outset – principles of natural and social ecology, planning for community development, and concerns for the wider social, economic, and environmental contexts of aquaculture."
>
> (Costa-Pierce, 2002, p. 343)

The six characteristics of ecological aquaculture as defined by Costa-Pierce are: i) it preserves the form and function of natural ecosystems, ii) it practices trophic level efficiency (using animal waste and plants rather than solely fishmeal), iii) it ensures that no chemical or nutrient pollution takes place, iv) it uses native species and does not contribute to 'biological pollution' even if exotic species are used, v) it is integrated with communities and is a good community citizen, and vi) it shares information on a global scale (Costa-Pierce, 2002).

A 2007 FAO workshop produced the idea of an ecosystem-based approach to aquaculture (EAA), which is similar to the conceptualization of sustainable aquaculture discussed above. A number of experts defined EAA as "a strategic approach to development and management of the sector aiming to integrate aquaculture within the wider ecosystem such that it promotes sustainability of interlinked social-ecological systems" (Soto et al., 2008, p. 17). The three guiding principles of the EAA are that aquaculture should: i) be developed in the context of ecosystem functions and services and should not threaten the sustained delivery of these to society; ii) improve the welfare and equity of all relevant stakeholders; and, iii) be developed in the context of other sectors, policies, and goals (Soto et al., 2008).

2.2 Integrated Aquaculture Systems

Sustainable alternatives to conventional marine aquaculture have been proposed to address environmental and social concerns associated with this practice. It is clear that no single solution exists; rather a variety of alternatives have been proposed, some of which have been implemented. Examples of sustainable alternatives include closed-tank systems (Pendleton, David Suzuki Foundation & Coastal Alliance for Aquaculture Reform, 2005), inland pond culture (White et al., 2004), organic aquaculture (White et al., 2004), and polyculture or integrated systems (Chopin et al., 2008; Neori et al., 2007; White et al., 2004).

Among the alternatives to conventional aquaculture, integrated aquaculture systems have been well-documented in the literature and are often cited as a critical component of sustainable aquaculture (Halwell, 2008; Costa-Pierce, 2002; Naylor et al., 2000). Integrated farming can be generally defined as taking place when "an output from one subsystem in an integrated farming system, which otherwise may have been wasted, becomes an input to another subsystem resulting in a greater efficiency of output of desired products from the land/water area under a farmer's control" (Edwards, Pullin, & Gartner, 1988, p. 5). Furthermore, it is critical for a sustainable integrated farming system to mimic the way the natural ecosystem functions as much as possible (Neori et al., 2004; Folke & Kautsky, 1992). These systems can either be land-based integrated culture or coastal integrated mariculture (Neori et al., 2004). By integrating multiple species into the aquaculture operation, the system will start to mimic the natural ecosystem and waste recycling will occur. Nutrient loading is a common problem associated with aquaculture and it can be problematic if it exceeds the assimilative capacity of the local aquatic environment (Hoagland et al., 2007). Integrated systems can potentially remediate the problem of nutrient loading.

Numerous examples of integrated aquaculture systems can be found in the literature. One example involved the integration of salmonids and *Gracilaria* seaweeds, which resulted in improved water quality and increased economic output (Troell et al., 1997). Studies have also discussed the potential for integrating mussel and finfish aquaculture (Bodvin et al., 1996; Folke & Kautsky, 1992). Another study looked at the prospect for integrated shrimp/oyster production, which can produce greater economic yields and increase ecological efficiencies (Wang, 1990).

More recently, the concept of IMTA has emerged which, as the name suggests, integrates extractive aquaculture species that filter nutrient waste (e.g. shellfish and seaweeds), with fed aquaculture species that generate nutrient waste (e.g. fish or shrimp) (Neori et al., 2007). A version of this system, involving salmon, mussels, and seaweed, has been implemented on the east coast of Canada with some success (Chopin et al., 2008). The remainder of the literature review will focus on IMTA and the research to date on the economics of IMTA.

2.3 Integrated Multi-Trophic Aquaculture

IMTA, as a type of integrated system, involves growing marine species at different trophic levels on the same site (Ridler et al., 2007). The practice combines the cultivation of fed species (e.g. finfish), with extractive aquaculture species (e.g. shellfish and seaweed). Appendix A provides a graphical depiction of an IMTA system.

One of the main concerns with conventional finfish aquaculture is nutrient pollution, which is created and released in the water column (Asche et al., 1999). Unconsumed feed and finfish discharge, in the form of particulate organic matter (POM) and dissolved inorganic nutrients (DIN), can cause nutrient enrichment in the local aquatic ecosystem. Nutrient enrichment (elevated concentrations of nutrients in the marine ecosystem) can result in eutrophication resulting in negative environmental impacts on the surrounding marine ecosystem. By integrating extractive species at lower trophic levels, which naturally consume POM and DIN, the IMTA system uses the by-product wastes from one resource (finfish) as productive inputs for others (shellfish and seaweeds). Additionally, extractive aquaculture species (e.g. shellfish) can produce nutrient waste that can also be taken up by other parts of the system (e.g. deposit feeders and seaweeds) (Paltzat at al., 2008). This practice recreates a simplified, cultivated ecosystem while producing a range of marketable aquaculture products.

It must be noted that IMTA does not have one narrow definition with a required combination of species. Rather, the IMTA concept is flexible and can involve most cultured finfish species, a variety of shellfish such as mussels, scallops, and oysters as well as different species of seaweed and other organisms including deposit feeders like sea cucumbers and sea urchins.

2.4 Economics of Integrated Multi-Trophic Aquaculture

Existing research on the economics of IMTA has focused on three main areas of analysis: economic, financial, and market. Section 2.4.1 presents studies that have addressed the economics of aquaculture, including IMTA, from a public perspective (Nobre et al., 2010; Ferreira et al., 2007; Chopin et al., 2001; Alvarado, 1996; Folke et al., 1994). These studies analyze the economic value of aquaculture and IMTA from society's point of view, rather than solely from a private operator's perspective, by taking into account the external costs and benefits associated with aquaculture production. Section 2.4.2 presents financial analyses, which have been completed on IMTA systems, which focus mainly on the profitability of IMTA from the private perspective (Bunting & Shpigel, 2009; Whitmarsh et al., 2006; Chopin et al., 2001; Troell et al., 1997; Petrell & Alie, 1996;). Financial analyses are a subset of the literature on the economics of IMTA and do not consider externalities of aquaculture production. Section 2.4.3 presents IMTA market analyses that have been completed to date (Barrington et al., 2010; Shuve et al., 2009; Ridler et al., 2007). These studies look at public attitudes toward the IMTA production method and consumer willingness to pay for IMTA products.

2.4.1 Economic Analysis of IMTA

Given the various environmental externalities associated with conventional aquaculture production and the role that IMTA plays in internalizing some of these external environmental costs, economic analysis of IMTA represents an important research area to determine the true value of IMTA to society. However, only one study has attempted a complete economic analysis of an IMTA system where the financial costs and benefits, as well as the external costs and benefits, are account for (Nobre et al., 2010).

Nobre et al. (2010) applied the Differential Drivers–Pressure–State–Impact–Response (Δ DPSIR) methodological approach to an ecological and economic comparison between abalone monoculture and abalone-seaweed IMTA. The authors used data from a South African land-based commercial abalone farm as a case study. Results showed that, from a private perspective, an abalone monoculture operation would increase profits by 1.4% to 5% if it were to adopt an IMTA configuration. The authors also valued the external benefits of adopting IMTA (reductions in nutrient discharge, natural kelp bed degradation, and GHG emissions) and found their collective value to be substantially larger than the net gain in profits. These results suggest significantly increased profitability in an economy that rewards ecologically responsible aquaculture through subsidies or other economic instruments. The overall benefit of adopting IMTA to the farm and society in this case was estimated to be between US $1.1 and US $3.0 million per year. These values take into account the difference in profitability between monoculture and IMTA as well as both the cost of implementing IMTA and the value of environmental externalities.

Chopin et al. (2001) also valued the external cost of nutrient discharge associated with a salmon monoculture using information from a technical and economic cost-benefit analysis of a land-based salmon-seaweed farm in Chile (Alvarado, 1996). The authors used solid and dissolved waste volumes (Buschmann et al., 1996) and the cost of waste treatment (Folke et al., 1994) to value the external cost of nutrient discharge from a single farm. Chopin et al. (2001) estimated the environmental cost of 250 tons of gross fish production to be US $201,441. However, the environmental cost of production associated with nutrient loading was reduced to US $64,000 when an IMTA configuration was adopted.

While few studies have looked at the external environmental costs and benefits associated with IMTA directly, a number of studies have valued the external environmental costs and benefits associated with other aquaculture practices (Zheng et al., 2009; Ferreira et al., 2007; Folke et al., 1994). Zheng et al. (2009) conducted a benefit-cost analysis of mariculture based on ecosystem services in Sanggou Bay, China. The authors analyzed how the aquaculture operations in the bay, which only produce extractive aquaculture species, impacted four ecosystem services: food production, oxygen production, climate regulation, and waste treatment. The authors valued the largely positive impact of these aquaculture activities on the ecosystem services and used a benefit-cost analysis to demonstrate that the benefits of mariculture in the bay outweighed the costs from society's perspective.

Ferreira et al. (2007) applied the Farm and Resource Management (FARM) model to shellfish aquaculture production in coastal European Union waters. As part of the study, the authors assessed the eutrophication impacts associated with shellfish culture and found that water quality was either maintained or enhanced for all farms. Based on the modelling results, the authors found that shellfish aquaculture provided an estimated net value of € 11-17 billion (US$

15 – 24 billion) per year in ecosystem goods and services (eutrophication reduction) in coastal EU waters.

While studies such as Zheng et al. (2009) and Ferreira et al. (2007) have focussed on shellfish and seaweed aquaculture where the environmental impacts and associated economic value are largely positive, other studies have looked at aquaculture species such as shrimp and finfish which have a negative environmental impact and therefore an external environmental cost. Of particular relevance to IMTA is the study by Folke et al. (1994), which valued the environmental impact of nutrient discharge from fish farms. The authors found that nutrient effluent from one fish farm with a production volume of 100 tons is equal to the untreated sewage generated by 850 to 1950 persons. When these values were scaled up to total salmonid production in Nordic countries in 1994, the authors found the nutrient discharge equalled the untreated waste from approximately 6 million persons. Using the cost of removing nitrogen and phosphorous from municipal sewage as a means of valuing salmonid nutrient discharge, the eutrophication cost from one fish farm producing 100 tons of salmon was calculated to be between SEK 425,000 (USD 66,000) and SEK 725,000 (USD 112,000). When the external cost of coastal eutrophication was internalized as an additional cost to production, production costs became greater than the highest historical price paid for farmed salmonids.

A variety of studies have valued the external environmental costs and benefits of aquaculture production. However, relatively few studies consider and value the environmental benefits provided by IMTA. Thus, the knowledge gap represents an area of research that should be further investigated to determine the true economic value of IMTA to society.

2.4.2 Financial Analyses of IMTA

The majority of literature on the economics of IMTA has focussed on the financial dimensions of IMTA from the private operator perspective. Financial profitability is a critical factor of successful IMTA implementation at the commercial scale and a number of studies have addressed this research area.

Petrell & Alie (1996) developed a spreadsheet model of an integrated salmon-seaweed system to determine the financial profitability of growing seaweed in close proximity to salmon aquaculture operations. For the purposes of the study, the authors focussed solely on the profitability of the seaweed component. The authors considered two species of seaweed, *Laminaria saccharina* and *Nereocystis luetkeana*, grown in different areas of the farm (labelled A, B, and C). Site A was located between two rows of salmon cages and received the most nutrients while sites B and C were located 30m away from the outer edge of each row. Results demonstrated that producing *L. saccharina* was profitable under all production options (production in A, B, and/or C), while *N. luetkeana* was deemed profitable only when grown in areas A, B, and C, or just area A. Growing either species in all areas (A, B, and C) was the most financially profitable. Differences in financial profitability between the two species were due to differing harvest periods (*L. saccharina* can be harvested at double the rate) and harvesting costs (*N. luetkeana* is twice as costly to harvest). The main conclusion of the study was that seaweed production, alongside salmon aquaculture operations, can be profitable under certain conditions.

In a similar study, Troell et al. (1997) analyzed an integrated salmon-seaweed production system where the seaweed species *G. chilensis* was cultivated near salmon aquaculture cages. Amongst various findings of the study, the authors determined that the cultivation of *G. chilensis* would result in an additional harvest of US $34,000 per annum. Troell et al. (1997) concluded that integrated salmon-seaweed production systems have economic and environmental advantages.

Bunting & Shpigel (2009) evaluated the financial potential of adopting 'horizontally integrated land-based marine aquaculture', meaning IMTA, using a bio-economic modelling approach. The study considered two different systems and results were mixed. The first system was a temperate water system developed in France combining fish, microalgae, shellfish and a polishing lagoon. The bio-economic modelling results for the temperate system failed to generate a positive internal rate of return (IRR) over the ten-year time horizon, except in the case where land and labour opportunity costs were left out and a 20% product price premium was assumed. The second system was a warm water system developed in Eilat, Israel, which combined sea urchins, shrimp, and seaweed. Assuming baseline production of one million sea urchins annually from year three onwards, modelling outcomes for the system showed a reasonable ten-year IRR of between 18% and 133%, depending on several assumptions about sea urchin mortality and *Salicornia* yield. The authors concluded that bio-economic modelling can aide in the optimization of horizontally integrated systems but stated that:

> "where horizontal integration does hold promise, an enabling institutional framework should be encouraged to promote its adoption and development, ideally including policy instruments favouring the internalisation of environmental costs through horizontal integration."
>
> (Bunting & Shpigel, 2009, p. 50).

Ridler et al. (2007) constructed a capital budgeting model to determine the financial viability of an IMTA system compared to salmon monoculture, based on actual data from a pilot salmon-mussel-kelp farm in Eastern Canada. Over a 10-year period at a 5% discount rate, the NPV for the IMTA system (US $3,296,037) was 24% higher than the NPV of the monoculture operation (US $2,664,112). These results indicated that using the waste of one crop as feed for another could increase profits. A sensitivity analysis was conducted to determine the vulnerability of both systems to price fluctuations and production loss. To account for economic risk associated with market conditions, an immediate 12% decrease for all product prices was assumed for the 10-year period. Under these conditions, the IMTA system generated a profit margin of 3.2% whereas the salmon monoculture system generated a margin of only 0.3%. Additionally, three scenarios tested the variability of salmon harvested over the 10-year time horizon to account for the probability of lost salmon production due to disease and/or weather. The analysis revealed that under all three scenarios, the IMTA system was more profitable, pointing to the value of product diversification. In summary, the study found that IMTA increases profitability and reduces the economic risk associated with loss of production and changing market conditions.

Whitmarsh et al. (2006) investigated the financial profitability of an integrated salmon-mussel production system using baseline data from Scottish mussel and salmon aquaculture farms. The authors analyzed three different systems over a 20-year time horizon: salmon monoculture, mussel monoculture, and integrated salmon-mussel culture. Capital-budgeting model results demonstrated that the net present value (NPV) of the integrated system (£ 1.425 million) was greater than both the salmon monoculture system (£ 0.922 million) and the mussel monoculture system (£ 0.353 million), assuming mussel production rates were 20% higher in the integrated system. The authors dubbed this additional financial benefit associated with the integrated system an ‘economy of integration’. However, a sensitivity analysis revealed that the integrated system is highly sensitive to price changes. They determined that a 2% per annum decrease in salmon prices, holding all else constant, made an investment in the integrated system unattractive. The authors concluded that economies of integration, while significant, were not sufficient to guarantee the adoption of integrated systems and that market conditions and future price forecasts will play an important role as well. The general message from these financial studies is that integrating shellfish and/or seaweeds with existing finfish monoculture can increase farm profits while reducing economic risks and environmental costs and generating environmental benefits.

2.4.3 Market Analysis of IMTA Products

Social acceptability and consumer perceptions of IMTA are an important component of the discussion regarding the economics of IMTA. Positive public perception of the IMTA system and goods produced through the IMTA production method is important to the mainstream acceptance of the system. Three studies have addressed these questions to date.

Ridler et al. (2007) conducted an attitudinal survey in New Brunswick to gauge public acceptance of IMTA. Respondents had a positive opinion of salmon monoculture largely due to its economic and employment impact. However, respondents indicated a greater approval for IMTA. Respondents also felt that IMTA would improve the public image of the aquaculture industry. A critical finding was that while the principle of IMTA was attractive, respondents had limited knowledge of IMTA.

To address this lack of knowledge, a focus group study was conducted with some of the respondents from the 2003 survey to determine if support for IMTA would be maintained when respondents were provided a detailed description of the system (Barrington et al., 2010; Ridler et al., 2007). Opinions on IMTA were gathered from restauranteurs, residents living near aquaculture operations, and the general population through focus group sessions after participants were provided with a description of IMTA. The authors found that all participants considered IMTA products safe to eat and that 50% were willing to pay a 10% premium for environmentally friendly seafood products. Additionally, the authors concluded that "people felt that IMTA had the potential to reduce the environmental impact of salmon farming, while improving waste management in aquaculture, creating employment opportunities, benefiting community economies, and improving industry competitiveness, food production, and the sustainability of aquaculture overall" (Barrington et al., 2010, p. 206).

The authors also found that participants seemed "sceptical or unsure if IMTA could address disease outbreaks, replenish natural stocks, or improve food quality" (Barrington et al., 2010, p. 206). Barrington et al. (2010) concluded that a promotional campaign would be helpful to educate the public about the benefits of IMTA.

Shuve et al. (2009) conducted a survey of New York seafood consumers to determine consumer attitudes toward the IMTA system and IMTA products. The study found that 88% of the respondents supported the use of IMTA. Respondents felt that, compared to monoculture systems, IMTA was better for the environment and more considerate of animal welfare. IMTA seafood was also considered to be of equal or higher quality, freshness, and taste compared to conventional seafood. Additionally, a penetration analysis determined that 38% of respondents would pay a 10% premium and 18% would pay a 20% premium for IMTA mussels. The authors concluded that consumers would pay a price premium for IMTA mussels but a strong marketing plan is critical to developing a market for this product.

Based on the limited attitudinal and market research completed to date, public attitudes towards IMTA appear to be positive. Additionally, the Barrington et al. (2010) and Ridler et al. (2007) studies revealed that a price premium for IMTA products is a realistic possibility. While these results are positive, it is clear that a strong information sharing and marketing campaign would aide in helping IMTA to achieve mainstream market acceptance.

Research on the economics of IMTA has focussed on three main areas: economic studies which have considered environmental externalities, financial analyses which have addressed operational profitability, and finally market analyses which have looked at the public and consumer perception of the IMTA practice and IMTA products. To date, the literature on the economics of IMTA has not considered the potential market implications of increased extractive aquaculture production associated with IMTA adoption. This is an important research area and represents a literature gap in existing research on the economics of IMTA. The study presented here fills this gap. Additionally, market studies addressing consumer perception of IMTA have strictly focussed on the east coast of North America thus far. My study expands this analysis to the west coast which is a valuable addition to the literature.

Chapter 3: Background

Aquaculture has become a critical part of our global seafood supply system, largely as a result of rising demand for seafood and increasing pressure on capture fisheries. In 2008, aquaculture accounted for 46% of the total world food fish supply (FAO, 2010). Canada accounts for only 0.36% of total world aquaculture production, or 1.14% of the total value (Alain, 2005).

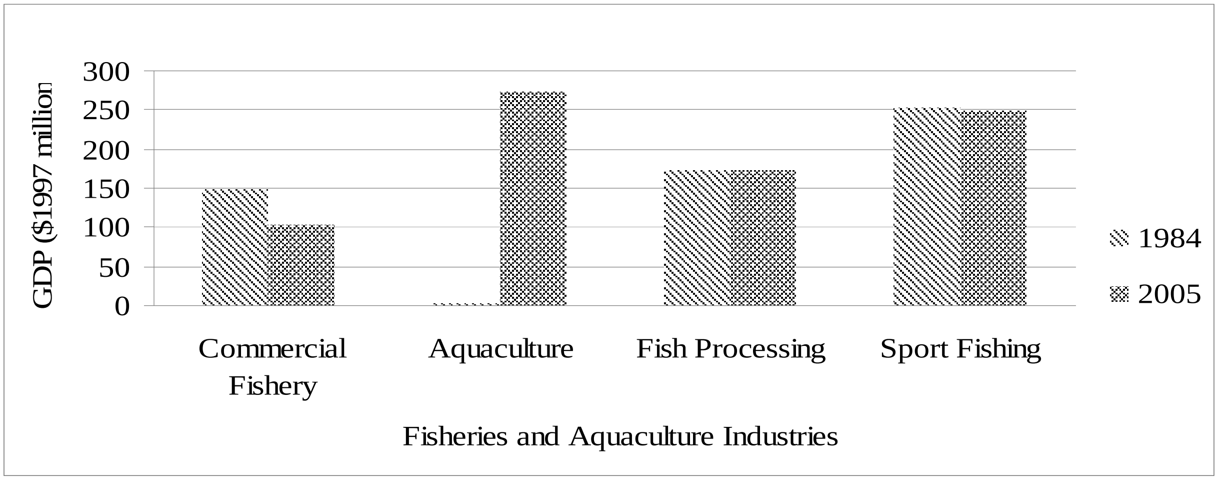
3.1 Aquaculture in Canada

Although Canada's contribution to global aquaculture production is small, the aquaculture industry has become an important sector of the Canadian economy, producing goods totalling $526.5 million and employing 5,000 to 6,000 people in 2004 (Alain, 2005). Aquaculture in Canada is primarily salmon and shellfish production, both of which have experience considerable growth. Salmon farming's contribution to Canada's GDP grew from $300,000 in 1984 to $214 million in 2005. Similarly, shellfish farming's contribution to Canada's GDP grew from $3 million to $31 million during the same period (Ministry of Environment, 2007).

3.2 Aquaculture in BC

Aquaculture represents the largest industry in the Fisheries and Aquaculture Sector of the BC economy, which consists of aquaculture, commercial fisheries, sports fishing and fish processing (Ministry of Environment, 2007). Since 1984, aquaculture has exhibited impressive growth compared to other industries in the fisheries and aquaculture sector (Figure 1). The observed growth in the aquaculture industry was fuelled primarily by growth in salmon and shellfish farming.

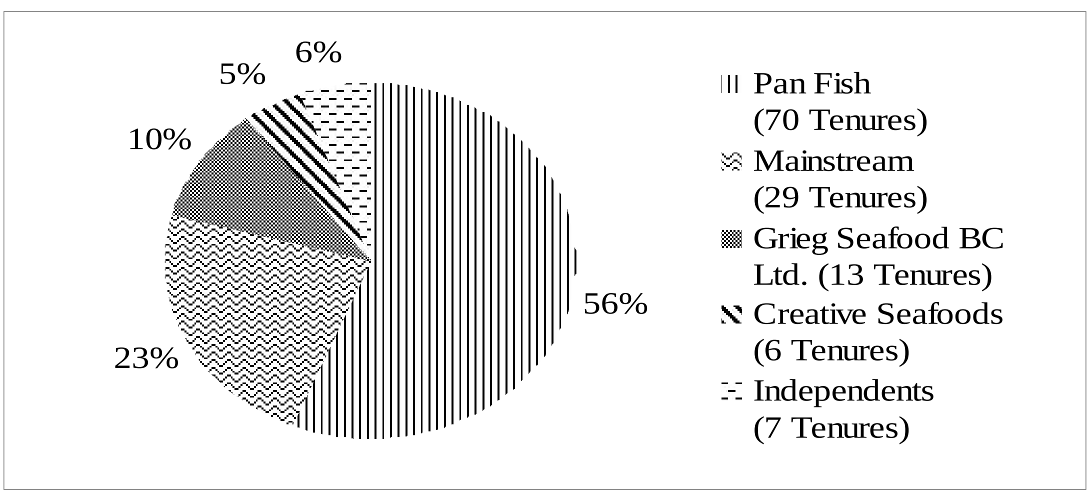
Figure 1: BC fisheries and aquaculture sector growth (Ministry of Environment, 2007)



3.2.1 Salmon Aquaculture Industry in BC

As of 2007, 125 salmon farm tenures were on the west coast of British Columbia (MacKay et al., 2007). The salmon farming industry is a consolidated industry where almost 95% of the tenures are control by 4 multi-national companies and the remaining 5% are controlled by independent growers (Figure 2). The majority of tenures (75%) are located in the North Vancouver Island and Georgia Strait region, 20% are located in the South and West Vancouver Island region and the remaining 5% are on the South Coast (Appendix R).

Figure 2: Breakdown of BC salmon farming tenures (MacKay et al., 2007)



Both Pacific and Atlantic salmon are cultured on the BC coast. However, Atlantic salmon are by far the more commonly cultured species (Table 1). Atlantic salmon is the preferred species for culture and represents the province's most significant aquaculture commodity with the greatest harvest and largest landed value of any wild or cultured species (Ministry of Environment, 2008).

Table 1: Canadian salmon aquaculture harvest totals (tonnes) and landed values ($ million) (Ministry of Environment, 2008)

Type of Salmon	Harvest ('000 tonnes)	Landed Value ($ millions)	Wholesale Value ($ millions)
Atlantic	77.2	381.80	455.50
Pacific	4.2	24.30	39.70
Total	81.4	406.10	495.20

3.2.2 Shellfish Aquaculture Industry in BC

The shellfish industry emerged in earnest with the culturing of oysters. Product diversification took place during the early 1990s with the production of mussels, clams, and scallops. Currently, the three main species of shellfish cultured in B.C. are the Pacific oyster (*Crassostrea gigas*), Manila clam (*Tapes philippinarum*), and Pacific scallop (*Patinopecten yessoensis x caurinus*) (Salmon & Kingzett, 2002). Other species being developed for commercial culture include the Blue mussel (*Mytilus edulis*), Mediterranean mussel (*Mytilus galloprovincialis*), Northern abalone (*Haliotis kamtschatkana*), and native geoduck clam (*Panopea abrupta*).

Unlike the BC salmon farming industry, the BC shellfish industry is unconsolidated, consisting of numerous small producers. As of 2008, 482 licensed shellfish tenures were operating on the coast of B.C. occupying a total of 2114 hectares. The average tenure size is 4.39 hectares, while 35% of all tenures are less than 2 hectares. The industry also employs over 800 workers (Salmon & Kingzett, 2002). Appendix C provides a map of tenure locations. Appendix

D provides the frequency distribution of tenure sizes in 1998 and a breakdown of number of tenures, area, average tenure size, and farm gate value for main growing regions in BC.

Industry Production and Price

Oysters have been and remain the most commonly cultured species in BC; BC accounts for roughly 64% of domestic oyster production (Figure 3). With regards to the mix of provincial production, oysters make up the bulk of provincial shellfish production, averaging 6,803 tonnes between 2005 and 2009 versus 281 tonnes and 174 tonnes for mussels and scallops, respectively (Figure 4). Appendix B provides additional information on BC and Canadian shellfish production quantities between 1986 and 2009.

In terms of the contribution to global production, B.C. is the 12th largest single producer of Pacific oysters but only produces 0.12% of the value (Salmon & Kingzett, 2002). According to the FAO, B.C. accounted for 5% of total North American landed oyster culture value (Salmon & Kingzett, 2002). BC oysters are predominantly sold live into the half-shell market (Interviewee #1, 2010).

Figure 3: BC oyster production and Canadian oyster production between 1986 and 2009 (DFO, 2010)

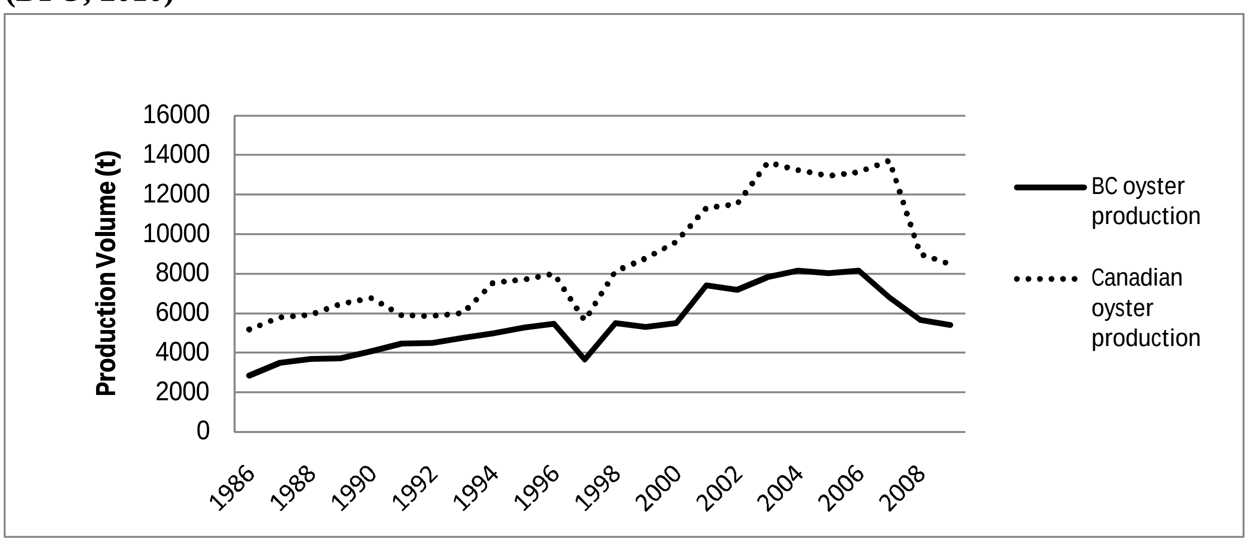
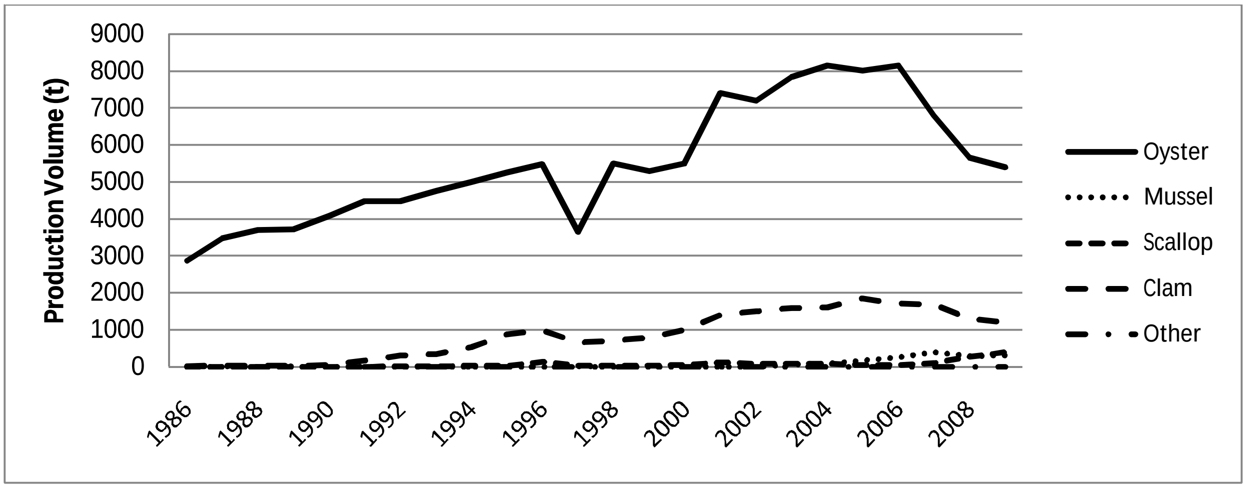
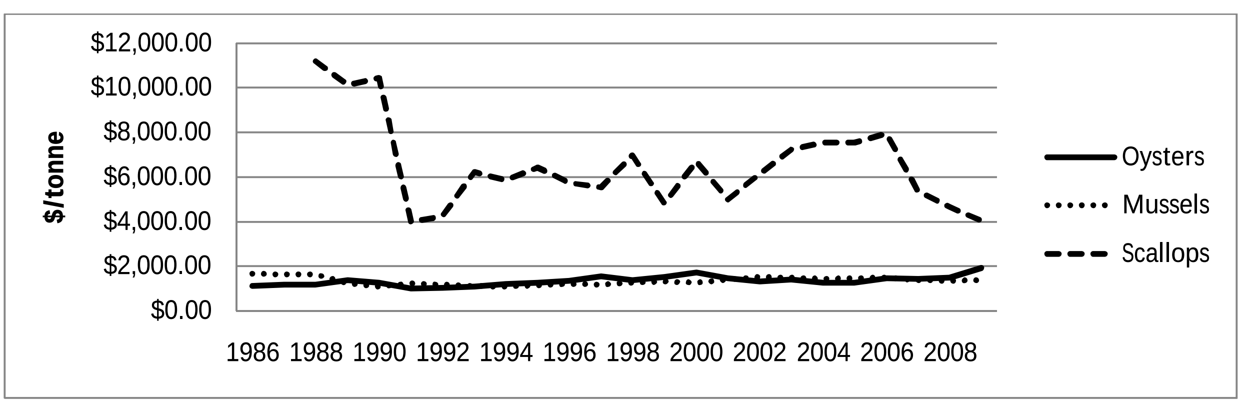


Figure 4: BC shellfish production between 1986 and 2009. Species include oyster, mussels, scallop, clam, and others such as geoduck and cockles (DFO, 2010)



The landed value for oyster has been steadily increasing since 1986 (Figure 5). Initially close to $1,000/tonne in the late 1980s, the landed value of cultured oysters in BC nearly doubled to $1,918/tonne by 2009. Landed value of mussels has gradually declined since 1986 from a peak of $1,675/tonne in 1986 to $1,389/tonne in 2009. Finally, scallops represent the highest value species of the three with a significant landed value in 1988 and in 2009 remained more than double the landed value of oysters, the next highest valued species. The 5-year average landed value between 2005 and 2009 for oysters, mussels, and scallops was $1,517/tonne, $1,420/tonne, and $5,913/tonne respectively.

Figure 5: Landed value for BC oysters, mussels, and scallops between 1986 and 2009 (DFO, 2010)

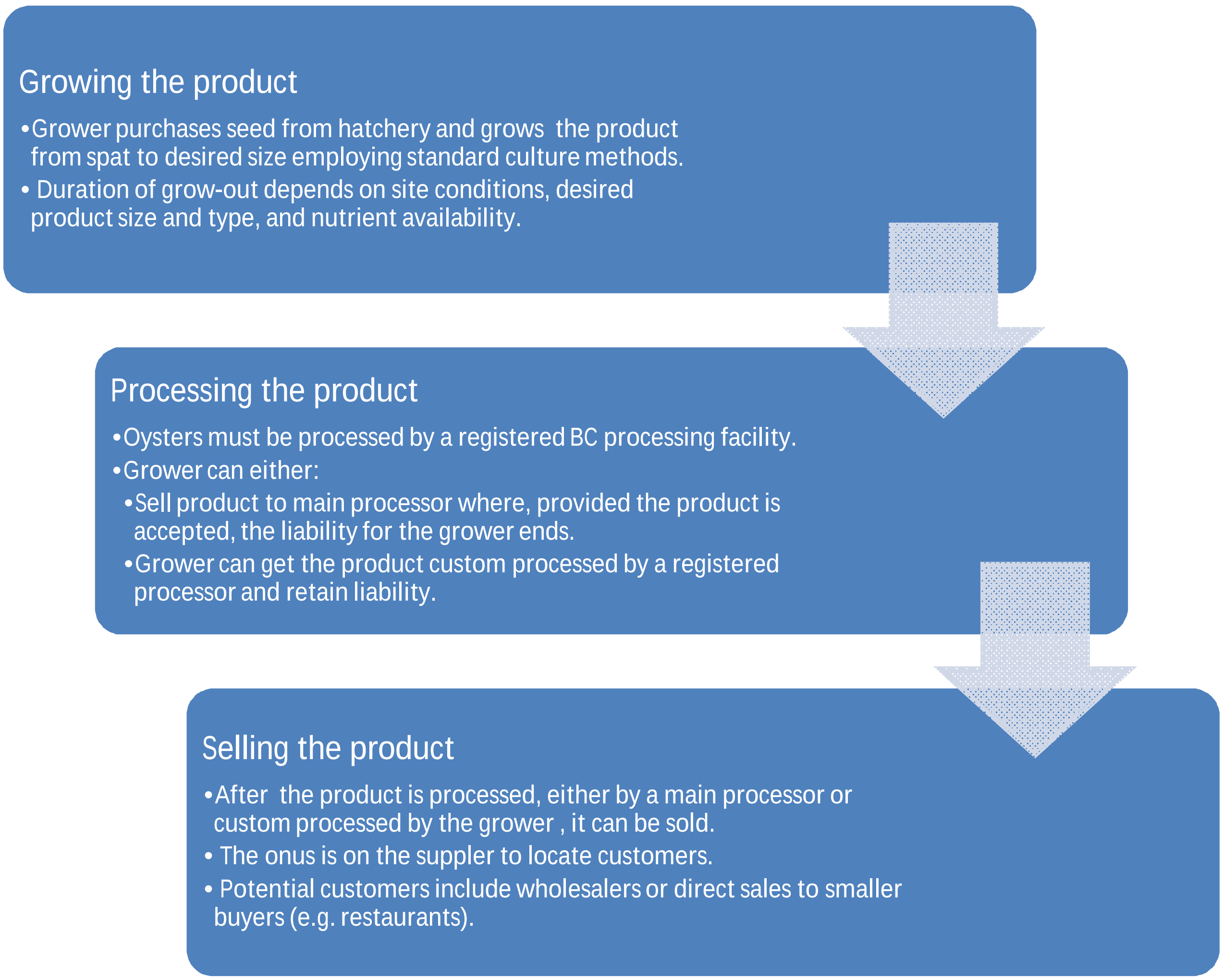


Note: Data was not available for BC scallops for years 1986 and 1987

Supply Chain

The supply chain describes the process the product must go through from farm to consumer (Figure 6) (Interviewee #1, 2010; Interviewee #2, 2010).

Figure 6: Supply chain for BC shellfish industry (Interviewee #1, 2010; Interviewee #2, 2010)



Markets

A study commissioned by the Vancouver Island Economic Developers Association Marine Frontiers Project analyzed the profile and potential of the B.C. shellfish industry (Salmon & Kingzett, 2002). The study found that roughly 80% of BC's shellfish aquaculture products are exported. Generally speaking, the main markets for BC shellfish exports are the U.S. and the Pacific Rim nations. The primary competitors with BC for these shellfish markets are Eastern Canada, Western US, China and New Zealand. With regards to specific shellfish species, 80% of BC oysters are exported to the US. Other markets for BC oysters include Canada, Singapore, and China (Interviewee #1, 2010). In contrast, 45% of BC scallops are exported to the US with the remainder sold domestically or exported to Pacific Rim nations and BC mussels are mainly sold in the BC market.

About 90 to 95% of oyster consumption in North America takes place in restaurants and household consumption is minimal (Interviewee #1, 2010; Interviewee #4, 2010). With regards to the US market specifically, Zimet & Smith (2000) found that 15% of the US population consumes approximately 85% of all oysters sold in the US. They also found that the average oyster consumer is male, between 18 and 49, residing in a coastal area, and earning in excess of US $60,000 per year. In Asian markets, household consumption is much more common and more volume is consumed (Interviewee #1, 2010).

Industry Challenges and Constraints

The following list includes a number of specific industry challenges and constraints:[2]

1) Restrictive Regulations and Policies – Existing policies and regulations, including a requirement for Canadian Environmental Assessment Review, do not promote or encourage growth (Salmon & Kingzett, 2002).

2) Transportation – Airfreight is a hurdle for moving product, especially leaving Vancouver Island. Enhanced airfreight service on Vancouver Island could help with access to world markets

[2] The primary sources for the list of industry challenges and constraints to growth are Interviewee #1 (2010) and Salmon & Kingzett (2002).

but sufficient product volume is a limiting factor (Salmon & Kingzett, 2002). Only sufficient total product volume will make direct flying routes financially viable.

3) Access to tenure sites – All marine aquaculture takes place on tenured Crown land. Access to the land base is difficult and is considered one of the most important factors limiting industry growth and competitiveness (Salmon & Kingzett, 2002).

4) Environmental & Public Perceptions – Shellfish farming is increasingly scrutinized as the public grows more sensitive to food production methods and their environmental sustainability (Salmon & Kingzett, 2002). Public concern over the impact of aquaculture is an impediment to industry growth. An example of an environmental impact associated with shellfish farming is the bio-deposition (faeces and pseudo faeces), which accumulates under shellfish culture systems (Paltzat et al., 2008).

5a) Oversupply of oysters to traditional markets – Historically, BC oyster supply has been below demand. However, due to increased provincial and North American production, traditional markets have become soft (Interviewee #1, 2010; Salmon & Kingzett, 2002).

5b) Insufficient oyster supply to access new markets – While traditional markets for oysters are soft, new markets for oysters (e.g. China, Philippines) require huge volumes that currently the BC oyster industry cannot supply on a year-round basis (Interviewee #1, 2010; Salmon & Kingzett, 2002).

6) New species development – The shellfish industry depends predominantly on Pacific oyster and Manila clam production with limited shellfish production otherwise (Salmon & Kingzett, 2002). However, seafood buyers normally prefer to purchase a range of products from one supplier.

7) Securing Financing – The shellfish industry has been financed privately and a lack of available funding has proved to be a problem. In a ranking of limiting factors to BC shellfish industry growth, Coopers and Lybrand (1997) ranked securing financing as *High*.

8) Water Quality – Main sources of coastal water pollution in BC include sewage, pulp mills, vessel discharges, forestry activities, and non-point source pollution; all of which can have significant adverse impacts on shellfish production (Salmon & Kingzett, 2002).

9) Price paid to oyster grower – The price per oyster paid to the farmer is low due to undercutting and the dissolution of the oyster marketing board (Interviewee #1, 2010; Interviewee #4, 2010). A better price for farmers above simply covering costs is important (Interviewee #4, 2010).

10) Ocean acidification – Human emissions of CO_2 causes ocean acidification (decrease in surface ocean pH) consequently lowering oceanic carbonate concentrations, which adversely affects the ability of shell-making organisms to build calcium carbonate structures (i.e. shells) (Gazeau et al., 2007). Gazeau et al. (2007) demonstrated that calcification rates of edible mussels (*Mytilus edulis)* and Pacific oyster (*Crassostrea gigas)* decline linearly with increasing pCO_2. They found that mussel and oyster calcification rates may decrease by 25% and 10%, respectively. Given the importance of shellfish to coastal ecosystems as well as the global aquaculture industry, a reduction in calcification will likely have an impact on ecosystems as well as aquaculture production (Gazeau et al., 2007).

11) Cadmium Concentrations in BC Oysters – Research has shown that occasionally BC oysters grown in certain areas have tissue cadmium concentrations equal to or above 2 $\mu g\ g^{-1}$ which exceeds certain international food safety guidelines (Orians, 2010; Lekhi et al., 2008). The source of the cadmium is primarily natural; however, anthropogenic sources of cadmium exist in

the areas as well (Orians, 2010). Bendell & Feng (2009) tested a sample of sites throughout the BC coast and found evidence of cadmium concentration in excess of 2 µg g^{-1} at 5 of 24 sites tested. Concerns about cadmium levels in BC oysters have resulted in the temporary closure of European and Hong Kong markets to BC oysters. Appendix E provides additional information and locations from the Bendell & Feng (2009) study.

Addressing Challenges and Constraints to Growth

The following list comprises proposed ways of addressing the industry challenges[3]:

1) Developing new species – Product diversification is important for industry growth.

2) New product development (e.g. frozen, vacuum packed shellfish) allows processors to expand market penetration and continually supply product to market (Salmon & Kingzett, 2002). Developing new products can also make transportation cheaper as product can be shipped by sea, effectively reducing transportation costs (Interviewee #1, 2010).

2) Increased supply – Export opportunities for BC shellfish products currently exist. However, the industry has limited production capacity to provide the consistent, year-round supply that purchasers demand (Interviewee #1, 2010; Salmon & Kingzett, 2002). Therefore, increasing supply to be able to access the larger markets is important.

3) Expansion of existing markets – The main market for BC oysters is the US. However, Canada supplies only a limited percentage of all oysters consumed in the US (Interviewee #1, 2010). In 1995, BC provided only 5% of the oysters supplied to the US market and 3% of US clam supplies (Coopers and Lybrand, 1997). Gaining more of this market share would stimulate industry growth.

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[3] The primary sources for the list of potential ways to address industry challenges and constraints to growth are Interviewee #1 (2010) and Salmon & Kingzett (2002).

4) Developing new markets – New markets exist primarily in Asia (e.g. Japan, China, Hong Kong) however as stated previously, order volumes are usually far too large for BC producers to currently satisfy (Interviewee #1, 2010; Salmon & Kingzett, 2002). Once again, increasing supply is critical to accessing these new markets. Other potential markets include Russia, Brazil, Dubai, and the UAE (Interviewee #1, 2010).

5) Restaurant/Retail potential in Asian markets – In Asian markets, not only is there restaurant market potential, but also huge retail potential assuming the supply is sufficient (Interviewee #1, 2010).

6) Salmon & Kingzett (2002) also argue that industry growth depends on the following additional factors:

- improving cost competitiveness and efficiency;
- addressing regulatory and legislative uncertainty;
- focussing on processing and marketing in addition to production;
- ensuring a cooperative approach to marketing which could have spill-over benefits in terms of improving consistency and uniformity of BC oyster production;
- growing a product to suit a particular market;
- improving product quality management, including farm-level quality management and oyster-grading standards;
- making marketing and promotion of BC shellfish a priority;
- assuring quality of product and encouraging new product/value added development;
- attracting investment capital;
- expanding base of skilled workforce;
- encouraging research and development.

6) Industry potential – The study commissioned by the Vancouver Island Economic Developers Association Marine Frontiers Project listed five key attributes, which provide a strong foundation for growth (Salmon & Kingzett, 2002). They include vast bio-physical potential, large pristine coastline (meaning clean water and, therefore, high quality product), environmental sustainability, available workforce, existing technology and access to export markets. Therefore, the potential for growth exists, but other obstacles restrict opportunities at present.

IMTA in BC

Integrated Multi-Trophic Aquaculture is currently practiced at only one site in BC. Kyuquot SEAfoods is operating a sablefish farm with an organic and inorganic extractive aquaculture component on the west coast of Vancouver Island in Kyuquot Sound (Appendix F). While IMTA is in its infancy in BC, a large number of BC salmon farms could adopt IMTA. Of the 125 salmon farms on the BC coast, 45% have the necessary site characteristics (oceanographic dynamics, site location, etc.) to adopt IMTA (Interviewee #5, 2010). Additionally, new farms could practice IMTA.[4] IMTA has a larger presence on the East Coast, specifically New Brunswick, where the practice has been adopted by Cooke Aquaculture at a number of its farm sites.

[4] The potential for new IMTA farms is a reality but is not considered in the analysis. The study is limited to a consideration of IMTA adoption at existing salmon farms.

Chapter 4: Study Methodology

Chapter 4 describes the methodology used to answer the research questions posed in Chapter 1. Section 4.1 describes the production scenario analysis carried out to determine the potential increase in oyster production associated with a range of hypothetical IMTA adoption rates by BC salmon farmers. Section 4.2 describes the survey and willingness-to-pay methodology used to determine consumer perception of IMTA and their willingness-to-pay for IMTA oysters. Section 4.3 describes the semi-structured interview process used to gain insight into the BC shellfish industry and market which, combined with other information sources, was used to draw conclusions about the market implications of increased shellfish production associated with IMTA adoption in BC.

4.1 Analysis of Potential IMTA Production Scenarios

I conducted a production scenario analysis to estimate the potential increase in BC oysters supplied to the market as a consequence of IMTA adoption by BC salmon farmers. The objective of the analysis was to generate the annual quantity of IMTA oyster production in BC and to determine the sensitivity of the production quantity to changes in key variables through a sensitivity analysis. With production quantities in hand, I compared BC IMTA oyster production to provincial, national and global oyster production to understand the potential supply impact of IMTA adoption. Whitmarsh et al. (2006) conducted a similar production scenario analysis as part of an investment appraisal for a representative salmon-mussel farm in Scotland. While the parameters, species and objective were different, the approach of designing a representative system to estimate production quantities was similar. Data sources included literature on BC oyster production as well as information and parameter values supplied by interviewees. To achieve the analysis objective, I took the following steps:

Step 1: Determine the number of salmon farms capable of adopting IMTA

With information obtained through discussions with an industry expert, I determined that 45% or 56 of the 125 salmon farms in BC possess the appropriate site characteristics to adopt IMTA (Interviewee #5, 2010). Therefore, 45% was treated as the maximum percentage of farms capable of adopting IMTA. I varied the percentage of sites that adopted IMTA through a sensitivity analysis to account for the fact that a portion of the 45% (or 56 sites) might not adopt IMTA. The percent of salmon farms adopting IMTA was set at 4 different levels (5%, 15%, 30% and 45% of 125 salmon farm sites) to present a range of production outcomes across possible scenarios.

Step 2: Determine how to retrofit existing salmon farms with IMTA (oyster production)

As no salmon farm site on the west coast has been retrofitted with IMTA to date, I needed to determine how a salmon farm would most likely do so. Based on discussions with an industry expert, I developed a realistic and appropriate scheme (Table 2) (Interviewee #5, 2010). The average salmon farm has 12 salmon cages measuring 30 m^2 each aligned in two rows of six. To adopt IMTA, the rows of salmon cages would be realigned into a line of 12 and shellfish rafts would be positioned along the side that is “down current” from the salmon cages. Industry standard shellfish rafts measuring 8 meters by 8 meters would be used and standard raft culture practices applied (Interviewee #5, 2010) (See BCSGA (2011) and Salmon & Kingzett (2002) for discussion of raft culture production methods). A line of shellfish rafts stretching the length of the realigned salmon farm would equal 45 rafts or 30 rafts with a spacer of 4 m between rafts. Additionally, a second row of shellfish rafts might be needed to further offset the organic waste. This would bring the total number of rafts to 90, or 60 with the spacer. For the analysis, I included a spacer in the shellfish raft rows and estimated annual production quantities for one row of rafts with spacer (30 rafts) and two rows with spacer (60 rafts). Appendix H provides a graphic of the IMTA system.

Table 2: Summary of measurements of representative IMTA farm (Interviewee #5, 2010)

Description	**Value**
Length of one salmon cage	30 m
Number of cages per average salmon farm	12
Length of conventional salmon farm (2 rows of 6)	180 m
Length of IMTA salmon farm (Realigned - 12 cage row)	360 m
Length of shellfish raft	8 m
Number of shellfish rafts per 360 m (no spacer)	45
Spacer between shellfish rafts	4 m
Number of shellfish rafts per 360 m (with spacer)	30

Step 3: Allow for the fact that IMTA shellfish production may not be solely oysters

IMTA oysters are not the only candidate shellfish species for an IMTA system. Mussels and scallops are also potential options for IMTA. To account for this, I varied the proportion of rafts that were used to produce oysters (rather than other species) through a sensitivity analysis. I assumed that oyster production took place on 33, 66, or 100% of the total number of shellfish rafts in the system.

Step 4: Determine the annual oyster production per industry standard oyster raft

Oyster production is not a standardized practice and methods can vary depending on the site, product being cultured, and size of operation. Thus, there is not a standard average annual production volume per raft. As a result, I used information from the literature and interviewees to determine a range of annual production quantities per raft, which was incorporated into the analysis. Three annual raft production quantities were used; 4095, 7007, and 10,920 dozen live oysters per raft, annually. Continuous seeding and grading was assumed to take place year-round and mortalities were accounted for in the raft production values.

Step 5: Determine how annual BC IMTA oyster production augments BC, Canadian, and global production

I calculated IMTA oyster production quantities (tonnes of oysters) using the representative IMTA oyster component production system I developed. The sensitivity analysis ensured a range of production quantities was presented, given different values for key parameters. I compared these values to BC, Canadian and global oyster production (DFO, 2010; FAO Fishstat Plus Database, 2010), to determine the degree that IMTA oyster production in BC could augment existing production.

4.2 Consumer Perception and Valuation Survey

To address the second research objective, I conducted a consumer perception survey to understand how oyster consumers perceive the IMTA concept and value IMTA oysters. The following section describes the methods employed to design and carry out the survey. The first section discusses the survey and valuation approach including survey method, location and sample as well as the selection of a method for valuation. The second section discusses the survey design, including the structure of the questionnaire, the type of questions, choice of Payment Card WTP format and the methods of data analysis.

4.2.1 Survey and Valuation Approach

Surveys are the most common approach to studying consumer perception and attitudes towards environmental goods and services, as well as market goods. Countless examples can be found in the literature of survey research conducted to elicit consumer attitudes and willingness to pay values (Aguilar & Vlosky, 2007; Loureiro & Bugbee, 2005a; Loomis et al. 2000).

Selection of Oysters as Representative IMTA Shellfish Product

I selected oysters as the representative IMTA shellfish product and the entire survey focussed on IMTA oysters, rather than IMTA shellfish in general. The purpose of using a representative species was to ensure the survey was straightforward for respondents and it was clear what they were valuing. Moon & Balasubramanian (2003b) used a similar approach in their study where breakfast cereal was used as a representative, genetically modified food to determine if there was a market for genetically modified foods in Europe. Oysters are sold in a variety of product forms. For the survey, the product form selected was halfshell oysters, which is the predominant form found in the restaurant market.

Location of Survey and Screening

With oysters being the focus of the survey, it was critical to determine where BC oysters were sold and survey consumers in those markets, since BC IMTA oysters would likely follow similar distribution channels. Interviews with key informants as well as literature on BC shellfish markets revealed that the US represents the primary market for BC oysters (Interviewee #1, 2010; Interviewee #2, 2010; Interviewee #3, 2010; Salmon & Kingzett, 2002) . Within the US, the main markets for BC shellfish are San Francisco and Los Angeles, followed by Seattle and Portland (Interviewee #2, 2010). San Francisco was selected as the market to survey. Within San Francisco, I selected popular public areas and sea-side boardwalks, often near seafood restaurants, for surveying due to the increased likelihood of intercepting restaurant consumers of oysters. Restaurant consumers of oysters, versus at-home consumers, were selected for surveying because 90 to 95% of North American oyster consumption takes place in restaurants and household consumption is limited (Interviewee #1, 2010; Interviewee #4, 2010). If potential respondents met the requirements of the survey (i.e. oyster consumer in restaurants and over the age of 18), they were asked to participate in exchange for a small incentive.

In-Person Intercept Interviews

I chose in-person intercept interview format for a number of reasons. Firstly, face-to-face interviews are the preferable method of administering a CVM survey as recommended by the NOAA Panel on Contingent Valuation (Arrow et al., 1993). Secondly, numerous CVM studies have employed the in-person interview format (Radam et al., 2010; Becker & Freeman, 2009; Krystallis & Chryssohoidis, 2005; Loureiro & Bugbee, 2005a). Thirdly, it ensures that the concepts and questions are clearly presented and understood. I employed two interviewers to administer the survey. Surveyors were trained and took part in survey pre-testing to ensure they were prepared and consistently administered the survey. Lastly, in-person surveying allows interviewers to intercept potential respondents in appropriate locations. For example, Krystallis & Chryssohoidis (2005) surveyed purchasers of organic products at grocery stores. To screen respondents, interviewers approached potential respondents and asked them to select from a list of 12 definitions of the term “organic” food. Those who answered correctly were included in the sample. Our study employed a similar intercept screening process: interviewers approached potential respondents at random in popular seafood restaurant areas and asked if they had consumed oysters at a restaurant in a given year. If the respondent answered yes and was willing to complete the survey, they were included in the sample. A sample size of 180 respondents was estimated as appropriate for our study.

Selection of Valuation Method

Contingent valuation method (CVM) is a direct elicitation (or expressed preference) valuation technique (Boyle, 2003; Hanemann, 1984). While CVM is more commonly used to value non-market environmental goods and services, CVM has been also been applied to understand consumer preferences and WTP for environmentally friendly market goods and food products (Aguilar & Vlosky, 2007; Loureiro & Bugbee, 2005a; Loomis et al., 2000). CVM was selected for our survey for a number of reasons. Firstly, as previously discussed, a number of studies which sought to answer a similar question have used CVM which gave us good reason to do the same. Secondly, as Moon & Balasubramanian (2003a) argued, CVM can be employed to forecast the market potential for new product concepts and has been recommended as a pre-test market evaluation procedure (Cameron & James, 1987). Thirdly, the CVM is flexible and can easily be shaped to fit a study such as this. Lastly, CVM is a relatively straightforward technique for measuring WTP and is simple for respondents to grasp.

4.2.2 Survey Design

The survey was presented on a portable iPad[5] computer allowing for an interactive experience as well as a graphic depiction of the IMTA system. I designed the survey using established survey methods (Dillman, 2000), the assistance of my committee members, as well as input from members of the Canadian Integrated Multi-Trophic Aquaculture Network (CIMTAN) and Gauge Design.[6] The survey included questions similar to those found in other CVM studies (Blaine et al., 2005; Loomis et al., 2000). The survey questions were developed to gather information from respondents on consumption behaviour, aquaculture knowledge, perceptions of the IMTA concept, willingness to pay for IMTA oysters, and finally demographic characteristics. The survey was divided into five main sections: oyster consumption behaviour, aquaculture knowledge, IMTA description and WTP for IMTA oysters,

[5] An iPad is a portable computing device equipped with color, touch screen technology and wireless internet capability.
[6] Gauge Design was the Consumer Surveying Firm hired to administer the survey.

environmental/aquaculture attitudes, and lastly demographics. I discuss the sections in detail below. Appendix G provides the final consumer survey.

Section 1: Oyster Consumption Behaviour

The purpose was to understand how often they consumed oysters, how consumption behaviour changed in response to changes in the price of oysters. Consumption behaviour questions are commonly used in consumer research (Gunduz & Bayramoglu, 2011; Tsakiridou et al., 2006).

Section 2: Aquaculture Knowledge

The purpose was to understand how knowledgeable the respondent was with regards to aquaculture. The section also presented information to the respondent about aquaculture. A standard definition of aquaculture was presented to all respondents to ensure a base level of understanding of aquaculture amongst respondents. Additionally, respondents were informed that farmed oysters account for over 95% of total global oyster consumption (Monterey Bay Aquarium, 2011).

Section 3a: IMTA Description

Respondents were presented with a visual graphic combined with a verbal description of IMTA and the role of shellfish (i.e. oysters) in the system. The NOAA panel recommended the use of visuals aids in CVM studies and the graphic was particularly appropriate in the case of our survey (Arrow et al., 1993). The description can be found in Appendix G.

Section 3b: Willingness to Pay Question

After being presented with a description of IMTA, respondents were asked the CVM question to assess willingness to pay (WTP). A variety of contingent valuation question formats exist in the literature including dichotomous choice (DC) (Loomis et al., 2000), open-ended

(OE), and payment card (PC) (Loureiro & Bugbee, 2005a; Loureiro & Lotade, 2005b). The PC technique initially developed by Mitchell & Carson (1981), was selected as the WTP elicitation format. The PC technique presents respondents with a range of bid values and asks them to select the maximum value they would pay for the good in question.

The PC technique was selected for a number of reasons. Firstly, the format allowed us to directly present an option for respondents to pay less that the reference price, which is a realistic possibility. Secondly, other types of questions require larger sample sizes (e.g. the NOAA panel recommends a sample size of at least 1,000 for the DC format (Arrow et al., 1993). For reasons including the interview format and budgetary restrictions, a sample size of more than 200 was not possible. The PC technique is more appropriate for smaller samples. Thirdly, the PC format has been used in a variety of surveys that analyzed eco-friendly products and foods. Examples of PC CVM studies in the literature include consumer WTP studies for eco-friendly/eco-labelled products (Aguilar & Vlosky, 2007; Loureiro & Lotade, 2005b), eco-friendly production methods (Moon,et al., 2002), organic products (Gunduz & Bayramoglu, 2011), pre-market goods (Soloman & Johnson, 2009), and genetically modified foods (Moon & Balasubramanian, 2003a). Fourthly, as Boyle, (2003) and Ryan et al., (2004) argue that payment card avoids the problem of yea-saying that other techniques encounter. Lastly, some argue that argue that the PC technique mimics real life by allowing individuals to "shop around" for the maximum value they would pay (Ryan et al., 2004; Donaldson et al., 1997).

The payment vehicle for the WTP question was the price paid for IMTA oysters at a restaurant. Respondents were given a reference price for non-IMTA oysters and asked what the maximum amount they would pay for an identical oyster produced through IMTA. The reference price of $2.00 per oyster was calculated based on a survey of prices of oysters on the half shell at

San Francisco restaurants. A reference price is used in other studies as well (Soloman & Johnson, 2009; Loureiro & Lotade, 2005b; Cranfield & Magnusson, 2003). The use of dollar values, as opposed to percentages, was intended to make the situation more realistic. Other PC studies have opted for actual prices versus percentages as well (Radam et al., 2010; Moon & Balasubramanian, 2003b). The bid values on the payment card were determined through survey pre-testing in Vancouver and San Francisco. Additionally, including *Less than $2.00*, *$2.00*, and six premium prices (*$2.20, $2.40, $2.60, $2.80, $3.00, More than $3.00*) on the payment card afforded respondents the opportunity to select any value either below, equal to, or above the reference price. The number of bid values was limited to eight based on a review of research (Kanninen, 1995; Alberini, 1995a; Alberini, 1995b; Kanninen, 1993a; Kanninen, 1993b), which suggests that an optimal WTP bid design has 5 to 8 bid values. Open-ended WTP questions were added to supplement the PC question. *More than $3.00* and *Less than $2.00* were used to gather more information on respondent's willingness to pay. A qualitative follow-up question asking why respondents selected the bid value they did provided additional information to be used in conjunction with the statistical analysis in determining reasons for expressing a specific WTP.

Section 4: Attitudes towards Aquaculture, Eco-certification, IMTA, and the Environment

Respondents were asked about their opinion on statements about aquaculture, eco-certification, IMTA, and environmental issues. A Likert scale was used to gauge respondents' attitudes.

Section 5: Demographics

The final section gathered demographic information including gender, age, income, education level, household size, and residency status (San Francisco resident or tourist).

Demographic information was used to understand how the sample compared to the general population of San Francisco as well as for statistical analysis purposes.

4.2.3 Survey Data Analysis

I analyzed the data using descriptive statistics to understand respondents' consumption behaviour, knowledge of aquaculture, attitudes, as well as perception of IMTA and WTP for IMTA oysters. I used cross tabulations of the change in consumption behaviour, given a decrease in the price of oysters, to understand the own price elasticity of demand. I calculated the Mean WTP using the Lower-bound Turnbull mean, which uses the lower bound of the PC interval to avoid assumptions about the respondent being willing to pay a value higher than what they stated (Turnbull, 1976). The lower-bound mean technique appeals to many researchers, policy makers and analysts, as it provides a conservative estimate and does not overestimate the mean value (Hoehn & Randall, 1989). Recent willingness to pay studies have utilized the lower-bound mean of WTP including Blaine et al. (2005), who studied WTP for curb side recycling and Aguilar & Vlosky (2007) who analyzed WTP for environmentally-certified wood products.

I used three separate analyses to analyze factors that influenced respondents' stated WTP for IMTA oysters; qualitative response analysis, principal component analysis and finally regression analyses. The three will be discussed in turn.

Qualitative Response Analysis

The first analysis was qualitative response interpretation. All respondents were asked, after having answered the WTP question, why they chose the particular bid value. These responses were analyzed to gain insight into why respondents responded as they did. Other studies have included a qualitative follow-up question to help understand WTP responses as well (Becker & Freeman, 2009).

Principal Component Analysis (PCA)

I conducted the PCA to identify principal components that would be subsequently included in the regression analysis. The purpose of a PCA is to “reduce the dimensionality of the data set consisting of a large number of interrelated variables, while retaining as much as possible of the variation present in the data set” (Jolliffe, 2002, p.1). In other words, the technique reduces the number of variables and detects structure in the relationships between variables, effectively classifying them (Statsoft, 2011). The Varimax method of orthogonal rotation was employed which maximizes “the variance (variability) of the ‘new’ variable, while minimizing the variance around the new variable” (Statsoft, 2011). I used the Kaiser Normalization which retains only the components with Eigen values greater than 1 for further analysis. I used the Kaiser-Meyer-Olkin measure of sample adequacy to indicate the proportion of the variance in the variables that was common variance. High values (close to 1.0) indicate that the analysis is appropriate whereas low values (below .50) indicate that the analysis may not be of use. Finally, I saved the individual respondent’s Z-scores associated with each component to use in the regression analysis.

The independent variables included in the PCA were selected on the basis of their expected influence and the possibility of relationships between variables. Of those variables selected, three variables were related to environmental attitudes, two variables to the desirability of aquaculture generally and two variables to IMTA specifically (Table 3). The PCA was carried out using the SPSS 17.0 statistics package.

Table 3: Variable definitions and coding for the Principal Component Analysis (PCA)

Variable Number	Variable Name	Question	Coding for PCA
1	GOODIDE	Do you think IMTA is a good idea?	1 = if respondent responded yes 0 = otherwise
2	ENVORG	Are you a member of an environmental organization?	1 = if respondent was a member of an environmental organization 0 = otherwise
3	ENVPROB	To what extent do you agree or disagree with the statement *Tackling environmental problems should be a top priority in our country*	1 = if respondent agreed with the statement 0 = otherwise
4	ECOCERT	To what extent do you agree or disagree with the statement *Eco-certification of seafood products by a reputable body is important to me*	1 = if respondent agreed with the statement 0 = otherwise
5	ENVAQ	To what extent do you agree or disagree with the statement *I am concerned about the environmental impact of fish (e.g. salmon) aquaculture operations (not IMTA)*	1 = if respondent agreed with the statement 0 = otherwise
6	IMTASUS	To what extent do you agree or disagree with the statement *IMTA has the potential to improve the environmental sustainability of aquaculture*	1 = if respondent agreed with the statement 0 = otherwise
7	AQACC	To what extent do you agree or disagree with the statement *Aquaculture, in general, is an acceptable form of seafood production*	1 = if respondent agreed with the statement 0 = otherwise

Regression Analyses

The third analysis involved two separate regression analyses of WTP to identify demographic, behavioural, and attitudinal variables that influenced respondent WTP. Regression analysis is common in WTP studies and is found, in various forms, in the WTP literature (Ryan et al., 2004; Moon & Balasubramanian, 2003a; Loomis et al., 2000). The statistical package LIMDEP 9.0 was used for all regression analysis. Binary probit and ordered probit were conducted; the empirical models are discussed below.

Analysis 1: Ordered Probit Model

I used an ordered probit model to determine what factors influence respondents WTP a higher price for IMTA oysters. The ordered probit model is commonly used in PC studies because the dependent variable (WTP) is both ordinal and has more than two possible outcomes (Aguilar & Vlosky, 2007; Moon & Balasubramanian, 2003a; Boccaletti & Moro, 2000). The *Less than $2.*00 reference price was analyzed qualitatively and omitted from the ordered probit model so that the dependent variable is coded where No Premium is the lowest category as is standard in PC WTP analyses. The values in the dependent variable (WTP) correspond to the different levels of WTP that respondents were presented with on the PC.

WTP_0 = \$2.00
WTP_1 = \$2.20
WTP_2 = \$2.40
WTP_3 = \$2.60
WTP_4 = \$2.80
WTP_5 = \$3.00
WTP_6 = More than \$3.00

The ordered probit model is based on the assumption that the consumer's response to the WTP question depends on a latent variable (Gunduz & Bayramoglu, 2011; Green, 2000):

$$WTP^* = \beta x + \varepsilon, \quad \varepsilon | x \sim \text{Normal } [0,1]$$

Where:

WTP* = An unobserved willingness to pay
x = A vector of independent variables that may influence willingness to pay
β = A vector of parameters reflecting the relationship between willingness to pay and variables in x
ε = An independently and identically distributed error term with mean 0 and variance 1.

The relationship between WTP* and the observed variable WTP is a function of cut-off points (μj) which are estimated along with the regression coefficients and vary with individuals (Govindasamy & Italia, 1999). The ordered probit model assumes the following relationship between the WTP* and the observed variable WTP (Daykin & Moffat, 2002):

If $0 < WTP_i^* \leq \mu_1$	WTP = 0
If $\mu_1 < WTP_i^* \leq \mu_2$	WTP = 1
If $\mu_2 < WTP_i^* \leq \mu_3$	WTP = 2
If $\mu_3 < WTP_i^* \leq \mu_4$	WTP = 3
If $\mu_4 < WTP_i^* \leq \mu_5$	WTP = 4
If $\mu_5 < WTP_i^* \leq \mu_6$	WTP = 5
If $\mu_6 < WTP_i^* \leq \mu_7$	WTP = 6

Where:

WTP = The *i*th respondent's selected WTP bid value for the product.
μ_j = Unknown threshold parameters of WTP* to be estimated with β

The probability that a consumer's willingness to pay response falls within a certain category can be expressed as follows (Green, 2000):

$$\text{Prob (WTP = 0)} = \Phi(-\beta' x)$$
$$\text{Prob (WTP = 1)} = \Phi(\mu_1-\beta' x) - \Phi(-\beta' x)$$
$$\text{Prob (WTP = 2)} = \Phi(\mu_2-\beta' x) - \Phi(\mu_1-\beta' x)$$
$$\text{Prob (WTP = 3)} = \Phi(\mu_3-\beta' x) - \Phi(\mu_2-\beta' x)$$
$$\text{Prob (WTP = 4)} = \Phi(\mu_4-\beta' x) - \Phi(\mu_3-\beta' x)$$
$$\text{Prob (WTP = 5)} = \Phi(\mu_5-\beta' x) - \Phi(\mu_4-\beta' x)$$
$$\text{Prob (WTP = 6)} = 1 - \Phi(\mu_5-\beta' x)$$

Where:

$\Phi(.)$ = Cumulative probability function of normal distribution for the range of consumer utility

Using this arrangement and structure, the log likelihood function is developed and maximized with respect to β, μ_1, μ_2, μ_3, μ_4, and μ_5 in order to obtain the maximum likelihood estimates (MLEs) for both sets of parameters (Gunduz & Bayramoglu, 2011; Daykin & Moffat, 2002; Green, 2000).

The ordered probit model uses maximum likelihood estimation techniques to generate estimated coefficients that were used to understand if and/or how a set of independent variables influenced the dependent variable. Independent variables thought to influence the dependent variables were demographic characteristics (income, household size, education level, gender, and age), attitudes towards IMTA, aquaculture, and the environment, and oyster consumption behaviour. Behavioural, attitudinal, and demographic independent variables are commonly included in WTP models in the literature (Batte et al., 2007; Loureiro & Lotade, 2005b; Loomis et al., 2000).

P-values were used to determine the statistical significance of independent variables and their estimated coefficients as well as the estimated cut-off points in the ordered probit model (alpha values (α) of 0.1, 0.05 and 0.01). I used the likelihood ratio test to determine model significance and interpreted the sign and value of the parameter coefficient to understand how an independent variable influenced the dependent variable (Gunduz & Bayramoglu, 2011). I calculated and analyzed the marginal effects of independent variables on WTP probabilities as well which is common in ordered probit analyses in PC studies (Gunduz & Bayramoglu, 2011; Aguilar & Vlosky, 2007). Marginal effects can be interpreted as the change in the probability of falling into a specific WTP category, given a unit change in the independent variable under consideration.

Analysis 2: Binary Probit Model

I used a binary probit model to determine what factors influence a respondent's willingness to pay a 10% premium for IMTA oysters. For the purposes of the binary model, I collapsed the responses for the willingness to pay variable into two categories; the first representing those "not willing to pay a 10% premium" populated by respondents who selected *$2.00*, and those "willing to pay a 10% premium" populated by respondents who selected a premium price on the payment card (*$2.20* or higher). Lumping of bid values has been carried out in other studies including a Misra et al. (1991) WTP study on pesticide-free produce. Additionally, analyzing WTP a 10% premium or not was analyzed in a similar fashion by Govindasamy & Italia (1999) who studied WTP for organically-grown produce.

The binary probit model is a simplified version of the ordered probit model with only two possible outcomes (0 or 1) and only one cut-off point, or threshold value, is estimated (Daykin & Moffat, 2002). As was the case with the ordered probit model, maximum likelihood estimation was used in the binary probit model. I used the McFadden R^2 value and the likelihood ratio test to determine the goodness of fit and overall significance of the model. For the binary probit model, the dependent variable (WTP) was arranged as follows:

WTP_0 = \$2.00
WTP_1 = \$2.20, \$2.40, \$2.60, \$2.80, \$3.00, More than \$3.00

4.3 Semi-Structured Interviews

Limited research has been conducted on the BC shellfish industry. Therefore, I conducted semi-structured interviews with stakeholders in the BC shellfish industry to learn about the industry and fill in knowledge gaps. My objectives for the semi-structured interviews were to learn about the BC shellfish industry, BC shellfish markets, and industry challenges and potential for growth as well as more specific information regarding production methods, parameters, and the potential for IMTA. Appendix S provides a list of sample interview questions.

Chapter 5: Results

Chapter 5 presents the results of the study. Section 5.1 presents the results of the supply side analysis (production scenario analysis). Section 5.2 presents the results of the demand side analysis (IMTA oyster consumer survey).

5.1 Supply Side Analysis

The supply side analysis employed a production scenario analysis to estimate the potential increase in BC oyster production associated with the adoption of IMTA in BC. Due to the fact that exact adoption levels and IMTA production volumes depend on a host of factors that are variable, a range of production quantities were generated through the production scenario analysis. Key parameters included in the sensitivity analysis were:

- Size of shellfish component of IMTA operation (30 rafts, 60 rafts)
- Quantity of oysters produced per raft (4095/7007/10, 920 dozen per raft)
- Proportion of rafts dedicated to oyster production (33%, 66%, 100%)
- Number of salmon farms adopting IMTA (5%, 15%, 30%, 45%)

The results presented below are for a 60 raft system producing 7007 dozens oysters per raft annually, while proportion of rafts dedicated to oyster production and the number of salmon farms adopting IMTA are both varied. A 60 raft system could, in theory, offset more waste than a 30 raft system thereby achieving the goal of IMTA (Interviewee #5, 2010). Therefore, it was chosen as the configuration to present here. Additionally, the production of 7007 dozen oysters per raft was selected because it represents the middle value of the three considered. Finally, I assumed that all IMTA production was incremental and represented a net increase in provincial oyster production. The relocation of existing shellfish farms to salmon farms sites to achieve

IMTA would reduce the net provincial production increase; however, the possibility is not explored in this analysis due to uncertainty regarding both feasibility and interest on the part of salmon and shellfish growers. Appendix I provides the sensitivity analysis for quantity of oysters produced per raft and size of shellfish component of the representative IMTA operation.

5.1.1 IMTA Oyster Production in BC

Based on a 60 raft IMTA shellfish component producing 7007 oysters per raft per year, annual oyster production quantities would range widely, depending on the level of adoption and proportion of rafts dedicated to oyster production (Table 4). If 5% or roughly 6 BC salmon farms adopted IMTA and 33% of their shellfish production is dedicated to oysters, annual production of IMTA oysters in BC would 596 tonnes. However, if 45% of salmon farms adopt IMTA and shellfish production remains at 33% oysters, IMTA oyster production would equal 5363 tonnes. This represents a 900% increase in IMTA oyster production as the level of adoption increases from 5% to 45%. The proportion of rafts dedicated to oyster production also proved to be an important parameter in determining IMTA oyster production. If the proportion of farms adopting IMTA was to increase to 100%, IMTA oyster production would equal 16,090 tonnes, a further 300% increase.

Table 4: Annual production volume (tonnes) for a 60 raft system producing 7007 dozen oyster per raft per year

		Proportion of rafts dedicated to oyster production (%)		
		33	**66**	**100**
Percent of Salmon Farms adopting IMTA (%)	**5**	596	1192	1788
	15	1788	3576	5363
	30	3576	7151	10727
	45	5363	10727	16090

The production value of IMTA oyster production, in addition to production quantity, should also be considered. The landed value[7] of BC oysters averaged $1,517/ tonne between 2005 and 2009 (DFO, 2010). Using this 5 year average landed value and assuming non-IMTA oysters and IMTA oysters are of equal value, I determined the value of IMTA oyster production (Table 5).[8] Clearly, the production value of IMTA oysters can range but what is important to highlight is the potential for IMTA oyster production to generate over $24 million which is attractive to the private operator, the shellfish industry, as well as the provincial economy.

Table 5: Total annual production farm gate value ($) for a 60 raft system producing 7007 dozen oyster per raft per year

		Proportion of rafts dedicated to oyster production (%)		
		33	**66**	**100**
Percent of Salmon Farms adopting IMTA (%)	**5**	904,034	1,808,068	2,712,102
	15	2,712,102	5,424,203	8,136,305
	30	5,424,203	10,848,407	16,272,610
	45	8,136,305	16,272,610	24,408,915

5.1.2 Impact of IMTA Oyster Production on Provincial, National and Global Production

To put IMTA oyster production into context as well as to gauge how it could augment BC oyster production, I compared IMTA oyster production to average annual BC oyster production, which equalled 6803 tonnes between 2005 and 2009 (Table 6) (DFO, 2010).[9] Once again, the range of values is important to note. One the low end, at 5% adoption and 33% of rafts producing oysters, total annual BC oyster production would increase by 9%. On the high end, at 45% adoption and 100% of rafts producing oysters, total annual BC oyster production would increase by 237%, which represents a considerable increase.

[7] Farm gate value, or value prior to processing.
[8] A 5 year average was chosen to present a balanced value that accounts for both short term price fluctuations and long term inflation effects.
[9] Average annual oyster production in BC is the 5 year average annual oyster production between 2005 and 2009 as reported to DFO.

Table 6: Annual production volume (tonnes) as a percentage of BC oyster production

		Proportion of rafts dedicated to oyster production (%)		
		33	**66**	**100**
Percent of Salmon Farms adopting IMTA (%)	**5**	9%	18%	26%
	15	26%	53%	79%
	30	53%	105%	158%
	45	79%	158%	237%

The annual oyster tonnage increase attributable to oyster production associated with IMTA adoption in BC could be significant (Figure 7). Based on a 60 raft IMTA component with 100% oyster production, IMTA adoption could significantly augment provincial oyster production. At 5% adoption, IMTA oyster production could increase BC oyster production to 8978 tonnes annually. At 45% adoption, oyster production would rise to 22,893 tonnes, a 237% increase. Additionally, at 30% and 45% adoption, IMTA would account for more than 50% of total oyster production in BC assuming non-IMTA oyster production remained constant.

In terms of domestic production, while BC has accounted for the majority of production since 1986, the contribution from other provinces to domestic production has not been insignificant. Average annual oyster production in Canada between 2005 and 2009 equalled 11,454 tonnes, 6803 tonnes of which was produced in BC (Appendix B) (DFO, 2010). IMTA oyster production in BC could significantly increase domestic oyster production if IMTA was adopted widely and oysters were cultured on a large scale (Figure 8).

Figure 7: Augmentation of BC oyster production due to IMTA adoption and subsequent IMTA oyster production (DFO, 2010)

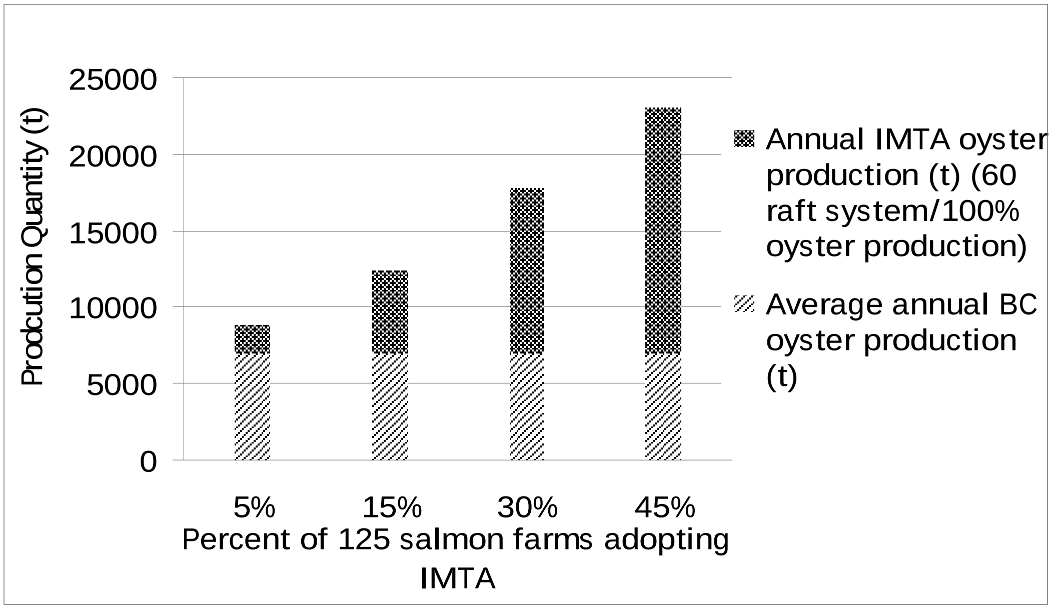
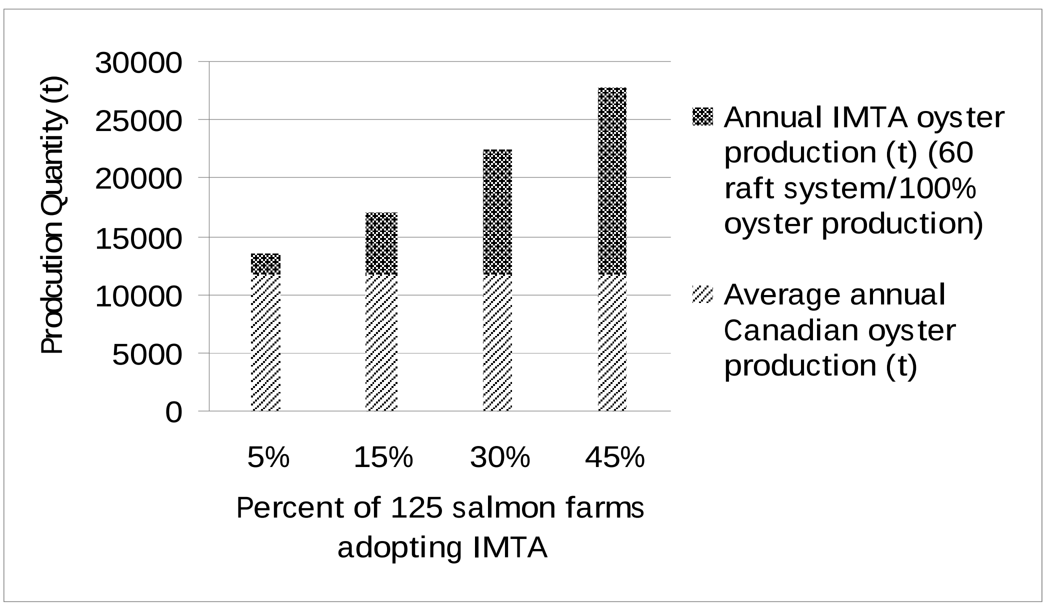


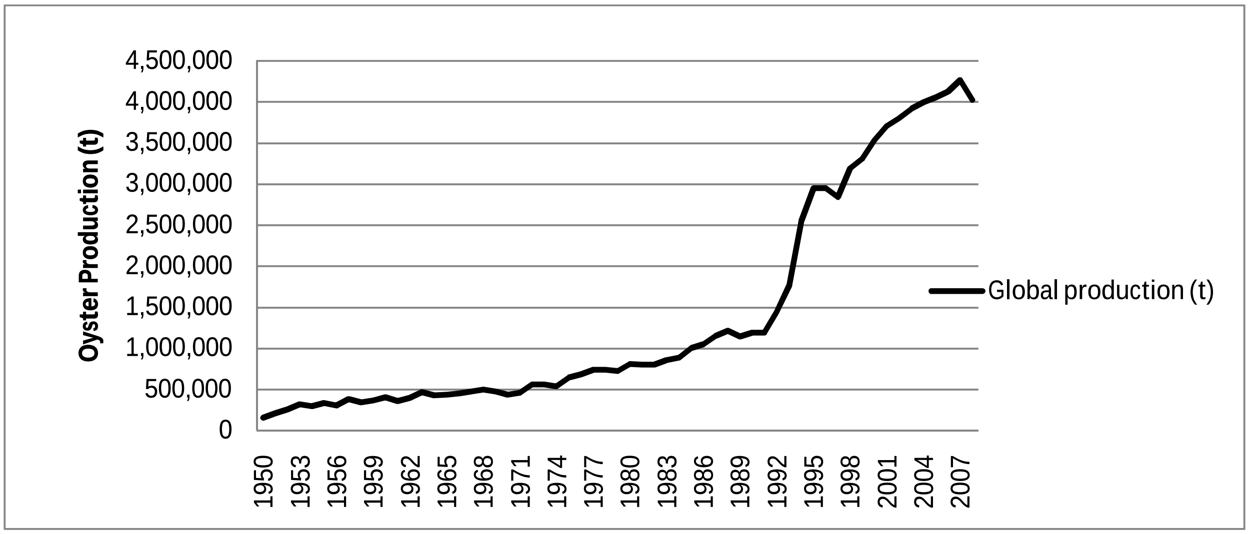
Figure 8: Augmentation of Canadian oyster production due to IMTA adoption and subsequent IMTA oyster production in BC (DFO, 2010)



While oyster production associated with IMTA adoption in BC could significantly augment production at a provincial and national level, the effect on global production would be marginal. In 2008, the most recent year on record, global production was 4,028,684 tonnes (Figure 9)

(FAO Fishstat Plus Database, 2010). Canada and BC accounted for less than 1.0 percent of this total production, at 0.22% and 0.14%, respectively (DFO, 2010; FAO Fishstat Plus Database, 2010). If IMTA were adopted in BC and the production scenario was most optimistic (45% adoption, 60 raft system, 100% oyster production), annual production would equal 16,090 which would increase global oyster production by 0.4%.

Figure 9: Global production (tonnes) of Pacific Oysters (*Crassostrea gigas*) (FAO Fishstat Plus Database, 2010)



5.1.3 Other Shellfish Species

While the production scenario analysis focused on oysters as the representative IMTA species, other candidate shellfish species could be included in an IMTA system. Mussels and scallops represent two additional candidate shellfish species that could be included in an IMTA system. For example, in the production scenario analysis discussed in section 5.1.1, the proportion of rafts dedicated to oyster production was varied. In theory, if 33% of the shellfish rafts were dedicated to oysters, the other 66% could be allocated to mussel and/or scallop production (Interviewee #1, 2010).

Average BC production of mussels and scallops between 2005 and 2009 equalled 166 tonnes and 174 tonnes respectively (Appendix B) (DFO, 2010). Therefore, any IMTA production would significantly increase BC production of these species. At the national level, Canadian production of scallops averaged 184 tonnes between 2005 and 2009 so scallop production associated with IMTA adoption in BC would have a similar impact on domestic production of scallops (DFO, 2010). However, with regards to mussels, the opposite is true. At the national level, average mussel production between 2005 and 2009 totalled 22,267 tonnes (DFO, 2010). Thus, given the fact that the mussel industry is fairly established in Canada in terms of production volume, mussel production associated with IMTA adoption in BC would not have as great an impact at the national level as it would in the case of scallops.

With that said, certain factors must be considered when discussing the potential for IMTA candidate shellfish species. For instance, certain sites may be appropriate for oysters and mussels, but not scallops, which will affect aggregate production quantities. Another consideration is the availability of seed. Oyster seed is sourced both from BC as well as Washington and is regularly available (Interviewee #1, 2010; Salmon & Kingzett, 2002). However, access to mussel and scallop seed is more difficult, which presents an obstacle to IMTA mussel and scallop production until addressed (Interviewee #1, 2010).

5.1.4 Additional Sensitivity Analysis

The discussion of results focussed on a 60 raft shellfish component to an IMTA system. Due to site restrictions, budgets, nutrient removal requirements, etc., a 30 raft system may be preferable from an operator’s perspective. Appendix I presents the same analysis discussed in Section 5.1.1 and 5.1.2 based on a 30 raft system as opposed to the 60 raft system presented here. Additionally, the discussion of results focussed on a representative oyster raft producing 7,007 dozen oysters per annum which was roughly the mid-point of annual raft production values found in the literature and interviews. However, this value is not the standard for all sites as growth rates of the Pacific oyster in BC vary from site to site due to differing site conditions including food supply and water temperature (Brown, 1988). To account for this as well as the range of raft production quantities reported, a sensitivity analysis testing for the sensitivity of results to annual production quantity per raft (4,092 dozen and 10,920 dozen) is included in Appendix I. Not surprisingly, the results are sensitive to both the configuration of the IMTA site (30 rafts versus 60 rafts) as well as the annual production quantity per raft.

The production scenario analysis demonstrated that IMTA adoption has the potential to significantly increase oyster production in BC. Moreover, the analysis revealed that the exact production increase is highly sensitive to the number of BC salmon farms that adopt IMTA, the proportion of shellfish rafts that is dedicated to oyster production, the annual production quantity per raft, and the number of rafts per system. If IMTA was adopted widely and oysters represented a significant proportion of shellfish production, IMTA oyster production could significantly augment provincial and domestic oyster production. However, such a production increase would have only a marginal effect on global production of Pacific oysters.

5.2 Demand Side Analysis

Section 5.2 presents the results of the consumer survey conducted in San Francisco. Section 5.2.1 presents the demographics, consumption behaviour, aquaculture awareness, and attitudes of the respondents sampled. Section 5.2.2 presents the results from the willingness to pay (WTP) question including WTP frequencies, analysis of qualitative responses, and finally mean WTP. Section 5.2.3 presents the results of the principal component analysis as well as the binary probit and ordered probit models employed to understand influencing factors on respondent WTP.

5.2.1 Sample Characteristics

Section 5.2.1 outlines the characteristics of the sample including demographics, consumption behaviour, factors influencing oyster purchases, aquaculture awareness, perceptions of IMTA, and finally attitudes towards the environment and aquaculture.

Demographics

The response rate for the survey was 47.6%. The average respondent was 39 years old, male and residing in San Francisco (Table 7). The average household income was $93,938.15 and average household size was 2.32. Zimet & Smith (2000) found that the average oyster consumer is male, between 18 and 49, residing in a coastal area, and earning in excess of US$ 60,000 per year, which matches the findings of this survey. Appendix J provides the frequency distributions for demographics.

Table 7: Demographic characteristics of survey sample

	Units	Min.	Max.	Median	Mean	Std. Dev.
Household Size	Number of people	1	6	2	2.32	1.199
San Francisco Residency	0 = San Francisco Bay Area Resident 1 = Non-resident	0	1	0	0.28	0.449
Income	Categories 1 - 12[10]	1	12	7	6.88	2.685
Education	Categories 1 - 6[11]	1	6	5	5.03	1.138
Age	Categories 1 - 12[12]	1	12	4	4.37	2.282
Gender	0 = male 1 = female	0	1	0	0.46	0.499

[10] Income Categories: 1= Less than 10,000 US Dollars/year, 2=10,000-14,999 US Dollars/year, 3=15,000 – 24,999 US Dollars/year, 4=25,000 – 34,999 US Dollars/year, 5=35,000 – 49,999 US Dollars/year, 6=50,000 – 74,999 US Dollars/year, 7=75,000 – 99,999 US Dollars/year, 8=100,000 – 124,999 US Dollars/year, 9=125,000 – 149,000 US Dollars/year, 10=150,000 – 174,999 US Dollars/year, 11=175,000 – 199,999 US Dollars/year, 12=200,000 + US Dollars/year

[11] Education Categories: 1= Elementary School, 2= Some High School, no diploma, 3= Graduated High School, 4= Associate's Degree, 5= Bachelor’s Degree, 6= Graduate or Professional degree

[12] Age Categories: 1= 18-24, 2=25-29, 3=30-34, 4=35-39, 5=40-44, 6=45-49, 7=50-54, 8=55-59, 9=60-64, 10=65-69, 11=70-74, 12=75+

Consumption Behaviour

I gathered information on oyster consumption behaviour, specifically the number of times the respondent ate oysters in a year and the number of oysters eaten per sitting. The average number of times respondents ate oysters in a year was 5.92 with a median of 3 times/year. The average number of oysters respondents ate per sitting was 7.69 with a median of 6 times/year. These values suggest that oysters are a luxury consumed in moderate amounts half a dozen times a year on average. Appendix K provides the frequency distributions for consumption behaviour.

I gathered price response information to determine how oyster consumers responded to changes in the price of oysters. The majority of respondents, 54% of the sample, indicated that they would not order oyster more times in a year if the price decreased by either 15% or 30%, while the remainder of the sample stated they would order oysters more often if the price decreased by some amount (Table 8). In reference to those who would eat oysters more often with a price decrease, 4% of respondents would eat more oysters if the price decreased by 15%, but not with a 30% increase because of concerns about a decrease in quality associated with a significant drop in price. A larger percentage of respondents (12%) would not eat more oysters with a 15% price decrease but would with a 30% price decrease because the 15% price decrease was insufficient to change consumption behaviour. Finally, 29% of respondents stated they would consume more oysters with either a 15% or 30% price decrease indicating they were sensitive to any price decrease.

Table 8: Cross tabulation showing changes in consumption behaviour due to oyster price change

		30% Price Decrease		
		No	**Yes**	**Total**
15% Price Decrease	**No**	98	22	120
	Yes	7	53	60
Total		105	75	180

Respondents who would increase consumption with a 15% price decrease would order oysters, on average, 3.41 additional times per year with a median of 2 additional times. Those who would increase consumption with a 30% price decrease would order oysters, on average, 9.64 more times a year with a median of 3 additional times.[13] The observed consumption increase with a 30% price decrease is greater than the consumption increase with a 15% price decrease, which makes logical sense. As the price decreases more, consumption will increase more as it becomes even more affordable. That being said, only a minority of the sample would consume more with any price decrease and the increase in consumption is minimal. Therefore, oyster demand appears to be largely inelastic.

Factors Influencing Oyster Purchases

Respondents were asked to rank a variety of factors that might influence their decision to order oysters where 1 was *Not Important* and 5 was *Very Important* (Table 9). Factors related to quality (Freshness and Food Safety) ranked the highest on average. Environmental factors including environmental friendliness and to a lesser degree production method also scored relatively high, with averages of 3.9 and 3.38, respectively. Price ranked 6th out of 9 indicating that is was not as important as other factors in influencing purchasing decisions. Appendix L provides frequency distributions each factor.

[13] One respondent indicated they would order oysters 365 additional times a year with a 30% price decrease. When this value is omitted, the average increase decreased to from 9.64 additional times to 4.84 times.

Table 9: Factors influencing oyster purchases - Aggregated results from survey ranked from highest to lowest sample mean. Ranking Scale: 1 (Not Important) to 5 (Very Important)

	Rank (based on mean)	Mean	Median	Standard Deviation
Freshness	1	4.85	5	0.512
Food Safety - Meets Safety Standards	2	4.62	5	0.695
Environmental Friendliness - The product is eco-certified	3	3.9	4	1.073
Origin of item (i.e. US vs. Imported)	4	3.58	4.00	1.277
Production Method	5	3.38	4	1.159
Price	6	3.30	4.00	1.205
Size	7	3.04	3	1.108
Type	8	3.01	3	1.217
Other Items on the Menu and their prices	9	2.64	3	1.245

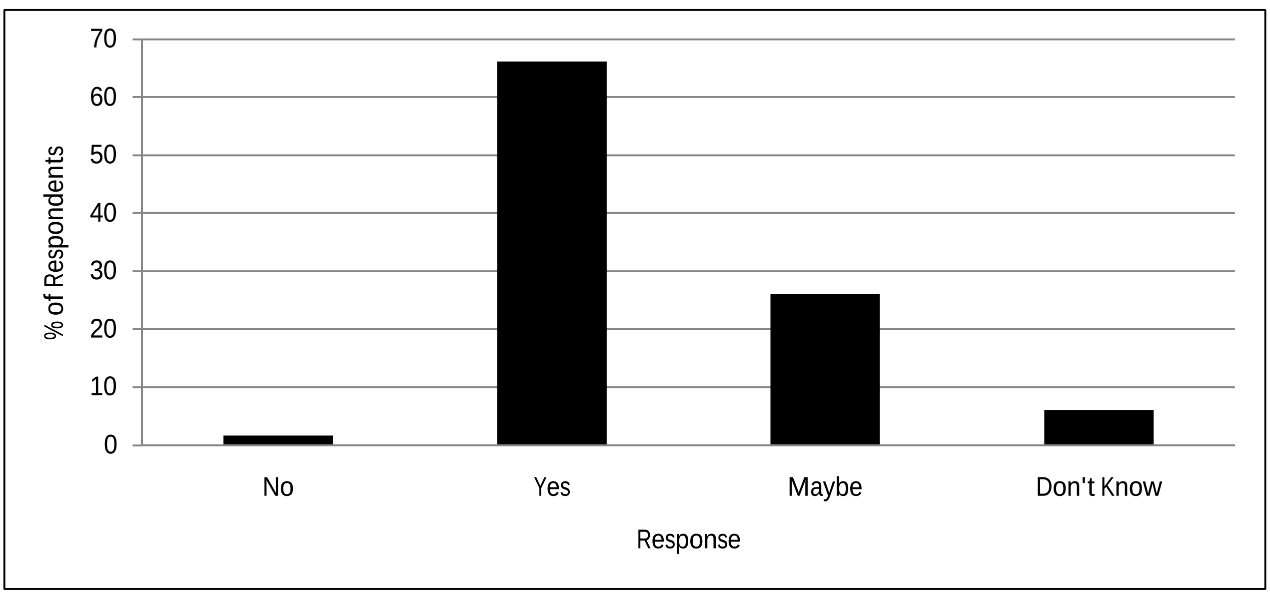
Aquaculture Awareness

Prior to the survey, the majority of those sampled (51.7%) had heard of the term aquaculture before. Of those surveyed, 40.6% indicated they were *Not knowledgeable at all* about aquaculture, 26.1% were *Not very knowledgeable*, 28.9% were *Somewhat knowledgeable*, and finally 4.4% were *Very knowledgeable.* In terms of knowledge of oyster farming, 35.6% of respondents were aware that farmed oysters account for virtually all of the world's total oyster consumption, while 62.2% were unaware that farmed oysters accounted for virtually all of global oyster consumption, with the remaining respondents unsure (Appendix M). Based on this information, we can conclude that the majority of individuals know what aquaculture is, have a low to moderate understanding of aquaculture and only one third of those sample know the degree to which farmed oysters account for global oyster supply.

Consumer Perceptions of IMTA

After a description of aquaculture as well as IMTA, respondents were asked *Do you think IMTA is a good idea?* In response, 1.7% of the sample replied *"No"* to the question (Figure 10). A qualitative follow-up question revealed that all respondents were concerned about disease transmission within the system. The substantial majority of respondents replying *"Yes"* to the question (66.1%) provided a variety of reasons including the possibilities that IMTA mimics the natural system, is a better use of resources, is more efficient, is environmentally friendly, and is an interesting technique for waste recycling. Additionally, respondents replying *"Maybe"* revealed that they were unsure if the system was proven, what the products taste like, or needed more information. Finally, respondents replying *"Don't Know"* (6.1%) needed more information or had no interest in farming methods.

Figure 10: Responses to survey question "Do you think IMTA is a good idea?



Attitudes towards Aquaculture, IMTA and the Environment

Respondents generally felt that aquaculture was an acceptable form of seafood production. The majority of respondents (72.2%) felt that aquaculture was an acceptable form of seafood production. That being said, most respondents (81.7%) were concerned about the environmental impacts of finfish aquaculture. After hearing an explanation of IMTA, the majority of respondents (68.3%) agreed that IMTA had the potential to improve the environmental sustainability of aquaculture. With regards to sustainable, eco-friendly seafood more generally, eco- certification of seafood products was important to most respondents (76.1%). Finally, 82.2% of respondents felt that addressing environmental problems should be a top priority in the country and a significant minority (30%) were members of an environmental organization. Appendix N provides frequency distributions of attitudinal responses.

5.2.2 Willingness to Pay for IMTA oysters

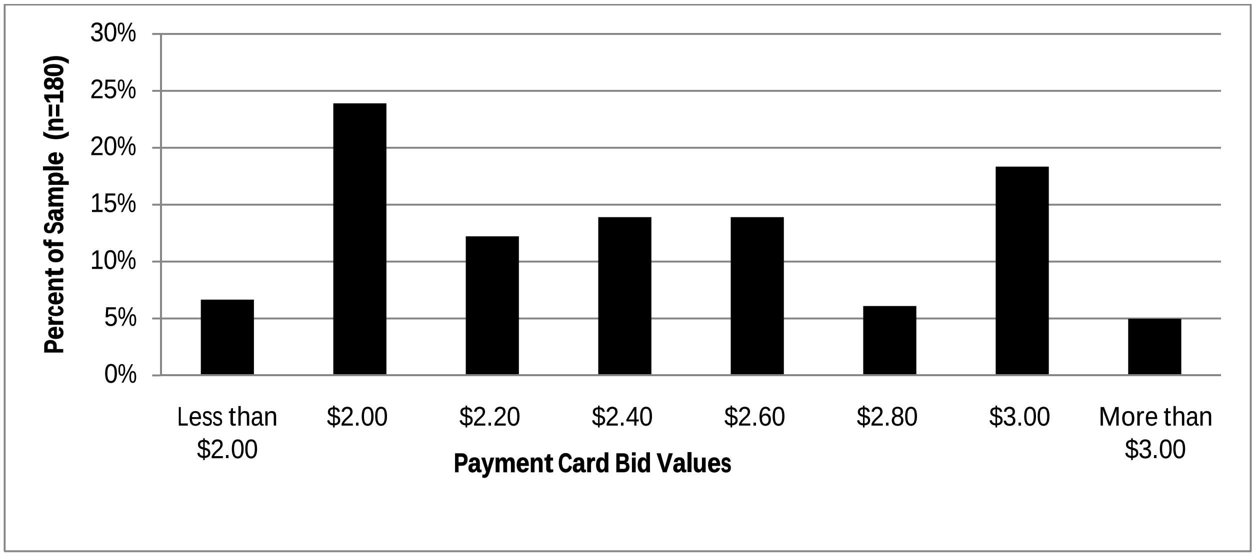
The payment card WTP question was used to determine how oyster consumers value IMTA oysters. Initially, respondents were given a description of aquaculture and the IMTA system specifically. Next, respondents were given a reference price of $2.00 for a non-IMTA oyster and asked to select their maximum willingness to pay value for one identical IMTA oyster from a list of bid values. One value was for those willing to pay less than the reference price of $2.00 indicating they value an IMTA oyster less than a non-IMTA oyster. One bid value was for the reference price of *$2.00* to allow respondents who see no difference between the two to express that. Finally, six separate premium bid values ranging from *$2.20* to *More than $3.00* were selected based on extensive pre-testing and included on the payment card. A qualitative follow-up question was included as well to gather information about why the respondent selected the particular value.

The results of the WTP questions revealed that a small percentage of respondents (6.7%) were only willing to pay less than the reference price, roughly a quarter of respondents (23.9%) of the sample indicated they would pay the reference price and the remainder of the sample

(69.4%) stated they would pay a premium (Figure 11). The distribution is relatively even with a spike at $3.00 demonstrating that the pre-tested bid-value range was accurate as approximately 5% of the sample selected the lowest and highest bid values with the remainder falling in between. The bimodal nature of the distribution has been observed in other payment card studies (Moon et al., 2002; Moon & Balasubramanian, 2003a).

The small percentage of respondents willing to pay *Less than $2.00* for an IMTA oyster provided reasons including that there was nothing wrong with the conventional method, it should cost less to produce, the price would provide an incentive to try it, and uncertainty and concern around the production method. Those that were willing to pay *$2*.00 felt that there was no difference between oysters, needed for more information before paying a premium, needed to see a proven system before paying a premium, needed to taste the product before paying more, weren't willing to pay more than a non-IMTA oyster and/or had a greater interest in quality and flavour over farming method. Finally, the majority of respondents who were willing to pay at least *$2.20* expressed that IMTA was an environmentally friendly production system, IMTA was a better production technique, that they were willing to pay more for a more sustainable way of farming seafood and that the waste recycling concept which mimics a natural ecosystem is appealing. Krystallis & Chryssohoidis (2005) and Laroche et al. (2001) assert that the most convincing evidence supporting the development of ecologically favourable consumer behaviour is the growing number of people willing to pay a more for environmentally friendly products. The fact that the majority of consumers are WTP a premium for IMTA oysters supports this argument.

Figure 11: Frequency distribution of WTP responses



The mean WTP for an IMTA oyster was calculated using the Turnbull Lower Bound Mean which provides the most conservative estimate of WTP, allows one to incorporate open-ended WTP responses as well as PC responses, and avoids any assumptions about an individual being willing to pay more than the value they selected (Blaine et al., 2005). The Turnbull Mean WTP equalled $2.48, which represents a 24% premium above the reference price of $2.00 for a non-IMTA oyster (Table 10). Clearly, on average, respondents considered the IMTA oyster to be a high-value product and expressed a willingness to pay a 24% premium for it.

Table 10: Mean WTP for IMTA oysters

WTP	**Mean WTP**	**Median WTP**
Sample WTP (n=174)	$2.48 (24% Premium)	$2.40 (20% Premium)
Stated Premium WTP (n=124)	$2.71 (36% Premium)	$2.60 (30% Premium)

Two other studies have analyzed WTP for IMTA seafood products. Barrington et al. (2010) conducted a focus group survey on IMTA in New Brunswick and found that over 50% of respondents were willing to pay a 10% premium for environmentally friendly seafood (not necessarily IMTA). Shuve et al., (2009) studied WTP for IMTA mussels specifically and found that 38% of respondents (n=595) were willing to pay a 10% premium compared to the 70% who indicated as such in this study. Additionally, 18% of respondents were willing to pay a 20% premium for mussels versus 57% of respondents in this study for IMTA. Clearly, the findings of all three studies were similar in that a significant percentage of respondents in all cases were willing to pay a premium for environmentally friendly or IMTA seafood products.

With the introduction of IMTA oysters on the market, a small percentage of respondents (21.6%) indicated they would eat oysters more often. Those who would eat oyster more often would do so, on average 3.5 additional times/year (median = 3). These results suggest that the presence of oysters at restaurants would not increase existing consumer demand for oysters in any significant way.

5.2.3 Modelling Influencing Factors on Willingness to Pay

Section 5.2.3 is organized as follows. First, I present the Principal Component Analysis (PCA) employed to assemble principal components out of a variety of possibly related independent variables. Second, I discuss the regression model specification which is identical for the binary probit and ordered probit models. Third, I present the results of the binary probit model used to identify factors influencing WTP a stated premium ($2.20 or higher). Finally, I present the results of the ordered probit model used to identify factors influencing WTP.

Principal Component Analysis (PCA)

I used the PCA to reduce the seven variables to uncorrelated principal components which are “ordered so that the first few retain most of the variation present in all of original variables” (Jolliffe, 2002, p.1) (Table 3). Three principal components emerged from the PCA and collectively accounted for 63.1% of the overall variance. The Kaiser-Meyer-Olkin measure of sampling adequacy was .651 which is well above the 0.50 threshold indicating the analysis is appropriate and useful. The Bartlett's Test of Sphericity was also significant at the 0.01 level (χ^2= 133.484, d.f. = 21).

The PCA identified three principal components (Table 11). The first component is defined by three variables including favouring eco-certification, prioritizing environmental problems, and concern around the impacts of finfish aquaculture. Generally, this component can be called Environmental Concern and Awareness. It explains 29.2% of the total variance. The second component includes variables related to the acceptability of aquaculture as well as perceptions of IMTA. Generally, the component can be called Perceptions of Aquaculture and IMTA. It explains 19.6% of the total variance. Finally, the third component is defined by membership in an environmental organization and can generally be referred to as Environmental Activism. It explains 14.3% of the variance. Appendix O provides additional information on the PCA.

Table 11: Rotated component matrix for PCA

Rotated Component Matrix			
	Component		
	1	**2**	**3**
ECOCERT	**.788**	.145	-.120
ENVAQ	**.692**	-.225	.238
ENVPROB	**.627**	.221	.160
AQACC	-.213	**.766**	.165
IMTASUS	.215	**.753**	.045
GOODIDE	.379	**.582**	-.307
ENVORG	.155	.088	**.908**

Binary and Ordered Probit Model Specification

The WTP binary and ordered probit models were analyzed under the same specification (Table 12). The dependent variable, WTP, was either arranged as a binary variable in the case of the binary probit model or as ordered categories in the case of the ordered probit model. Independent variables in the model included demographic characteristics (i.e. income, education, age, and gender) as well as attitudinal variables in the form of the principal components discussed above. Average annual oyster consumption (# of times one eats oysters in a given year) and residency (whether respondent was a resident of the San Francisco Bay Area or not) were also included as independent variables to test for influence on WTP. Using both demographic and attitudinal independent variables is characteristic of WTP regression analyses (Gunduz & Bayramoglu, 2011; Loureiro & Lotade, 2005b; Loomis et al., 2000).

The binary and ordered probit models were tested under the following specification:

WTP (Binary or Ordered Dependent Variable) = $\beta_0 + \beta_1$ AVGORDER + β_2 FAC1 + β_3 FAC2 + β_4 FAC3 + β_5 AGE + β_6 GENDER + β_7 EDUC + β_8 INC2 + β_9 INC3 + β_{10} INC4+ β_{11} HHSIZE + β_{12} RESTOUR

Where:

Table 12: Description of variables used for binary and ordered probit models[14]

Variable	Variable Form	Definition	Expected Sign
Dependent Variable			
WTP (binary model)	Binary	1 if stated WTP premium ($2.20 or higher) 0 = otherwise ($2.00)	N/A
WTP (ordered probit model)	Ordered	0 = $2.00 1 = $2.20 2 = $2.40 3 = $2.60 4 = $2.80 5 = $3.00 6 = More than $3.00	N/A
Independent Variables			
LNAVGORDER	Continuous	Log of the average number of times/year respondent eats oysters	-
FAC1	Continuous	PCA Component Z-Score[15]	+
FAC2	Continuous	PCA Component Z-Score[10]	+
FAC3	Continuous	PCA Component Z-Score[10]	+
AGE	Continuous	Midpoint of age range on survey	+
GENDER	Binary	1 = if individual is female 0 = otherwise	+
EDUC	Binary	1 = if individual completed a Bachelor's degree or higher 0 = otherwise	+
INC1*	Binary	1 if respondent's income (X) is < USD $25,000 0 = otherwise	+
INC2	Binary	1 = if USD $25,000 ≤ X < USD $75,000 0 = otherwise	+
INC3	Binary	1 = if USD $75,000 ≤ X < USD $150,000 0 = otherwise	+
INC4	Binary	1 = if USD $150,000 ≤ X 0 = otherwise	+
HHSIZE	Continuous	Number of people in household	-
RESTOUR	Binary	1 = if individual is not a resident of the San Francisco Bay area 0 = otherwise	-
* Variable was dropped from the model to avoid collinearity in the model			

[14] Note: Surveyor bias was tested for in initial model runs to determine if the surveyor administering the survey influenced the results. A dummy variable was used to test the influence of one of two surveyors on the result and results were statistically insignificant demonstrating that surveyor bias was not present.`

[15] PCA Component Z-Score range from approximately -3 to 3.

Descriptive statistics for the independent variables included in the binary probit and ordered probit models are in Appendix Q.

Binary Probit Analysis

The binary probit model was statistically significant ($\alpha = 0.05$) with a likelihood ratio test probability of 0.01631. The McFadden Pseudo R^2 value was 0.129 which is reasonable for cross-sectional data (Table 13). Finally, the model correctly predicted 77.38% of the observations. Appendix P provides the prediction tables. Therefore, the demographic, attitudinal principal component variables, consumption, and residency variables included in the binary probit model are relevant in explaining consumer WTP a stated premium for IMTA oysters.

The model yielded three statistically significant coefficients as well as two additional variables of interest (Table 13). Each significant variable is discussed in turn.

FAC1, the principal component defined as Environmental Awareness and Concern, was statistically significant at the 99% confidence level and the coefficient was positive as expected. The positive coefficient indicates that the FAC1 variable and the dependent variable (WTP) are positively correlated meaning that as the FAC1 score increases (i.e. the respondent is more aware of and concerned about the environment, the more likely they are to pay a premium for IMTA oysters (Table 13). The marginal effect of FAC1 variable is such that as it increases by one unit, the probability of a respondent paying a premium for IMTA oysters increases by 11% (Table 14).

FAC2, the principal component defined as Perception of Aquaculture and IMTA, was statistically significant at the 90% confidence level. The coefficient is positive as well meaning that as the FAC2 score increases (i.e. the respondent has more of a positive perception of aquaculture and IMTA), the more likely they are to pay a premium for IMTA oysters. The marginal effect of the FAC2 variable is such that as FAC2 increases by one unit, the probability of a respondent paying a premium for IMTA oysters increases by 7% (Table 14).

Finally, the INC2 coefficient is positive and statistically significant at the 90% confidence level. If a respondent falls in the US$25,000 to US$75,000 income range, they will be 64% more likely to pay a premium for IMTA oysters (Table 13). The INC3 is also statistically significant and has a similar effect on the dependent variable as INC2. Finally, INC4 has a similar effect as INC2 and INC3 but is not significant. An interesting point to mention is that the coefficients decrease in size, albeit marginally, between INC2 and INC4. The implication here is that the higher one's income is, the less likely they are to pay a premium for IMTA oysters, which is contrary to our expectations.[16]

Two additional variable of interest are LAVGORDER and GENDER. LAVGORDER almost significant (P-Value = 0.1586) and has a negative coefficient which was expected. As respondents go for oyster more often in a given year, the probability of paying a stated premium for IMTA oysters will decrease by 6% (Table 14). Muth et al. (2002) also found a negative correlation between frequency of oyster consumption and WTP a premium price. A reason for the negative relationship could be that, because they already spend a significant amount on oysters, a premium price on top of a luxury product price is unattractive. The GENDER variable is almost significant as well (P-Value = 0.107) and is positive meaning that if a respondent is female, they will be 39% more likely to pay a stated premium for IMTA oysters (Table 13). Other studies have found that females are more likely to pay premiums for environmentally-friendly products as well (Mohamed & Ibrahim, 2007; Laroche et al., 2001; Govindasamy & Italia, 1999).

[16] Once again, the difference between INC coefficients is minimal so this pattern is not meaningful.

Table 13: Estimated coefficients, p-values and model statistics for the binary probit model

Variable	Estimated Coefficient	P-Value
CONSTANT	0.13449566	0.8455
LAVGORDER	-0.18881784	0.1586
FAC1	0.35346232***	0.0034
FAC2	0.21645781*	0.0867
FAC3	-0.00819639	0.9454
AGE	0.00808555	0.4744
GENDER	0.38665908	0.107
EDUC	-0.16250104	0.6026
INC2	0.64309012*	0.0735
INC3	0.63795166*	0.0734
INC4	0.61138162	0.1392
HHSIZE	0.00859342	0.9308
RESTOUR	-0.35658045	0.1828
Model Statistics: McFadden Psuedo R2 = 0.12925, Prob [χ^2 > value] = 0.01631**		
α = 0.10	*	
α = 0.05	**	
α = 0.01	***	
Note: Dependent Variable (WTP) is binary where 0 = $2.00 and 1 = $2.20, $2.40, $2.60, $2.80, $3.00, More than $3.00		

Table 14: Marginal effects of independent variables in the binary probit model

Variable	Marginal Effect
LAVGORDER	-0.057127
FAC1	0.10694032
FAC2	0.06548949
FAC3	-0.0024798
AGE	0.00244629
GENDER	0.1156689
EDUC	-0.0473168
INC2	0.17496234
INC3	0.1814105
INC4	0.15594635
HHSIZE	0.00259995
RESTOUR	-0.1135252

Ordered Probit Analysis

The ordered probit model was statistically significant ($\alpha = 0.01$) with a likelihood ratio test probability of 0.0001. The McFadden Pseudo R^2 value was 0.064 (Table 15). Additionally, the estimated threshold values (μs) were all positive, properly ordered, and statistically significant at the 1% level of significance (Table 15). Therefore, the demographic, attitudinal principal component variables, consumption, and residency variables are relevant in explaining consumer WTP for IMTA oysters.

The model yielded four statistically significant coefficients as well as three additional variables that merit discussion (Table 15). Each significant variable coefficient is discussed followed by an analysis of the marginal effects of each significant variable.

FAC1, the principal component defined as Environmental Awareness and Concern, is statistically significant at the 99% confidence level and the coefficient is positive which was expected. The positive coefficient sign indicates that the FAC1 variable is positively correlated with the dependent variable. Those who are environmentally aware and expressed concern regarding the environmental impact of finfish aquaculture were more likely to pay a higher price for IMTA oysters.

FAC2, the principal component defined as Positive Perception of Aquaculture and IMTA, is also statistically significant at the 99% confidence level. The coefficient is positive as well indicating that those who accept aquaculture as a form of seafood production and have a positive perception of IMTA are, in general, more likely to pay a higher price for IMTA oysters.

Finally, both the INC2 and INC3 coefficients are positive and statistically significant at the 90% and 95% confidence level, respectively, indicating a positive correlation between income and WTP for IMTA oysters. As household income increases, the probability of WTP a higher price for IMTA oysters increases. Additionally, the estimated coefficient of INC3 (0.57) was greater than the INC2 coefficient (0.51) indicating that a higher income will have a greater effect on the probability of WTP. The coefficient for INC4 was lower than INC2 and INC3, but was not significant.

Other notable variables include FAC3 and RESTOUR. The FAC3 coefficient was positive and almost significant at the 90% level (P-Value = 0.1066) meaning that membership in an environmental organization had a positive, if small, effect on the probability of WTP a higher price for IMTA oysters. The RESTOUR coefficient was negative but insignificant (P-Value = 0.1627) indicating that residing outside of the San Francisco Bay Area has little effect on WTP for IMTA oysters. The remaining variables, including the majority of demographic variables, in the model were not significant.

Table 15: Estimated coefficients, p-values and model statistics for the ordered probit model

Variable	Estimated Coefficient	P-Value
CONSTANT	0.04026166	0.9371
LAVGORDER	0.01795711	0.8535
FAC1	0.31837098***	0.0005
FAC2	0.34881498***	0.0001
FAC3	0.14184996	0.1066
AGE	0.01120901	0.3273
GENDER	0.00585869	0.4715
EDUC	-0.01858217	0.9334
INC2	0.51020805*	0.0727
INC3	0.57954616**	0.0427
INC4	0.44788648	0.1664
HHSIZE	-0.01295196	0.8604
RESTOUR	-0.27931594	0.1627
μ_1	0.43458486***	0.0000
μ_2	0.85629194***	0.0000
μ_3	1.27763589***	0.0000
μ_4	1.48856888***	0.0000
μ_5	2.54807503***	0.0000
Model Statistics: McFadden Psuedo R2 = 0.06423, Prob [χ^2 > value] = 0.0001***		
α = 0.10	*	
α = 0.05	**	
α = 0.01	***	
Note: Dependent Variable (WTP) is ordered where 0 = $2.00, 1 = $2.20, 2 = $2.40, 3 = $2.60, 4 = $2.80, 5 = $3.00, 6 = More than $3.00		

The marginal effects of each independent variable provide additional information regarding the influence of the independent variable on the dependent variable (Table 16). Only statistically significant variables will be discussed here. First, the marginal effect of FAC1 on the WTP a premium price for IMTA oysters suggests that an increase in FAC1 variable decreased the probability of choosing $2.00 by 9.7%, $2.20 by 2.4% and $2.40 by 0.4%. On the other hand, an increase in the FAC1 variable increased the probability of choosing $2.60 by 1.6%, $2.80 by 1.4%, $3.00 by 7.1% and $3.00+ by 2.4%. The pattern suggests that those who are more environmentally conscious, and thus have a higher FAC1 PCA component score, are less willing to pay the same, or even a small premium, and are more willing to pay a higher premium for IMTA oysters. The marginal effect of FAC2 is similar to that of FAC2 and therefore FAC2 will not be discussed.

The marginal effect of INC2 on the WTP a premium price for IMTA oysters suggested that if the respondent is in the INC2 category (i.e. earns between US$25,000 to US$75,000), it decreased the probability of choosing $2.00 by 14.4%, $2.20 by 4.3% and $2.40 by 1.5%. On the other hand, falling in the INC2 category increased the probability of choosing $2.60 by 1.9%, $2.80 by 2%, $3.00 by 11.5% and $3.00+ by 4.74%. If a respondent falls within the INC3 category, it had the identical effect as INC2 so it will not be discussed in detail. However, an important point to mention is that when comparing the marginal effects of INC2 and INC3, in all but one case (WTP = 2), the marginal effect of INC3 is greater than that of INC2. The pattern indicates that falling in the higher of the two income categories will have relatively greater marginal effect on the probability of selecting the higher WTP bid values, which makes logical sense.

Table 16: Marginal Effects of independent variables in ordered probit model

Marginal Effects	WTP= 0 ($2.00)	WTP = 1 ($2.20)	WTP = 2 ($2.40)	WTP = 3 ($2.60)	WTP = 4 ($2.80)	WTP = 5 ($3.00)	WTP = 6 ($3.00+)
LAVGORDER	-0.0055	-0.0014	-0.0002	0.0009	0.0008	0.004	0.0014
FAC1	-0.0974	-0.0242	-0.0043	0.0167	0.0141	0.0709	0.0243
FAC2	-0.1067	-0.0266	-0.0048	0.0183	0.0154	0.0777	0.0266
FAC3	-0.0434	-0.0108	-0.0019	0.0075	0.0063	0.0316	0.0108
AGE	-0.0018	-0.0004	-0.0001	0.0003	0.0003	0.0013	0.0004
GENDER	-0.0483	-0.0121	-0.0023	0.0082	0.007	0.0353	0.0122
EDUC	0.0057	0.0014	0.0003	-0.001	-0.0008	-0.0041	-0.0014
INC2	-0.1439	-0.0427	-0.0147	0.0188	0.0197	0.1153	0.0474
INC3	-0.1678	-0.0463	-0.0135	0.0241	0.0232	0.1293	0.0511
INC4	-0.1216	-0.0395	-0.0161	0.0135	0.0164	0.1025	0.0447
HHSIZE	0.004	0.001	0.0002	-0.0007	-0.0006	-0.0029	-0.001
RESTOUR	0.0889	0.0191	0.0011	-0.0168	-0.0128	-0.0603	-0.0192

The regression analysis yielded important results regarding the factors that influence WTP for IMTA oysters. The binary and ordered probit models took different approaches to analyzing and interpreting the data. On the one hand, the binary model was used to understand factors that influenced those WTP a premium for IMTA oysters. On the other hand, the ordered probit model was used to understand how the independent variables influenced the probability of selecting each bid value on the payment card. The more comprehensive approach of the ordered probit model is the primary reason why the model is widely applied in Payment Card WTP studies. While the binary model provided interesting results, the ordered probit model is preferred as it provided more detailed information on how the independent variables influence factors influenced WTP.

While the models differed in their approaches, they yielded similar results. We found that FAC1 (Environmental Awareness and Concern) and FAC2 (Perception of Aquaculture and IMTA) had a positive relationship with WTP. Of the demographic variables, income had a statistically significant, positive relationship with WTP. The remaining demographic variables, as well as the LAVGORDER and RESTOUR variables, were not significant, the reason being either that there was no influence at all, or that due to the small sample size, the data did not have enough variability for the model to identify statistically significant relationships.[17] The regression analysis conducted allowed us to analyze the factors influencing an individual's WTP and clearly, attitudinal variables, and income to a lesser extent, have a strong influence on WTP for IMTA oysters.

[17] A larger data set may have revealed additional underlying relationship in the dataset.

Chapter 6: Discussion

A formal analysis of IMTA adoption by finfish farmers should take into account the economic and market implications of adoption on markets for extractive aquaculture products. I have, thus far, addressed the demand side and the supply side of the equation. The purpose of Chapter 6 is to integrate the findings of the study and combine the results with information on the state of the BC shellfish industry and global shellfish markets to understand the market implications of increased oyster production associated with the adoption of IMTA in BC. The chapter is organized into the following parts. Section 6.1 integrates the findings of the supply side and demand side analyses, as well as shellfish industry characteristics, to draw conclusions about the market implications of oyster production associated with IMTA adoption by BC salmon farmers. The market implications are presented graphically through conceptual supply and demand curves (Figure 12). Section 6.2 presents further issues related to IMTA adoption in BC, notably the existence of cadmium as well as the implications related to ocean acidification. Section 6.3 discusses the study limitations. Section 6.4 discusses areas of future research that have been identified over the course of the research study.

6.1 Integrating Findings: IMTA and the BC Shellfish Industry

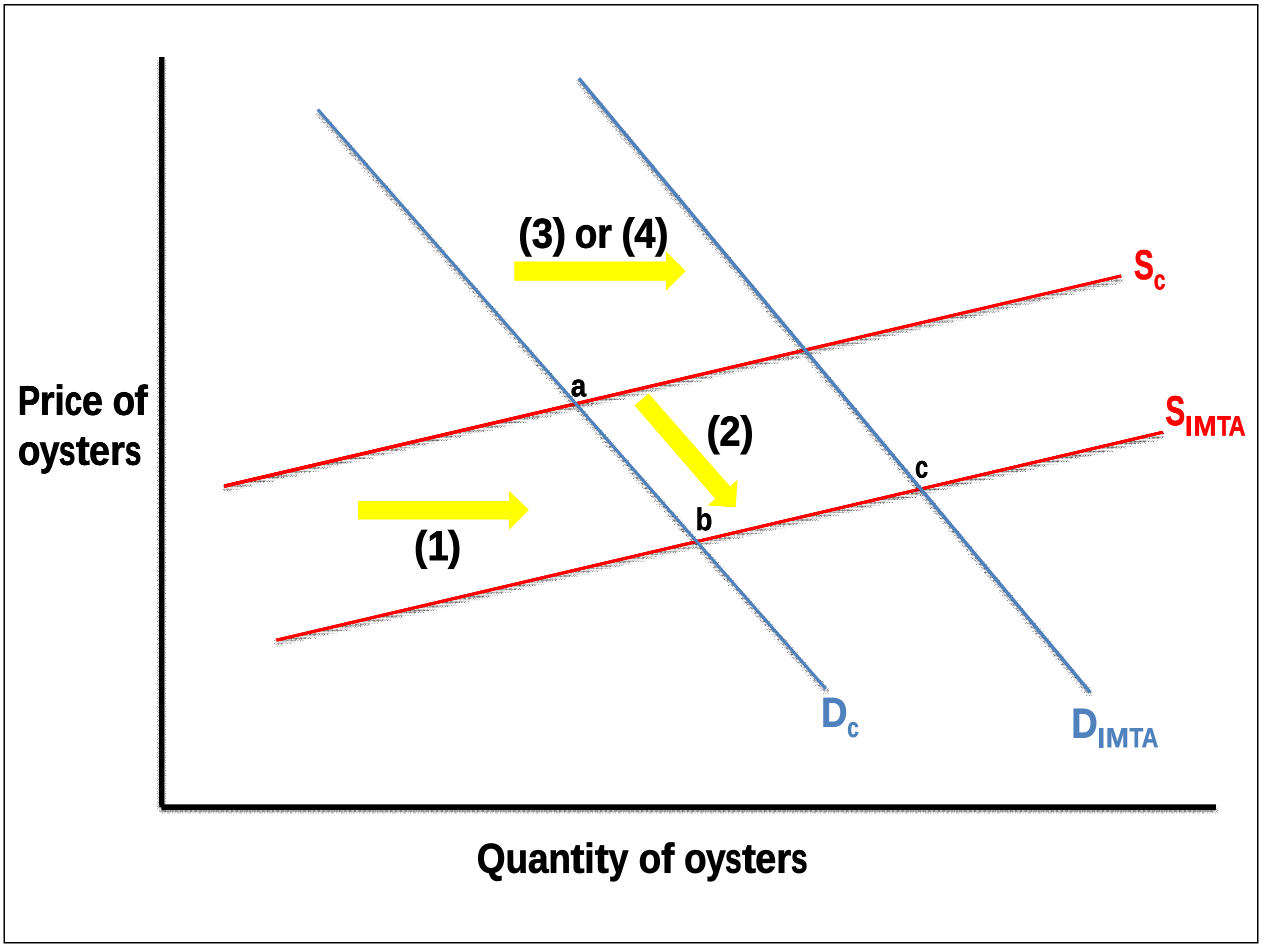
The following section summarizes and integrates the findings of the demand and supply side analyses with the use of conceptual supply and demand curves. The market implications of wide-scale IMTA adoption are discussed with regards to market supply and demand. Finally, conclusions are drawn regarding the potential for IMTA and the role IMTA could play in the BC shellfish industry.

6.1.1 Summary of Findings

The Supply Side

The supply side analysis revealed that oyster production associated with IMTA adoption could significantly increase BC production of oysters assuming a significant proportion of those able to adopt IMTA (56 of 125 salmon farms) do so and choose to produce oysters in addition to, or instead of, other shellfish products. S_c represents the current market supply curve for BC oysters (Figure 12). S_{IMTA} represents the potential market supply curve for the BC oysters industry if provincial production is augmented by additional oyster production associated with IMTA adoption in the province. A shift from S_c to S_{IMTA} represents a shift in the market supply curve that is due to an increase in the number of sellers in the market as BC salmon farms adopt IMTA and begin to produce a suite of new aquaculture products, including oysters (Mankiw et al., 2002). The market supply curve in the long run would be relatively elastic, meaning that quantity supplied to the market responds substantially to changes in demand for oysters and/or the price paid to the farmer (farm-gate price) (Figure 12) (Interviewee #1, 2010; Interviewee #4, 2010). However, the price paid to producers has generally not increased since the dissolution of the oyster marketing board (Interviewee #1, 2010; Interviewee #4, 2010). In the short term, the supply curve tends to be more inelastic due to production constraints, including limited access to capital/financing, limited tenure size as well as the extended duration of production (Mankiw et al., 2002). Finally, the extent of the shift in the supply curve will depend on whether, and the extent to which, IMTA product is from new operations or is sourced from shellfish operations that relocate their operations.

Figure 12: Potential market equilibrium implications for the BC oyster industry. (1) represents a shift in supply curve due to increase in oyster production associated with IMTA adoption. (2) represents movement along the market demand curve implying a price decline. (3) and (4) represent a shift in the market demand curve for oysters. Different states of market equilibrium are depicted by *a*, *b* and *c*.



The Demand Side

The demand side analysis revealed that there is general acceptance of IMTA oysters and in fact, the majority of consumers consider IMTA oysters to be a premium product. In terms of the market demand for oysters, the price change responses revealed two groups of consumers (Table 8). One group, populated by the majority of consumers surveyed, has an inelastic demand curve, meaning they might not change their purchasing behaviour (i.e. purchase more or fewer oysters) with a change (decrease or increase) in the price of oysters. The other group, represented by a significant minority of respondents, have a more elastic demand curve, meaning that they may consume more if the price of oysters decreased, or less if the price increases. Therefore, assuming this observation is characteristic of the existing market for BC oysters as a whole, the demand for oyster is largely, but not perfectly, inelastic (Figure 12). [18]

Demand for luxury goods, such as oysters, is usually highly elastic except if the product represents a small portion of the personal budget. Based on the consumer survey, the average consumer only eats oysters 5.92 times per year consuming 7.69 per sitting demonstrating that oysters, on average, make up a miniscule portion of the personal, annual budget. Thus, the conclusion that oyster demand is relatively inelastic may be justified. Oyster consumers appear to be less concerned about the price of the good as it is not a dietary staple. This point is supported by our consumer survey where price ranked 6th out of 9 factors in terms of its importance in influencing purchasing decisions.

Limited research exists on own-price elasticity of demand for restaurant-sold, halfshell oysters (Muth et al., 2002). Two studies were identified that address oyster elasticities generally. Cheng and Capps Jr. (1988) conducted a demand analysis of at-home consumption of shucked oysters and calculated an own-price elasticity estimate of 1.10, which implies elastic demand for that particular product. While this value is informative, it is not directly applicable to our study since we consider a different product: restaurant-sold, halfshell oysters. Muth et al. (2002) encountered a similar problem and calculated an own-price elasticity of 0.55 for halfshell oysters.[19] The Muth et al. (2002) elasticity value implies inelastic demand for oysters on the

[18] Inelastic market demand implies that as the price for oysters decreases (potentially due to a supply increase), the quantity demanded will not change substantially (Mankiw et al., 2002).

[19] Muth et al. (2002) derived the elasticity value in the following way. Assuming demand for halfshell oysters would be less elastic than for shucked oysters, the authors used an elasticity estimate of 0.55, half the value for shucked oysters found in the Cheng and Capps Jr. (1988) study.

halfshell, which is consistent with our conclusion that demand for restaurant-sold, halfshell oysters is largely inelastic.

6.1.2 Market Implications

A large supply increase in BC oysters could shift the supply curve to the right (Figure 12). The supply increase will increase competition in existing markets, assuming market size remains constant. For significant IMTA oyster production to take place and prices to remain unchanged, the BC oyster industry would need to increase market demand which is currently a key constraint to industry growth.

Selling additional BC oysters could occur in two ways, which are listed and discussed below.

- Decrease in market price of oysters (movement down demand curve)
    - Decrease in restaurant price of oysters
    - Decrease in wholesale price of oysters
- Increase the quantity of BC oysters demanded (rightward shift in demand curve)
    - Address consumer preferences to gain additional market share
    - Increase the number of buyers in the market

Decrease in Market Price of Oysters: Movement down the Demand Curve

With additional product supplied to market, the price must decline for the additional product to be sold and the market to clear, holding market demand constant. There are two levels of analysis to consider here. At the restaurant level, additional supply could be sold by lowering the price which would, theoretically, lead to downward movement along the demand curve relocating the market equilibrium from *a* to *b* (Figure 12). However, given the inelastic demand for oysters by consumers at the restaurant level, the resulting increase in quantity demanded would not be substantial. Therefore, limited additional product would be sold and the market would not clear. Additionally, restaurants would have little incentive to reduce prices to sell more oysters because the change in demand would not be significant and the price decrease could potentially result in a net loss in profit.

At the wholesale market level, the price paid to growers would have to decline for wholesalers to purchase additional supply from growers, assuming market demand was constant.[20] Growers would have to accept this lower price to sell their additional product.[21] This reality is unavoidable, unless wholesalers were willing to accept the loss by purchasing the additional supply at the normal price. However, it must be noted that wholesalers might not have the option of a lower price due to the fact that the price paid to growers is already relatively low and many growers are operating with tight profit margins (Interviewee #1, 2010; Interviewee #4, 2010). Therefore, accepting a lower price may not be possible for many growers and wholesalers might have to maintain the current price paid to growers, regardless of purchase volumes.

Thus far, we have assumed market demand to be constant. That is to say, the demand curve cannot shift and an increase in quantity demanded could only occur with a price decrease. However, if we allow market demand to change, an increase in market demand could allow producers to accept the same price from growers at no loss and purchase more volume as well. A discussion of these market equilibrium impacts is presented later in the section.

Increase the Quantity of BC Oysters Demanded: A Rightward Shift in the Demand Curve

A shift in the demand curve to the right could increase the quantity of oysters demanded at a given price (Figure 12). A shift in the demand curve can result from the introduction of a premium product (i.e. IMTA supply) for which consumers are WTP a price premium or from changes in expectations, the price of related goods, income, consumer preferences, market share,

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[20] Based on the assumption that wholesalers have a market for the additional product.
[21] Alternatively, growers could reduce production but that is not consistent with the IMTA production increase. Therefore, it will not be considered here.

and/or the number of buyers in the market and leads to an increase in the quantity of product demanded at all prices. With regards to the BC oyster market specifically, addressing consumer preferences and the number of buyers is critical to increasing demand.

Addressing Consumer Preferences

Targeting existing consumers and their preferences is one way to increase demand for BC oysters. In terms of existing markets such as the US, the BC oyster industry can increase demand by successfully marketing more of their product to existing consumers to gain a larger market share. Canada supplies only a small percentage of all oysters consumed in the US (Interviewee #1, 2010). In 1995, BC supplied only 5% of US oyster supplies (Coopers and Lybrand, 1997). A targeted marketing campaign aimed at increasing the profile of BC oysters in existing markets could increase the demand for BC oysters by existing consumers. This is currently taking place to a degree with the new Pacific Kiss Oyster marketing campaign (Interviewee #1, 2010). Related to this point, the Renwick and Associates (1996) study found through interviewing purchasers that a unique story about the product will influence their purchasing decisions. Both BC oysters and IMTA have a marketable story that could be of interest to purchasers.

Attracting Additional Buyers

With regards to increasing the quantity of oysters demanded by increasing the number of buyers, there are two avenues that could be pursued. Firstly, the industry could attempt to increase the number of buyers, both restaurants and customers themselves, in existing markets. While this is a possibility, it would be difficult to accomplish in any significant way as oysters are not a staple in the North American diet so it would be difficult to get significantly greater numbers of people comfortable with the product (Interviewee #1, 2010).

Secondly, the BC shellfish industry could increase demand by developing/accessing new markets for BC oysters, effectively increasing the number of buyers. The concept of developing new markets is far from a novel idea. In fact, new market opportunities have been identified in Asia (e.g. Japan, China, Hong Kong) as well as other locations including Dubai, Brazil and Russia and accessing them has been argued as the key to industry growth (Interviewee #1, 2010; Salmon & Kingzett, 2002). However, the main hurdle to new market access is that demand for oysters and purchase orders in new markets, especially China, are far too large for BC producers to satisfy currently. Supply of BC oysters would have to increase considerably to be able to supply Asian markets consistently, year round.

As a result, the BC oyster industry faces an interesting problem whereby on one hand, a soft market for oysters has emerged in existing markets creating a situation where demand, rather than supply, has become the main constraint to industry growth. In this environment, BC producers could use IMTA as a marketing tool to gain market share with no change in demand. On the other hand, a lack of sufficient supply in Asian markets (e.g. China) has stymied the development of new markets. IMTA, which can produce a significant volume of oysters based on the production scenario results of presented in Chapter 5, could bridge the gap in terms of volume requirements and help the BC oyster industry access these new markets.

While IMTA oyster production can potentially benefit the BC oyster industry, industries are always vulnerable to fluctuations in market demand as well. For example, a weak Japanese economy in the late 1990s resulted in decreased demand for BC oysters (Salmon & Kingzett, 2002). Conversely, a strong US economy in the late 1990s and early 2000s resulted in increased demand (Interviewee #1, 2010; Salmon & Kingzett, 2002). During the economic downturn in 2008, the supply of BC oysters to the US market decreased by 33%, leaving BC suppliers with excess product (Interviewee #1, 2010). Based on these events, one can infer a high income elasticity of demand for BC oysters, meaning the quantity of oysters demanded responds substantially to changes in income.[22] High income elasticity is indicative of luxury goods, such as oysters (Tibbetts, 2001; Shang, 1973).[23] The critical point here is that with luxury goods, market demand is volatile and can fluctuate with income, which can be problematic, as well as risky, for growers.

When discussing potential movements along, or shifts in, market supply and demand curves, the implications for market equilibrium must be considered. Based on economic theory, a shift of S_c to S_{IMTA} will result in a drop in the market price of oysters and an increase in the quantity demanded as the market equilibrium moves from *a* to *b*, assuming there is no change in market demand (Figure 12). However, if we assume that the BC oyster industry is successful in either increasing current market share or accessing new markets as well, we could see a shift of D_c to D_{IMTA} as well as S_c to S_{IMTA} moving the market equilibrium from *a* to *c*. The result, from a theoretical perspective, would be a significant increase in the quantity of oysters demanded with only a slight decrease in the price of oysters, or possibly no decrease in price.

While the theoretical conclusions are informative, it must be noted that real world conditions complicate the simplified market equilibrium analysis presented here. Firstly, the precise shape of the supply and demand curves is unknown. Secondly, the effects of an increase in BC production on market price could be minimal due to the limited market share the BC oyster industry currently holds. Thirdly, the processors/wholesalers in the supply chain serve as middlemen, which complicate, or distort, the relationship between grower supply and restaurant

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[23] No empirical estimate of income elasticity of demand for restaurant-sold, halfshell oysters exists in the literature. Cheng and Capps Jr. (1988) estimated an income elasticity of demand value of 0.18 (income inelastic) for retail, shucked oysters. However, similar to the price elasticity value, the income elasticity value is not applicable because it concerns a different product form.

price (Figure 6). Finally, the study assumes that oysters from all regions are homogenous products when in reality; oyster characteristics can and do vary geographically. This point is elaborated on in Section 6.3, Limitation #6.

6.1.3 The Role of IMTA in Addressing BC Shellfish Industry Challenges

The most important role IMTA might play in addressing BC shellfish industry challenges is by providing sufficient oyster supply to access new markets. Oyster production associated with IMTA adoption could help open up foreign markets, specifically China, which are presently largely inaccessible to BC producers. IMTA and conventional producers could supply existing markets as well as access new markets where market supply is the constraint, not market demand.

Associated with the previous point, IMTA could help improve transportation options for the BC shellfish industry. As previously discussed, airfreight is a hurdle for moving product, especially leaving Vancouver Island. Enhanced airfreight service on Vancouver Island could help with access to world markets but sufficient product volume is a limiting factor (Salmon & Kingzett, 2002). Only sufficient total product volume will make direct flying routes financially viable. With a significant increase in the volume of oysters produced in BC, direct flying routes may become financially viable which would benefit all shellfish producers seeking to access new markets. New product development can also play a role here. Products such as frozen, vacuum packed oysters allow processors to expand market penetration and continually supply product to market provided supply is sufficient to access the market in the first place (Salmon & Kingzett, 2002). Developing products such as this can also make transportation easier as product can be shipped by sea, effectively reducing costs (Interviewee #1, 2010).

So far, the discussion has focussed on oysters; however, similar conclusions can be drawn with regards to other candidate shellfish species, notably scallops and mussels. As discussed previously, BC mussel and scallop production is minimal in comparison to oyster production. However, IMTA adoption in BC could lead to a production increase of mussels and scallops allowing BC producers to penetrate US and international markets where BC currently does not hold a significant market share.

New species development has been highlighted as a constraint to industry growth as well. The IMTA concept could allow IMTA/shellfish producers to experiment with culturing new species, such as cockles and mussels as well as non-shellfish species like sea urchins and sea cucumbers, without dedicating a significant portion of their operating capacity towards it. Kyuquot SEAfoods, which is currently licensed for 11 species, is doing exactly this. Additionally, it could allow one producer to offer a suite of products to purchasers which is better as seafood buyers prefer to purchase a range of products from one supplier (Salmon & Kingzett, 2002). From a regulatory perspective, growing a variety of species on one site is permitted provided you are licensed to grow each species.

Negative public perceptions of shellfish farming and aquaculture in general, have been identified as an industry challenge. Shellfish farming is being increasingly scrutinized as the public grows more sensitive to food production methods and their environmental sustainability (Salmon & Kingzett, 2002). Results of the San Francisco IMTA survey as well as other consumer surveys on IMTA suggest that the practice is viewed in a positive light relative to conventional aquaculture. Therefore, IMTA could play a role in improving the public perception of aquaculture which would help aquaculture become more sustainable and gain more public acceptance.

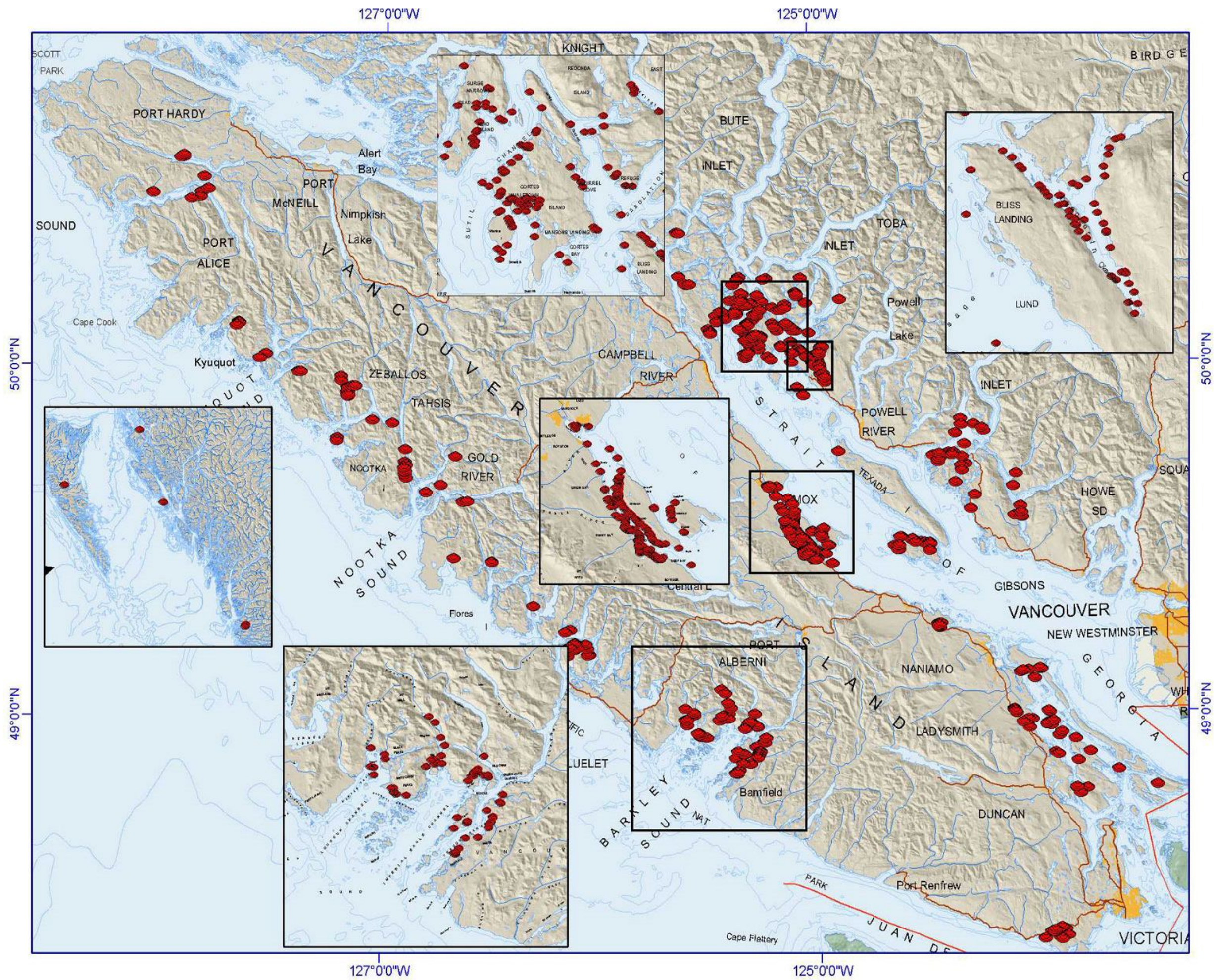
6.2 Further Environmental Issues

Section 6.2 considers the issues of cadmium concentrations in oysters and the potential of ocean acidification to adversely affect shellfish aquaculture.

Cadmium Concentrations in BC Oysters

As discussed in Section 3.1.2, cadmium levels in BC oysters have been a source of concern for the industry. Research has demonstrated that occasionally BC oysters grown in certain areas have tissue cadmium concentrations equal to or above 2 μg g^{-1} which exceeds certain international food safety guidelines (Orians, 2010; Lekhi et al., 2008). Bendell & Feng (2009) analyzed a variety of sites on the BC coast for evidence of cadmium in oyster tissue and found evidence of cadmium concentrations in excess of 2 μg g^{-1} at 5 of 24 sites tested (Appendix E). Concerns about cadmium levels in BC oysters have resulted in the closure of some European and Hong Kong markets to all BC oysters. The sites where elevated levels of cadmium were found are near some oyster growing areas on the west coast (Bendell, 2010) (Figure 13). The issue of cadmium concentrations in oysters represents a potential problem for growers, including IMTA operations proposing to produce oysters.

Figure 13: Map of BC shellfish tenures (British Columbia Shellfish Growers Association, 2007)



One potential solution for a grower consistently faced with high cadmium concentrations is to relocate near salmon farms to avoid further cadmium problems and practice IMTA, assuming IMTA and growing conditions at the salmon farm site are appropriate. The Bendell (2010) study found cadmium levels below 2 µg g^{-1} 19 of 24 sites tested.[24] The 19 sites identified by Bendell overlap with existing salmon farms. These sites represent locations where oyster farms could potentially relocate to avoid the risk of cadmium problems as well as practice IMTA (Figure 14). As a word of caution, the idea proposed here is simply one of several options. Shellfish or salmon growers have not been consulted regarding this concept.

[24] Note: The circles indicate the general location of the specific sites where Bendell (2010) sampled. For precise coordinates, see Appendix E for site names or the Bendell (2010) study for precise coordinates.

Figure 14: Map of BC salmon farm tenures (Wilderness Committee, 2002)

Ocean Acidification

As discussed in Section 3.1.2, ocean acidification could be problematic for the shellfish industry as it lowers carbonate concentrations which adversely affects the ability of shell-making organisms to build calcium carbonate structures (i.e. shells) (Gazeau et al., 2007). Gazeau et al.

(2007) found that calcification rates of edible mussels (*Mytilus edulis)* and Pacific oyster (*Crassostrea gigas)* decline linearly with increasing $pHCO_2$ which will have implications for shellfish aquaculture, as well as coastal ecosystems, worldwide. Additionally, ocean acidification can exacerbate the issue of cadmium concentrations in oysters (Interviewee #3, 2010). While the exact consequences of ocean acidification with regards to shellfish are difficult to determine, the risk and potential impacts of ocean acidification should be taken into account when considering the future of shellfish aquaculture as well as the shellfish component of IMTA. This is especially relevant given that ocean acidification accelerates with climate change prompted by rising levels of atmospheric carbon dioxide (Doney et al., 2009).

6.3 Study Limitations

A list of study limitations is presented below.

Limitation #1: The study focuses on the case study of increased shellfish production associated with the adoption of IMTA in BC to illustrate the economic and market implications of extractive aquaculture production associated with IMTA adoption by finfish farmers. The study is limited in the sense that it only considers the BC case, including BC producers and the main market for BC oysters. Market conditions as well as supply and demand dynamics may, and almost certainly will, differ in other regions and product markets. The case study is meant to shine a light on these issues and demonstrate that the economic and market implications associated with IMTA adoption should be considered in any formal analysis of IMTA's prospects.

Limitation #2: The study is based on the hypothetical scenario of IMTA adoption by BC salmon farmers. There is no indication whether this will or will not occur in the future.

Limitation #3: With regards to the production scenario analysis, a number of assumptions have been made about how finfish farms would be retrofitted with IMTA. While these assumptions were informed using the best information and advice available, it is still important to state that if/when IMTA is adopted by salmon farmers on the west coast, it may not be done exactly as described in our production scenario analysis. However, the analysis will serve as a useful tool for those trying to estimate farm oyster production volumes.

Limitation #4: With regards to the consumer survey, only one market was surveyed (San Francisco). It is realistic to assume that respondent demographics, attitudes, and perceptions of aquaculture and specifically IMTA will vary from market to market. Therefore, one should not take the results of the survey as representative of oyster consumers, or oyster markets, generally, although presumably there may be some common characteristics.

Limitation #5: Willingness to pay questions are hypothetical and gather expressed preferences, rather than revealed preferences. One must keep this in mind when interpreting the WTP analysis results.

Limitation #6: This study, as well as other studies including Cheng and Capp Jr. (1988) and Muth et al. (2002), regard oysters from all regions as one homogenous product. However, in reality, the attributes of oysters vary from region to region (Interviewee #1, 2010). Different growing regions and production methods produce oysters with unique characteristics (e.g. taste and size) and therefore the products are not always homogenous.

Related to this point, for the purposes of the consumer survey, we assumed that IMTA oysters are identical to non-IMTA oysters, with the obvious exception of the production method. However, this may well not be the case. Given the difference in diet between IMTA and conventional shellfish production, the attributes of an IMTA oyster could be distinct. For example, meat yields in mussels at IMTA farms have been found to be higher compared to those at control sites (Troell et al., 2009; Shuve et al., 2009).

6.4 Future Research Avenues

One main area of future research has been identified over the course of this study. The study hinges on the assumption that BC salmon farmers may adopt IMTA to reduce their environmental impact. There is limited information about if and how this might take place. Future research could look at the potential for IMTA adoption in BC from an industry perspective. Will IMTA be adopted in BC through new farms, retrofitted by salmon farms, a combination of the two, or not at all? Additionally, research into the rate of adoption of a new technology such as IMTA by the aquaculture industry would be useful. Similar studies have been conducted regarding new technology adoption in agriculture.

Chapter 7: Conclusion

The study posed three main research questions: (1) on the supply side, by how much could IMTA shellfish production augment existing shellfish production from BC, (2) on the demand side, how might consumers of BC shellfish view the IMTA concept and value IMTA shellfish products, and (3) what could be the potential market implications of IMTA adoption on the west coast for the BC oyster industry? The study considered the case of oyster production associated with IMTA adoption by BC salmon farmers to address these research questions.

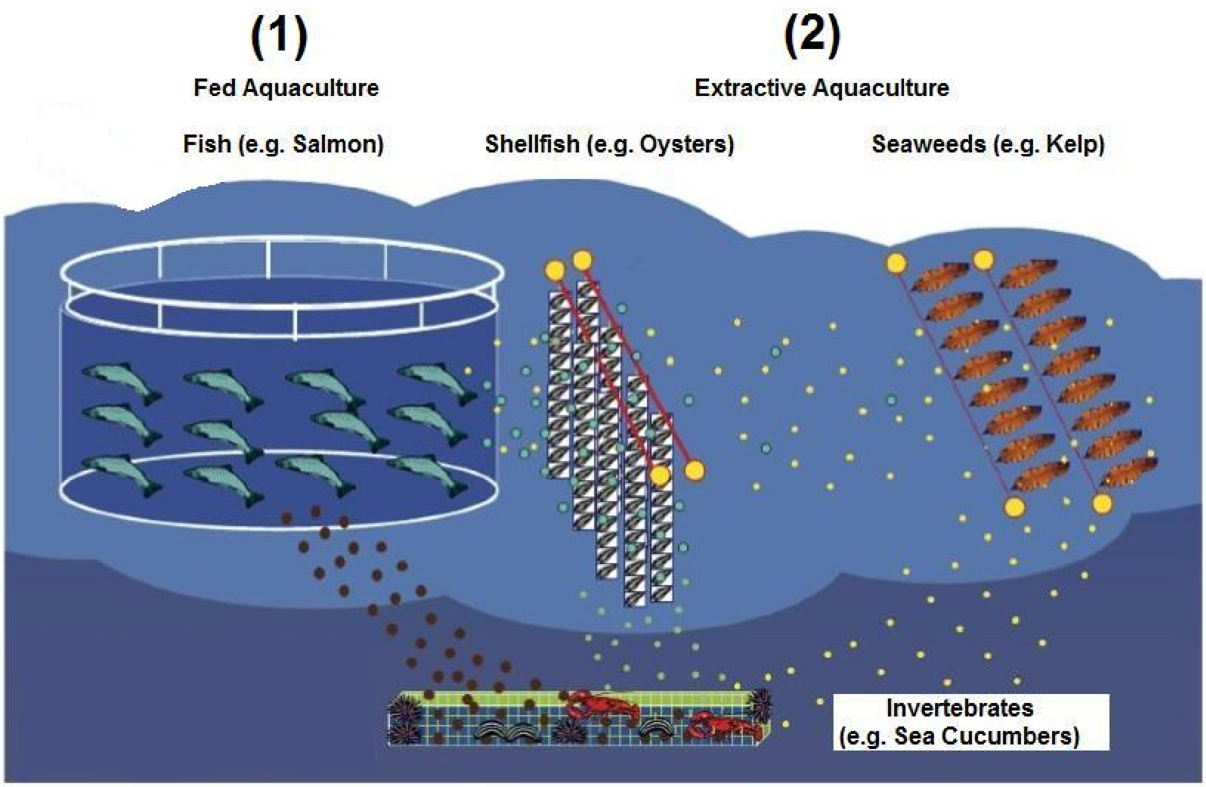
Results of a production scenario analysis demonstrate that IMTA adoption can augment BC oyster production by between 9% and 237%, depending upon the number of BC salmon farms adopting IMTA and the production quantity per farm. Results of a consumer intercept survey reveal that demand for oysters is largely price inelastic and that oysters are consumed in moderate amounts 5.92 times a year on average. With regard to consumer perceptions of IMTA, oyster consumers in San Francisco had a positive perception of IMTA and the majority of respondents were willing to pay a price premium for IMTA oysters.

An integration of findings revealed that IMTA oyster production in BC could cause the market supply curve to shift to the right as the number of sellers in the market increases. Therefore, increasing market demand would be important to absorb the additional supply and allow for BC shellfish industry growth. Traditional markets for BC oysters are soft; however, new markets (e.g. China) have been identified but require sufficient, consistent supply to be accessible. IMTA in BC could potentially provide sufficient supply to access these markets assuming it is adopted widely by BC salmon farmers.

The market implications of additional extractive aquaculture production associated with the adoption of IMTA by finfish farmers is an important consideration that has yet to be addressed in the literature. This study filled the knowledge gap with an analysis of the market implications of oyster production associated with IMTA adoption by BC salmon farms. While the exact implications are only relevant to the BC shellfish industry because industry characteristics as well as market supply and demand dynamics will differ between products and areas, the general lessons learned from the analysis are widely applicable. Consideration of the market implications of extractive aquaculture production associated with the adoption of IMTA by finfish farmers should be a component of any realistic assessment of the impacts of IMTA adoption.

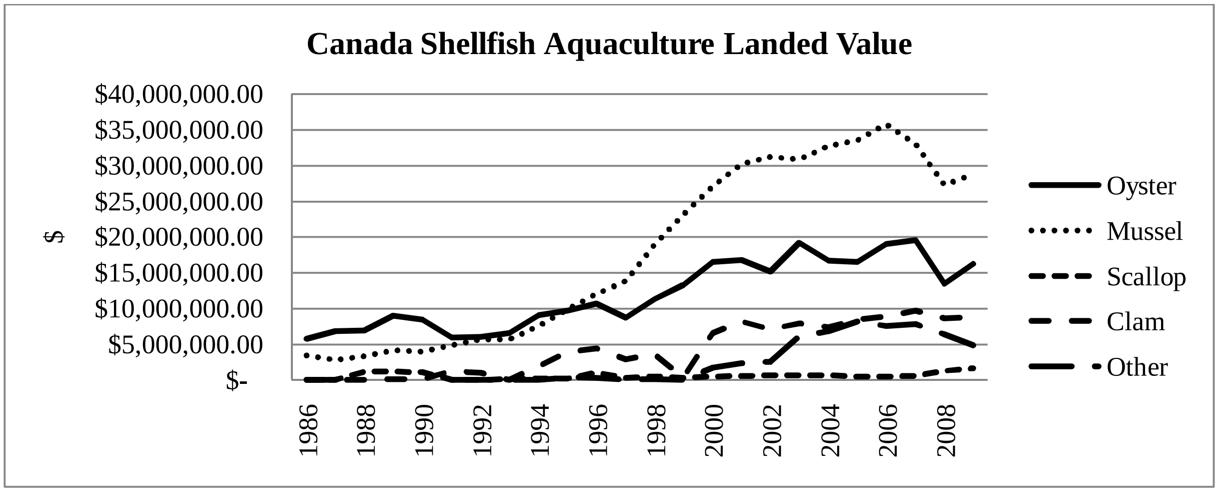
Appendices

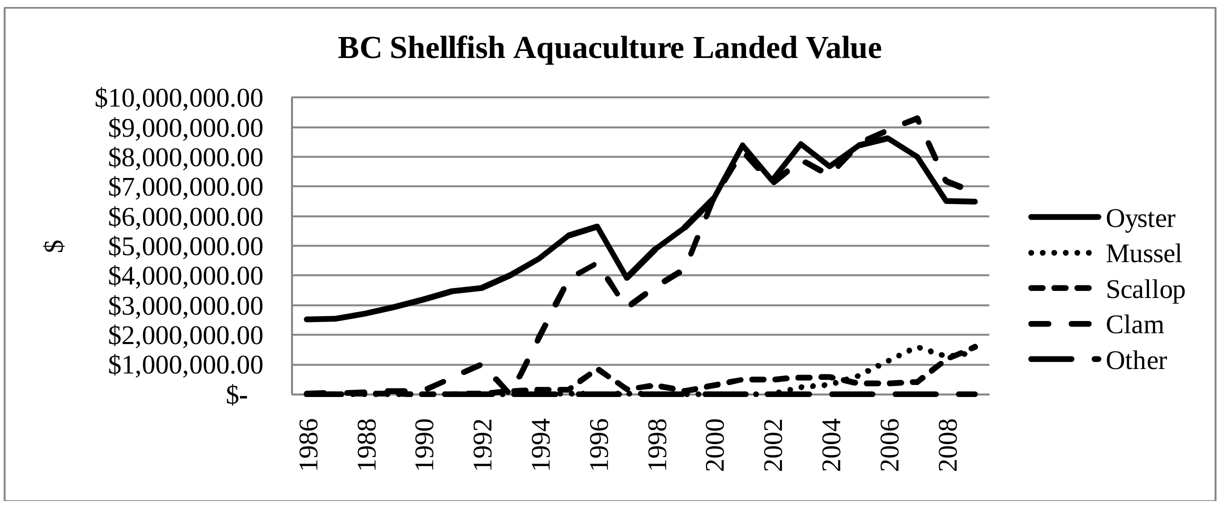
Appendix A: Graphical Depiction of Integrated Multi-Trophic Aquaculture

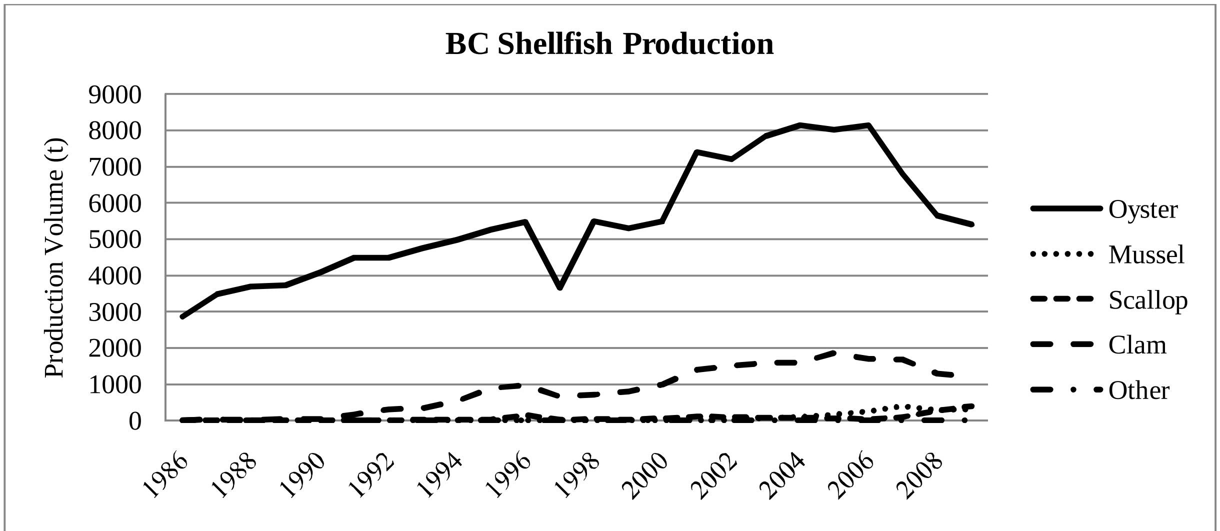


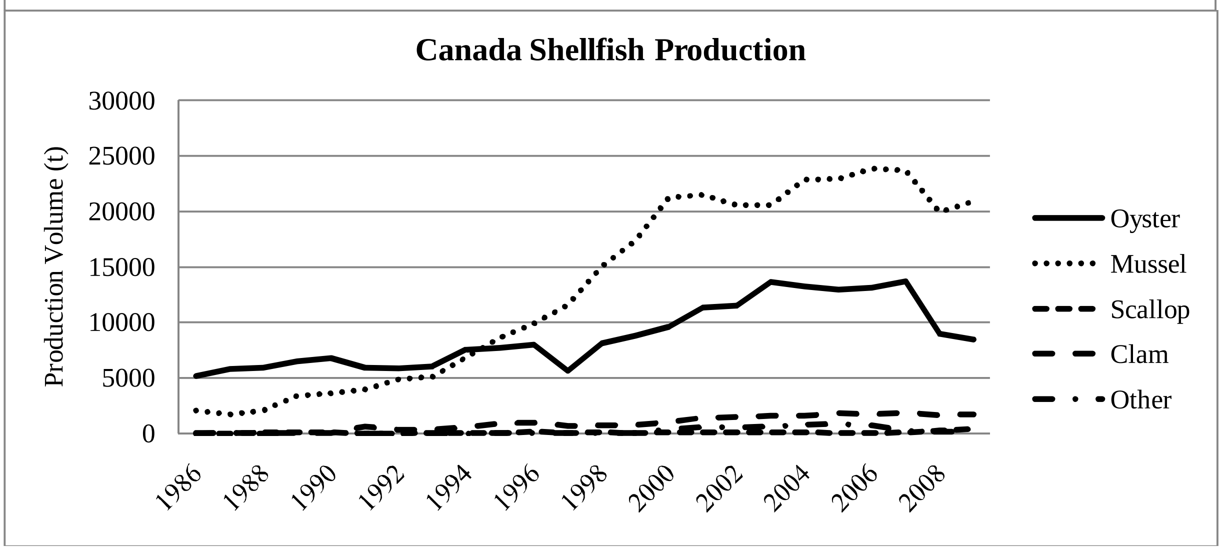
(Chopin et al., 2008)

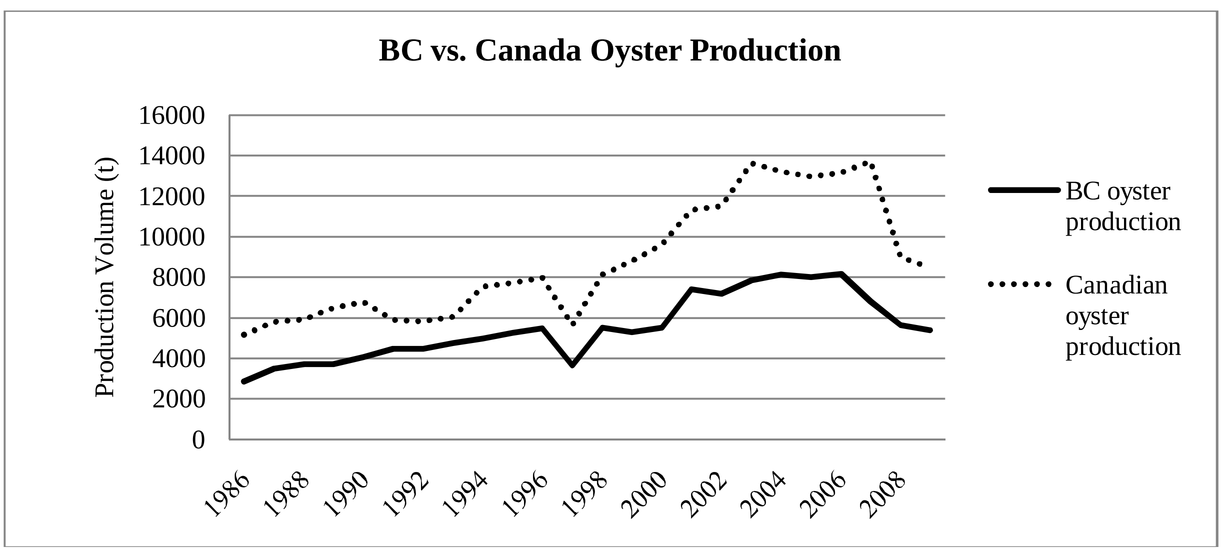
Appendix B: BC and Canadian Shellfish Aquaculture Landed Values (1986-2009).





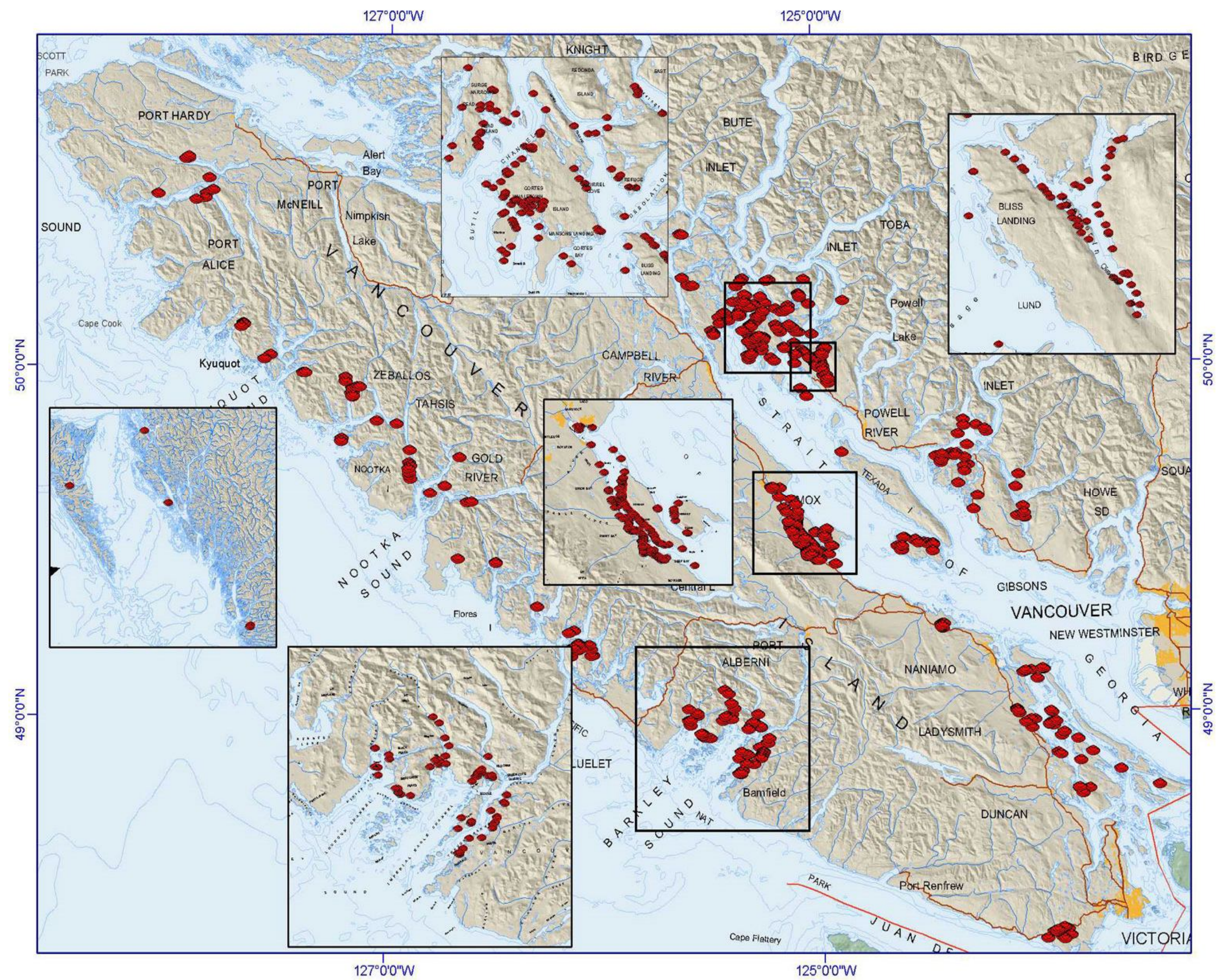

BC Shellfish Production
Production Volume (t)
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
Oyster
Mussel
Scallop
Clam
Other


Canada Shellfish Production
Production Volume (t)
30000
25000
20000
15000
10000
5000
0
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
Oyster
Mussel
Scallop
Clam
Other


BC vs. Canada Oyster Production
Production Volume (t)
16000
14000
12000
10000
8000
6000
4000
2000
0
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
BC oyster production
Canadian oyster production

(DFO, 2010)

Appendix C: BC Shellfish Tenure Locations

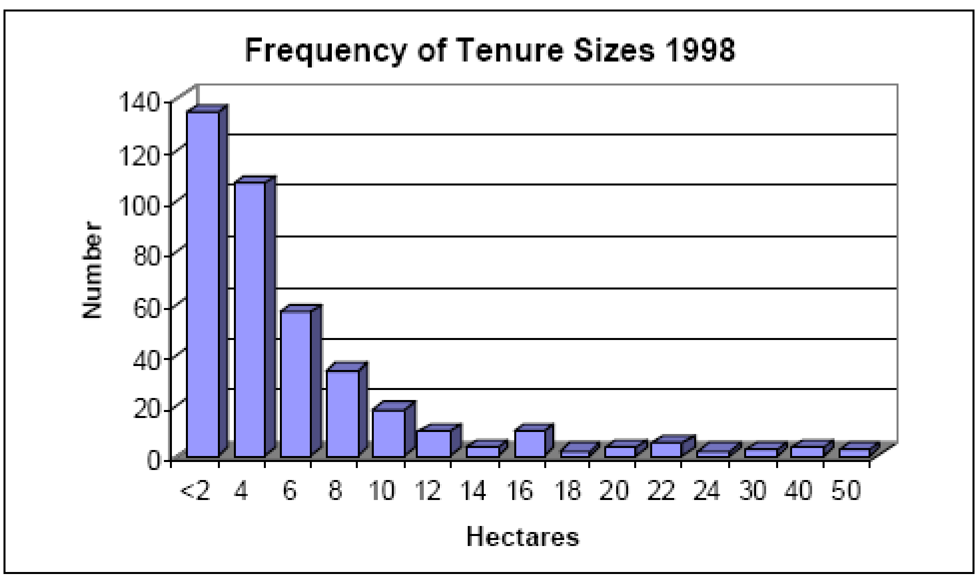


(British Columbia Shellfish Growers Association, 2007)

Appendix D: Breakdown of number of shellfish tenures, tenure area, average tenure size, and farm gate value for main growing regions in BC

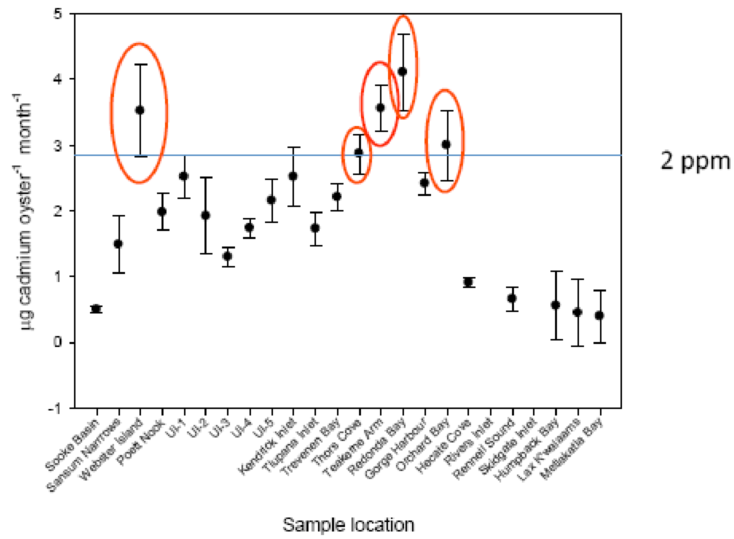
	Number of Tenures	Area (ha)	Average Tenure Size	Report Farmgate Value (all)
North Coast	3	12	4.00	$ -
Quadra Cortes	93	228.6	2.46	$ 1,840,667
Baynes Sound	135	624	4.62	$ 8,072,635
Okeover/ Malaspina	78	400.8	5.14	$ 1,623,066
Sunshine Coast	45	269.7	5.99	$ 332,036
South East VI	46	249.1	5.42	$ 2,234,391
West Coast VI	82	329.8	4.02	$ 1,311,127
Total	**482**	**2114**	**4.39**	**$ 15,413,922**

(Salmon & Kingzett, 2002)



(Salmon & Kingzett, 2002)

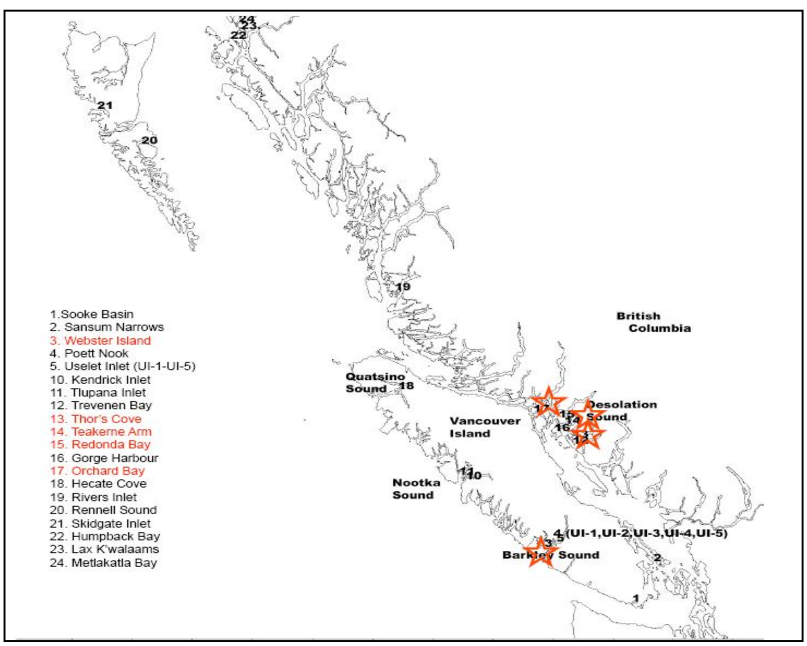
Appendix E: Sample sites with the highest rates of Cadmium uptake by BC oysters



2.8 ug * 36 months / **7.5** gram dry weight oyster

Figure 5. Sites with the greatest rates of Cd uptake by BC oysters.

(Bendell, 2010)



(Bendell, 2010)

Appendix F: Location of Kyuquot SEAfoods IMTA farm (Star on map)

(Davenport Maps, 2009)

Appendix G: IMTA Oyster Consumer Survey

Integrated Multi-Trophic Aquaculture Oyster Survey

Interviewer: Hello, would you like to participate in a survey about oysters. It will take roughly 10 minutes and we are offering an incentive for those willing to participate.

If yes, we need to see if you are eligible

a) Are you over the age of 18?
b) Do you eat oysters in a restaurant?

If No to either--[Interviewer: provide a polite THANK YOU and terminate the interview]

If YES to both, continue below

Interviewer: Thank you, if you would like to participate, please read this consent form. Be assured that we require no personal information from you.

Part A – Oyster Consumption and Aquaculture Awareness

Interviewer: To begin, I would like to ask you about your restaurant consumption of oysters.

A.1) What is the average number of oysters you like to order for one serving?

____

A.2) On average, how many times do you order oysters in a restaurant in a given year?

_____________________times

A.3a) If the price of oysters were to decrease by 15%, would you eat oysters more often?

☐-------Yes
☐-------No

A.3b) If Yes, how many additional times in a year would you order oysters?

____________________ times

A.4a) If the price of oysters were to decrease by 30%, would you eat oysters more often?

□-------Yes
□-------No

A.4b) If Yes, how many additional times in a year would you order oysters?

____________________ times

A.5) When you order oysters at a restaurant, what factors influence your decision? Please rate each factor, where 1 is not important and 5 is very important. Assume that all the product information is available at the restaurant.

Factor	1 = Not Important	2	3	4	5 = Very Important
a) The price of the item					
b) The origin of the product (i.e. USA vs. imported)					
c) Food Safety – It meets safety standards					
d) Environmental Friendliness – The product is eco-certified					
e) Type of oyster					
f) Size of oyster					
g) The freshness of the product					
h) The production method					
i) Other items on the menu and their prices					
j) Anything else (Open-ended)					

A.6) Have you heard of the term "aquaculture" prior to this survey?

□-------Yes
□-------No
□-------Don't Know

[Interviewer: If respondent answers No to A.6, input Not at all knowledgeable for A.7]

A.7) How would you rate your knowledge of aquaculture?

☐-------Very knowledgeable
☐-------Somewhat knowledgeable
☐-------Not very knowledgeable
☐-------Not knowledgeable at all

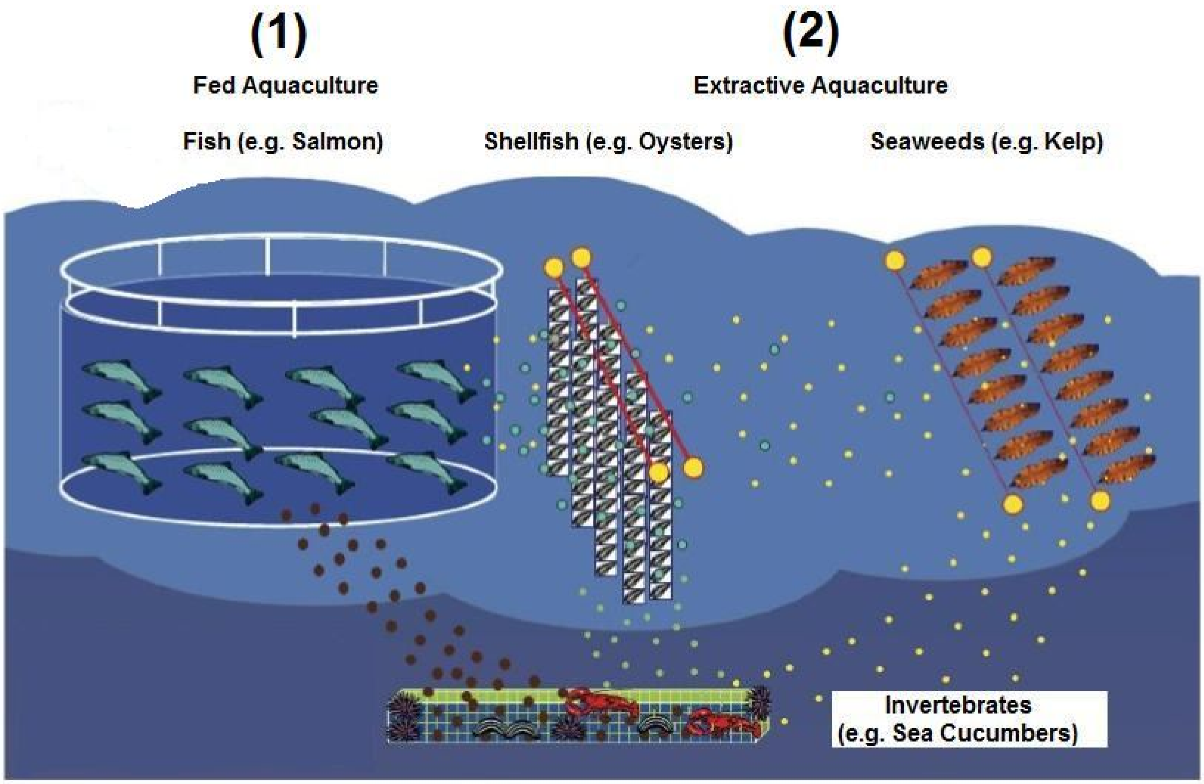
<u>Aquaculture Definition:</u> Aquaculture can be thought of as agriculture in water. It involves the 'farming' of organisms such as fish (e.g. salmon), shellfish (e.g. oysters), and seaweeds (e.g. kelps).

A.8) Prior to this survey, did you know that farmed oysters account for 95% of the world's total oyster consumption?

☐-------Yes
☐-------No
☐-------Don't know

Part B – Integrated Multi-Trophic Aquaculture Presentation

Interviewer: *I am now going to tell you about a new aquaculture technique. It involves raising several species within the same area and at the same time, as opposed to conventional aquaculture which raises a single species at a site.*



[Interviewer: Introduce and explain graphic]

#1) The system is called Integrated Multi-Trophic Aquaculture. Hereafter referred to as IMTA.

#2) Normally, oysters seen here [Interviewer: point to diagram] are grown alone.

#3) In the new IMTA system, the oysters are grown the same way, but are positioned beside other aquaculture species for a more balanced ecosystem approach to aquaculture.

#4) The oysters, as well as the other extractive aquaculture species (2), take advantage of the excess nutrients (e.g. uneaten feed and waste) from the fish aquaculture component (1) which would otherwise be discarded into the surrounding environment.

#5) This new IMTA technique seeks to replicate a simple aquatic ecosystem by raising a variety of species from different trophic levels at one site.

#6) IMTA products meet all FDA food safety and quality standards.

Interviewer: Is this clear?

[Interviewer – Ensure the respondent understands the following:
a) the concept of IMTA as depicted in the diagram
b) the difference between the two forms of oyster production (alone vs. amongst other species),
c) the extractive aquaculture species' consume the uneaten feed and waste from the fed aquaculture component, which makes fish farming more sustainable]

B.1) Prior to this survey, had you heard of IMTA?

- ☐-------Yes
- ☐-------No
- ☐-------Don't Know

B.2a) Do you think IMTA is a good idea?

- ☐-------Yes
- ☐-------No
- ☐-------Maybe
- ☐-------Don't Know

B.2b) Why or why not? _________________________

Part C – Willingness to Pay for IMTA oysters

Interviewer: I am now going to ask you a question about how much you would be willing to pay for products produced with IMTA.

C.1a) Suppose that you are in your favourite seafood restaurant and you are considering ordering fresh oysters. Assume the restaurant serves both conventionally produced oysters and oysters produced with the new IMTA system. The price of one conventionally produced oyster on the half shell is $2.00. What is the maximum you would be willing pay for an identical oyster produced through IMTA? (Please select a value from the list below)

Less than 2.00, 2.00, 2.20, 2.40, 2.60, 2.80, 3.00, More than 3.00

[Interviewer – If the respondent answers Less than $2.00 or More than $3.00, ask C.1b, If the respondent answers anything between 2.00 and $3.00, skip to C.2]

C.1b) Okay, what is the maximum you would pay? (Open-ended) $___________

C.2) Can you explain why you are willing to pay more, less, or the same?
____

C.3) If the price of IMTA oysters and conventionally produced oysters were equal, how often would you purchase IMTA oysters versus conventionally produced oysters?

□-------Always (100%)
□-------Often (about 75%)
□-------Sometimes (about 50%)
□-------Rarely (about (25%)
□-------Never (0%)

C.4a) Assuming IMTA oysters were widely available at the same price as conventionally produced oysters, would you eat oysters at a restaurant more often [Interviewer – remind them of their response in A.2]?

□-------Yes
□-------No
□-------Don't know

C.4b) If Yes, how many more times would you eat oysters in a restaurant?

________________ times

Part D – Consumer Attitudes towards Environment and Aquaculture

Interviewer: Let me ask you a few questions about your opinions on aquaculture and the environment.

D.1) To what extent do you agree or disagree with each of the following statements? *[Circle a number between 1 and 5 for each statement.]*

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Don't Know
Aquaculture, in general, is an acceptable form of seafood production.	1	2	3	4	5	
I am concerned about the environmental impact of fish (e.g. salmon) aquaculture operations (not IMTA).	1	2	3	4	5	
IMTA has the potential to improve the environmental sustainability of aquaculture.	1	2	3	4	5	
Eco-certification of seafood products by a reputable body is important to me.	1	2	3	4	5	
Tackling environmental problems	1	2	3	4	5	

should be a top priority in our country.						

Part E – Demographics

Interviewer: Moving on to the last section of the survey, I would like to ask you a few questions about your demographic characteristics. This is for statistical purposes to make sure the survey is representative and in no way will the data be assigned to you.

E.1) What is your gender? [Interviewer: fill this in without asking]

□ Female
□ Male

E.2) In which of the following age categories do you fall? [Interviewer: just ask how old they are]

□-------15-19
□-------20-24
□-------25-29
□-------30-34
□-------35-39
□-------40-44
□-------45-49
□-------50-54
□-------55-59
□-------60-64
□-------65-69
□-------70-74
□-------75-79
□-------80-84
□-------85+

E.3) What is the highest level of education you have completed?

□-------Elementary School
□-------Some High School, no diploma
□-------Graduated High School (includes equivalency)
□-------Some College, no degree
□-------Associate's degree
□-------Bachelor's degree
□-------Graduate or Professional degree

E.4) What was your total household income in 2009?

□-------Less than 10,000 US Dollars/year
□-------10,000-14,999 US Dollars/year
□-------15,000 – 24,999 US Dollars/year

☐-------25,000 – 34,999 US Dollars/year
☐-------35,000 – 49,999 US Dollars/year
☐-------50,000 – 74,999 US Dollars/year
☐-------75,000 – 99,999 US Dollars/year
☐-------100,000 – 124,999 US Dollars/year
☐-------125,000 – 149,000 US Dollars/year
☐-------150,000 – 174,999 US Dollars/year
☐-------175,000 – 199,999 US Dollars/year
☐-------200,000 + US Dollars/year

E.5) Are you a member of an environmental organization?

☐------- Yes
☐------- No
☐------- Don't know

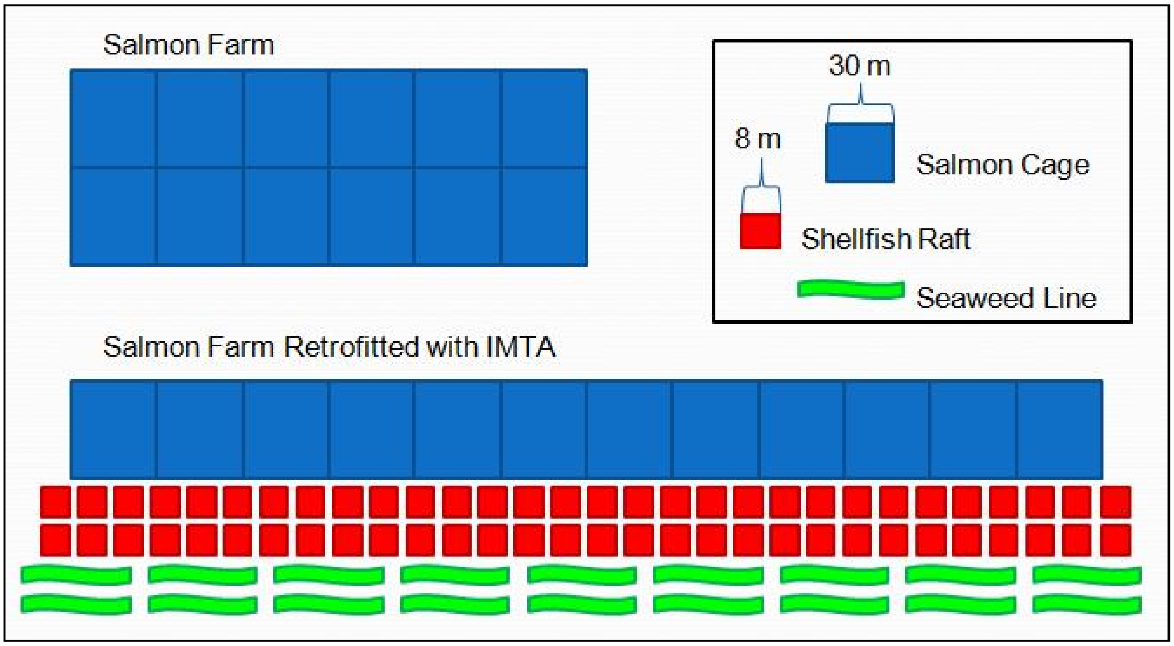
E.6) Where do you live?

☐-------San Francisco
☐-------Elsewhere in California
☐-------Oregon or Washington
☐-------Elsewhere in the U.S. (outside California, Oregon, Washington)
☐-------Outside the U.S.

E.7) How many people live in your household?

☐------- 1
☐------- 2
☐------- 3
☐------- 4
☐------- 5
☐------- 6+

Appendix H: Representative IMTA Farm



Appendix I: Production Scenario Sensitivity Analysis

Group #1) 60 Raft System, 4,095 dozen oyster per raft per year

60 raft system (4,095 dozen oysters per raft)				
		Proportion of Rafts dedicated to oyster production		
		33%	**66%**	**100%**
Percent of Salmon Farms adopting IMTA	**5%**	348	697	1045
	15%	1045	2090	3134
	30%	2090	4179	6269
	45%	3134	6269	9403

60 raft system (4,095 dozen oysters per raft) – BC Production Increase				
		Proportion of Rafts dedicated to oyster production		
		33%	**66%**	**100%**
Percent of Salmon Farms adopting IMTA	**5%**	5%	10%	15%
	15%	15%	31%	46%
	30%	31%	61%	92%
	45%	46%	92%	138%

60 raft system (4,095 dozen oysters per raft) - Canada Production Increase				
		Proportion of Rafts dedicated to oyster production		
		33%	**66%**	**100%**
Percent of Salmon Farms adopting IMTA	**5%**	3%	6%	9%
	15%	9%	18%	27%
	30%	18%	36%	55%
	45%	27%	55%	82%

60 raft system (4,095 dozen oysters per raft) – Landed Value				
		Proportion of Rafts dedicated to oyster production		
		33%	**66%**	**100%**
Percent of Salmon Farms adopting IMTA	**5%**	$ 528,331.49	$ 1,056,662.99	$ 1,584,994.48
	15%	$ 1,584,994.48	$ 3,169,988.96	$ 4,754,983.44
	30%	$ 3,169,988.96	$ 6,339,977.92	$ 9,509,966.88
	45%	$ 4,754,983.44	$ 9,509,966.88	$ 14,264,950.31

Group #2) 30 Raft System, 4,095 dozen oyster per raft per year

30 raft system (4,095 dozen oysters per raft)				
		Proportion of Rafts dedicated to oyster production		
		33%	**66%**	**100%**
Percent of Salmon Farms adopting IMTA	**5%**	174	348	522
	15%	522	1045	1567
	30%	1045	2090	3134
	45%	1567	3134	4702

30 raft system (4,095 dozen oysters per raft) – BC Production Increase				
		Proportion of Rafts dedicated to oyster production		
		33%	**66%**	**100%**
Percent of Salmon Farms adopting IMTA	**5%**	3%	5%	8%
	15%	8%	15%	23%
	30%	15%	31%	46%
	45%	23%	46%	69%

30 raft system (4,095 dozen oysters per raft) – Canada Production Increase				
		Proportion of Rafts dedicated to oyster production		
		33%	**66%**	**100%**
Percent of Salmon Farms adopting IMTA	**5%**	2%	3%	5%
	15%	5%	9%	14%
	30%	9%	18%	27%
	45%	14%	27%	41%

30 raft system (4,095 dozen oysters per raft)				
		Proportion of Rafts dedicated to oyster production		
		33%	**66%**	**100%**
Percent of Salmon Farms adopting IMTA	**5%**	$ 264,165.75	$ 528,331.49	$ 792,497.24
	15%	$ 792,497.24	$ 1,584,994.48	$ 2,377,491.72
	30%	$ 1,584,994.48	$ 3,169,988.96	$ 4,754,983.44
	45%	$ 2,377,491.72	$ 4,754,983.44	$ 7,132,475.16

Group #3) 30 Raft System, 7,007 dozen oyster per raft per year

30 raft system (7,007 dozen oysters per raft)				
		Proportion of Rafts dedicated to oyster production		
		33%	**66%**	**100%**
Percent of Salmon Farms adopting IMTA	**5%**	298	596	894
	15%	894	1788	2682
	30%	1788	3576	5363
	45%	2682	5363	8045

30 raft system (7,007 dozen oysters per raft) – BC Production Increase				
		Proportion of Rafts dedicated to oyster production		
		33%	**66%**	**100%**
Percent of Salmon Farms adopting IMTA	**5%**	4%	9%	13%
	15%	13%	26%	39%
	30%	26%	53%	79%
	45%	39%	79%	118%

30 raft system (7,007 dozen oysters per raft) – Canada Production Increase				
		Proportion of Rafts dedicated to oyster production		
		33%	**66%**	**100%**
Percent of Salmon Farms adopting IMTA	**5%**	3%	5%	8%
	15%	8%	16%	23%
	30%	16%	31%	47%
	45%	23%	47%	70%

30 raft system (7,007 dozen oysters per raft) – Landed Value				
		Proportion of Rafts dedicated to oyster production		
		33%	**66%**	**100%**
Percent of Salmon Farms adopting IMTA	**5%**	$ 452,016.94	$ 904,033.89	$ 1,356,050.83
	15%	$ 1,356,050.83	$ 2,712,101.66	$ 4,068,152.50
	30%	$ 2,712,101.66	$ 5,424,203.33	$ 8,136,304.99
	45%	$ 4,068,152.50	$ 8,136,304.99	$ 12,204,457.49

Group #4) 60 Raft System, 10,920 dozen oyster per raft per year

60 raft system (10,920 dozen oysters per raft)				
		Proportion of Rafts dedicated to oyster production		
		33%	**66%**	**100%**
Percent of Salmon Farms adopting IMTA	**5%**	929	1857	2786
	15%	2786	5572	8359
	30%	5572	11145	16717
	45%	8359	16717	25076

60 raft system (10,920 dozen oysters per raft) – BC Production Increase				
		Proportion of Rafts dedicated to oyster production		
		33%	**66%**	**100%**
Percent of Salmon Farms adopting IMTA	**5%**	14%	27%	41%
	15%	41%	82%	123%
	30%	82%	164%	246%
	45%	123%	246%	369%

60 raft system (10,920 dozen oysters per raft) – Canada Production Increase				
		Proportion of Rafts dedicated to oyster production		
		33%	**66%**	**100%**
Percent of Salmon Farms adopting IMTA	**5%**	8%	16%	24%
	15%	24%	49%	73%
	30%	49%	97%	146%
	45%	73%	146%	219%

60 raft system (10,920 dozen oysters per raft) – Landed Value				
		Proportion of Rafts dedicated to oyster production		
		33%	**66%**	**100%**
Percent of Salmon Farms adopting IMTA	**5%**	$ 1,408,883.98	$ 2,817,767.96	$ 4,226,651.94
	15%	$ 4,226,651.94	$ 8,453,303.89	$ 12,679,955.83
	30%	$ 8,453,303.89	$ 16,906,607.78	$ 25,359,911.67
	45%	$ 12,679,955.83	$ 25,359,911.67	$ 38,039,867.50

Group #5) 30 Raft System, 10,920 dozen oyster per raft per year

30 raft system (10,920 dozen oysters per raft)				
		Proportion of Rafts dedicated to oyster production		
		33%	**66%**	**100%**
Percent of Salmon Farms adopting IMTA	**5%**	464	929	1393
	15%	1393	2786	4179
	30%	2786	5572	8359
	45%	4179	8359	12538

30 raft system (10,920 dozen oysters per raft) – BC Production Increase				
		Proportion of Rafts dedicated to oyster production		
		33%	**66%**	**100%**
Percent of Salmon Farms adopting IMTA	**5%**	7%	14%	20%
	15%	20%	41%	61%
	30%	40%	82%	123%
	45%	60%	123%	184%

30 raft system (10,920 dozen oysters per raft) – Canada Production Increase				
		Proportion of Rafts dedicated to oyster production		
		33%	**66%**	**100%**
Percent of Salmon Farms adopting IMTA	**5%**	4%	8%	12%
	15%	12%	24%	36%
	30%	24%	49%	73%
	45%	36%	73%	109%

30 raft system (10,920 dozen oysters per raft) – Landed Value				
		Proportion of Rafts dedicated to oyster production		
		33%	**66%**	**100%**
Percent of Salmon Farms adopting IMTA	**5%**	$ 704,441.99	$ 1,408,883.98	$ 2,113,325.97
	15%	$ 2,113,325.97	$ 4,226,651.94	$ 6,339,977.92
	30%	$ 4,226,651.94	$ 8,453,303.89	$ 12,679,955.83
	45%	$ 6,339,977.92	$ 12,679,955.83	$ 19,019,933.75

Appendix J: Demographic statistics for survey sample

Household Size				
# of People	Frequency	Percent	Valid Percent	Cumulative Percent
1	52	28.9	28.9	28.9
2	64	35.6	35.6	64.4
3	27	15.0	15.0	79.4
4	30	16.7	16.7	96.1
5	5	2.8	2.8	98.9
6	2	1.1	1.1	100.0
Total	180	100.0	100.0	

San Fransisco Bay Area Residency				
	Frequency	Percent	Valid Percent	Cumulative Percent
San Fransisco Bay Area Resident	130	72.2	72.2	72.2
Non-resident	50	27.8	27.8	100.0
Total	180	100.0	100.0	

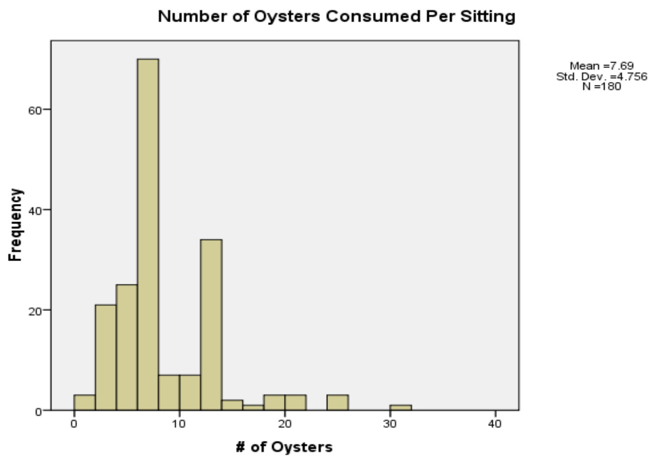
Income				
	Frequency	Percent	Valid Percent	Cumulative Percent
Less than 10,000 US Dollars/year	6	3.3	3.3	3.3
10,000-14,999 US Dollars/year	6	3.3	3.3	6.7
15,000 – 24,999 US Dollars/year	12	6.7	6.7	13.3
25,000 – 34,999 US Dollars/year	7	3.9	3.9	17.2
35,000 – 49,999 US Dollars/year	17	9.4	9.4	26.7
50,000 – 74,999 US Dollars/year	29	16.1	16.1	42.8
75,000 – 99,999 US Dollars/year	28	15.6	15.6	58.3
100,000 – 124,999 US Dollars/year	32	17.8	17.8	76.1
125,000 – 149,000 US Dollars/year	12	6.7	6.7	82.8
150,000 – 174,999 US Dollars/year	13	7.2	7.2	90.0
175,000 – 199,999 US Dollars/year	8	4.4	4.4	94.4
200,000 + US Dollars/year	10	5.6	5.6	100.0
Total	180	100.0	100.0	

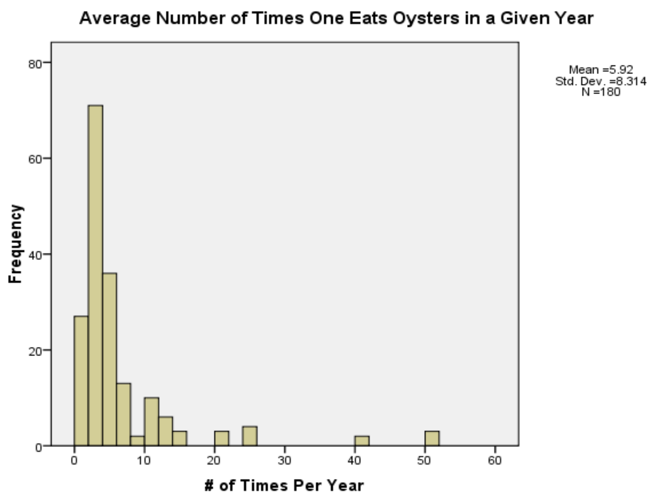
Education				
	Frequency	Percent	Valid Percent	Cumulative Percent
Elementary School	1	.6	.6	.6
Some High School, no diploma	7	3.9	3.9	4.4
Graduated High School	16	8.9	8.9	13.3
Associate's Degree	13	7.2	7.2	20.6
Bachelor's Degree	67	37.2	37.2	57.8
Graduate or Professional degree	76	42.2	42.2	100.0
Total	180	100.0	100.0	

Age				
	Frequency	Percent	Valid Percent	Cumulative Percent
18-24	8	4.4	4.4	4.4
25-29	31	17.2	17.2	21.7
30-34	32	17.8	17.8	39.4
35-39	41	22.8	22.8	62.2
40-44	21	11.7	11.7	73.9
45-49	19	10.6	10.6	84.4
50-54	11	6.1	6.1	90.6
55-59	7	3.9	3.9	94.4
60-64	2	1.1	1.1	95.6
65-69	4	2.2	2.2	97.8
70-74	2	1.1	1.1	98.9
75 +	2	1.1	1.1	100.0
Total	180	100.0	100.0	

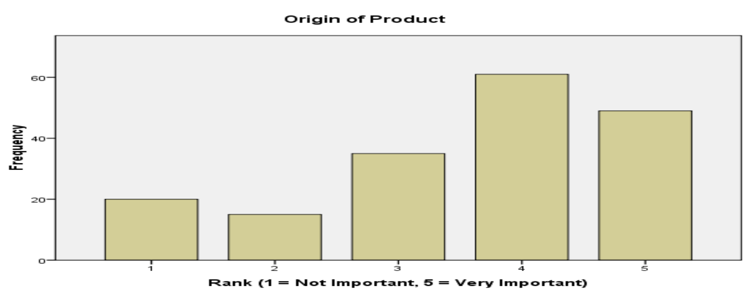
Gender				
	Frequency	Percent	Valid Percent	Cumulative Percent
Male	98	54.4	54.4	54.4
Female	82	45.6	45.6	100.0
Total	180	100.0	100.0	

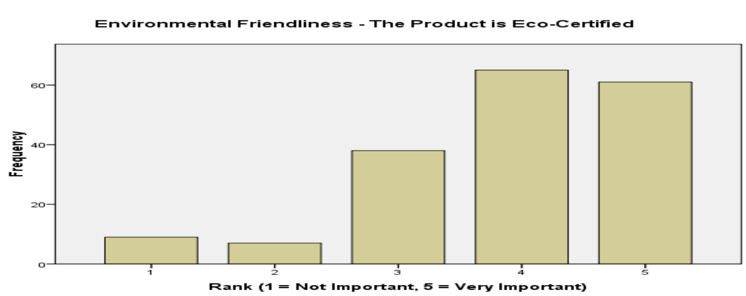
Appendix K: Oyster consumption sample frequency

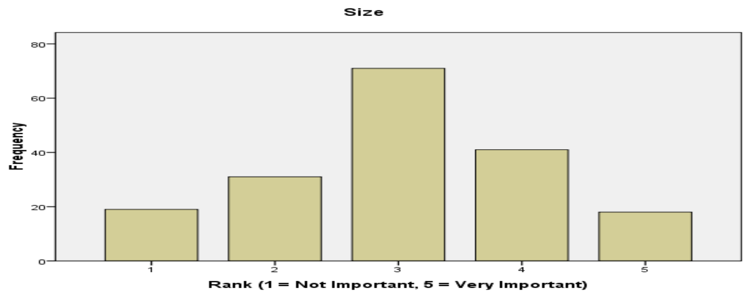


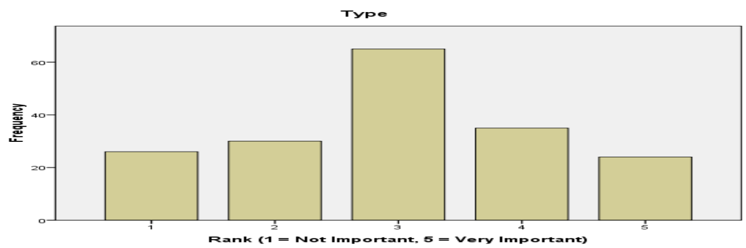


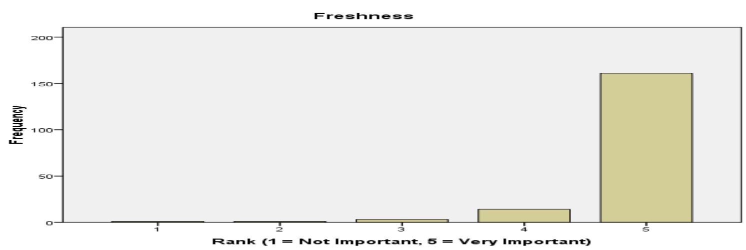
Appendix L: Frequency distributuions for factors influencing oyster purchasing decisions

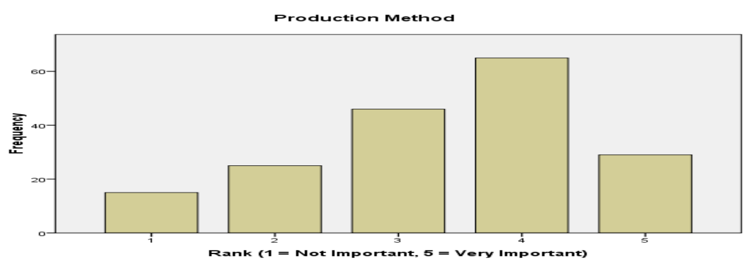





Size
Frequency
0
20
40
60
80
1
2
3
4
5
Rank (1 = Not Important, 5 = Very Important)

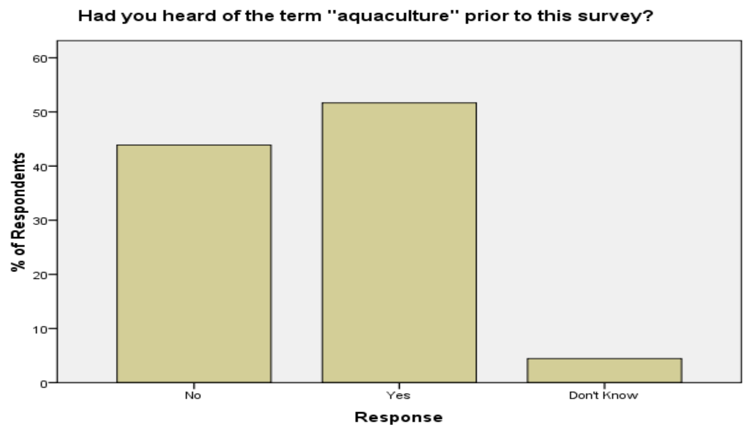

Type
Frequency
0
20
40
60
1
2
3
4
5
Rank (1 = Not Important, 5 = Very Important)

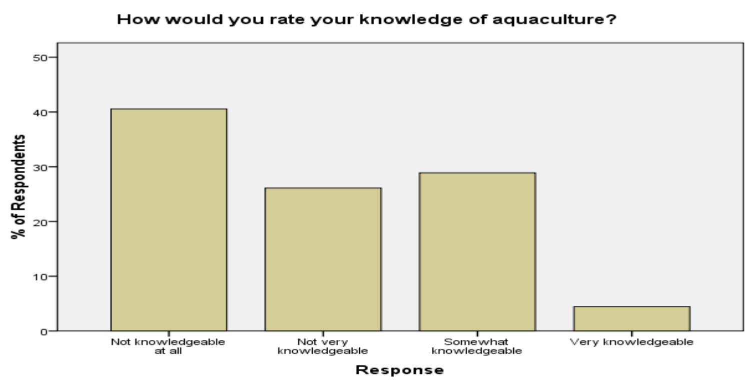

Freshness
Frequency
0
50
100
150
200
1
2
3
4
5
Rank (1 = Not Important, 5 = Very Important)

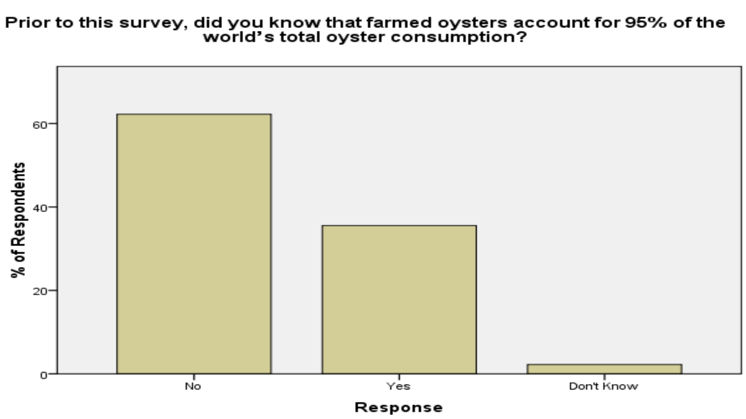

Production Method
Frequency
0
20
40
60
1
2
3
4
5
Rank (1 = Not Important, 5 = Very Important)


Other Items on the Menu and Their Prices
Frequency
0
10
20
30
40
50
60
1
2
3
4
5
Rank (1 = Not Important, 5 = Very Important)

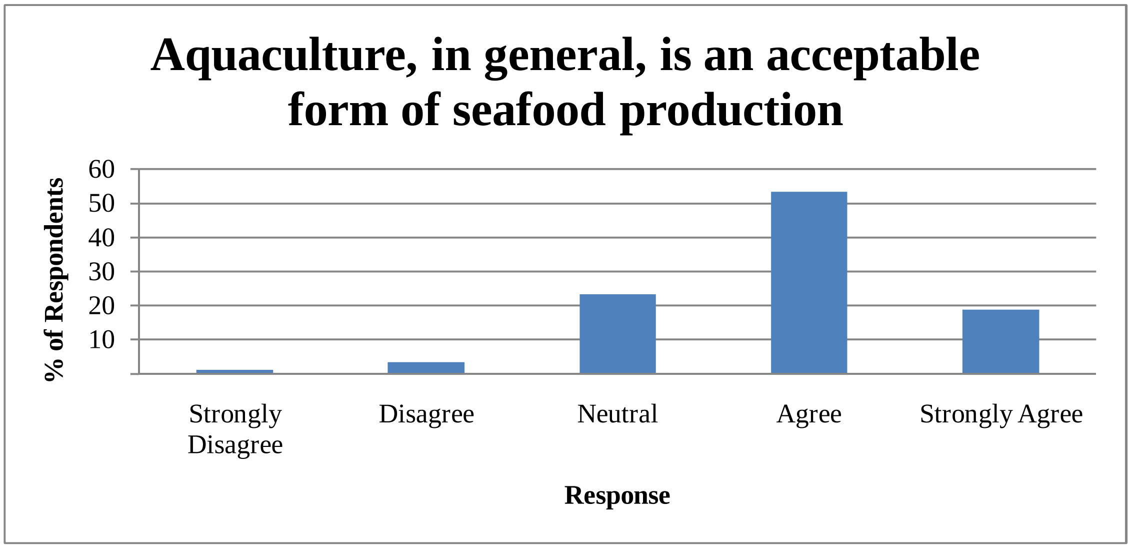
Appendix M: Aquaculture awareness frequency distributions

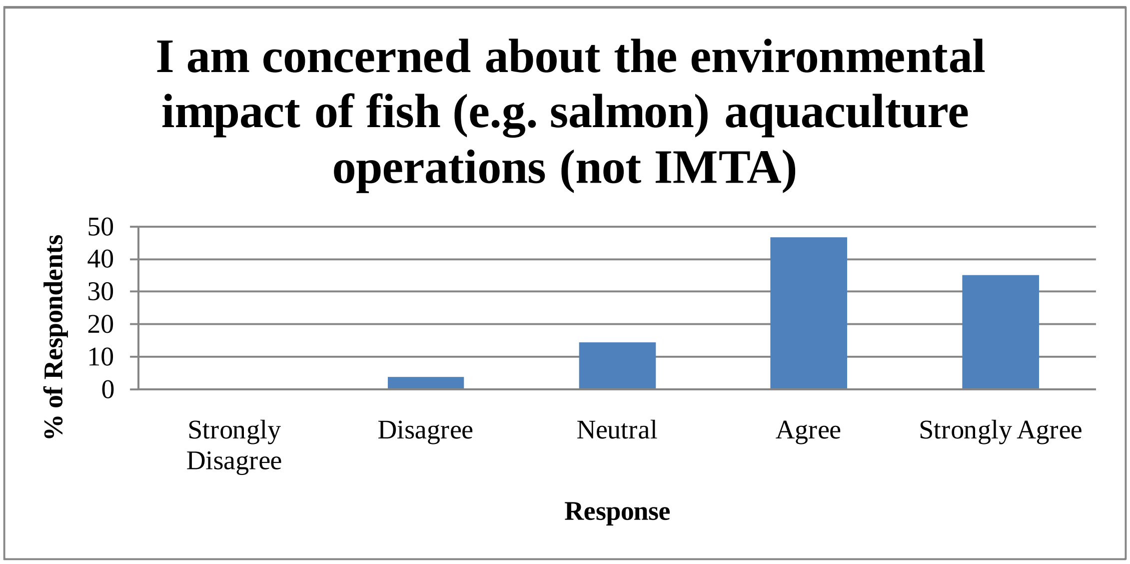


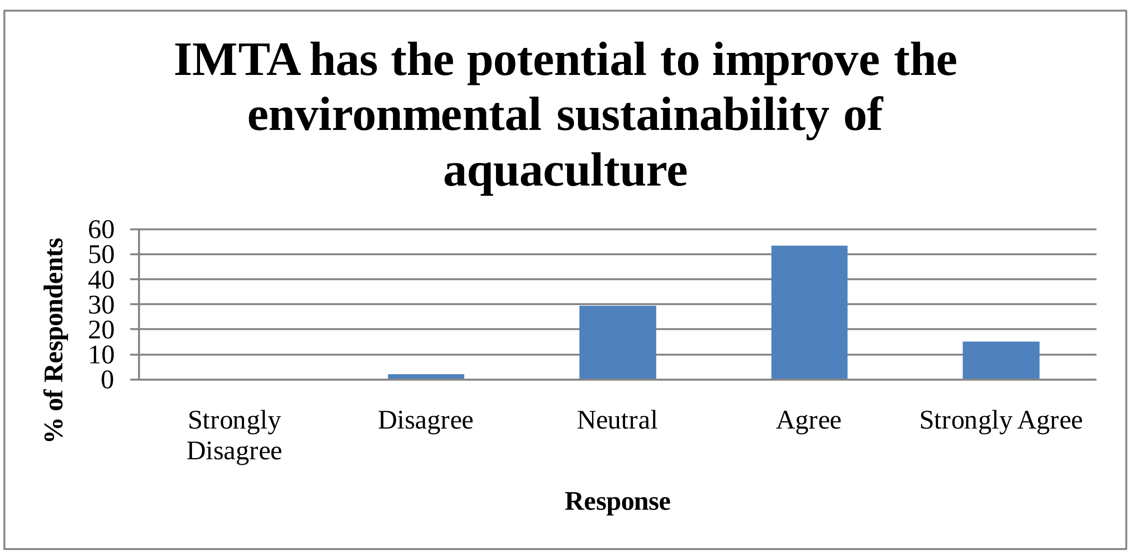


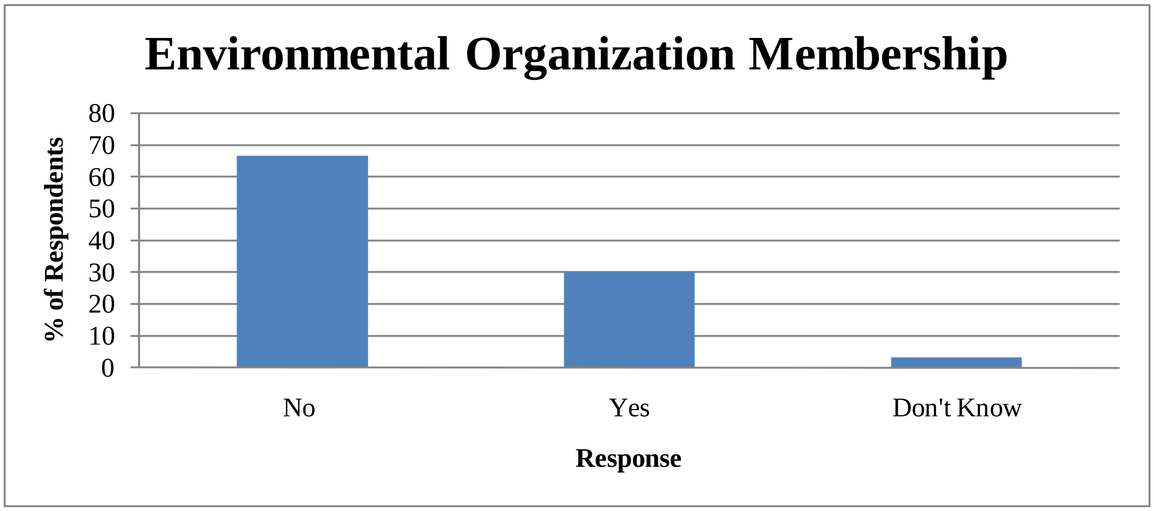


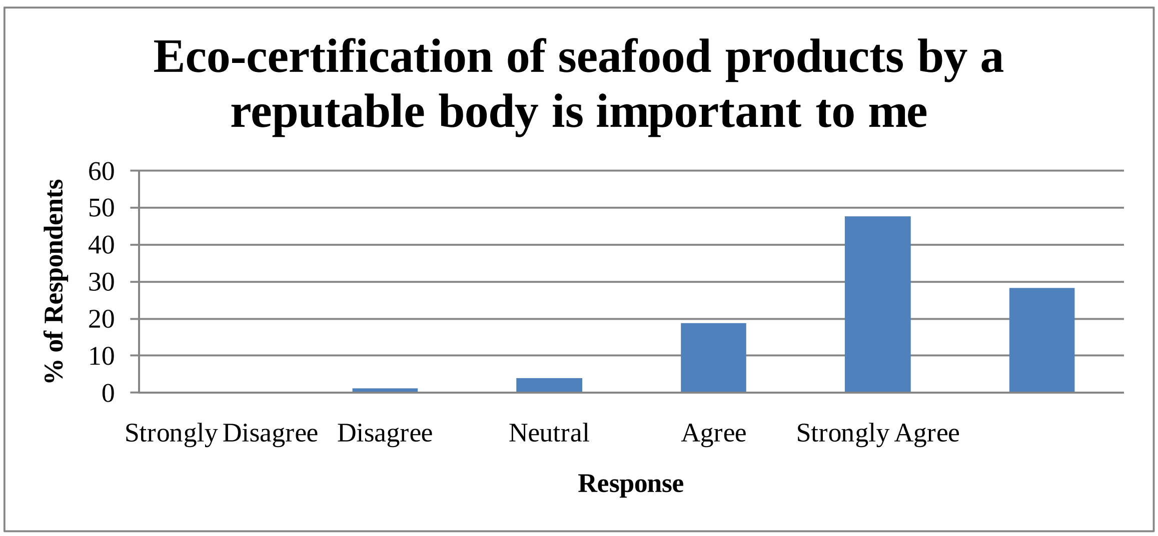
Appendix N: Respondent attitudes frequency distributions

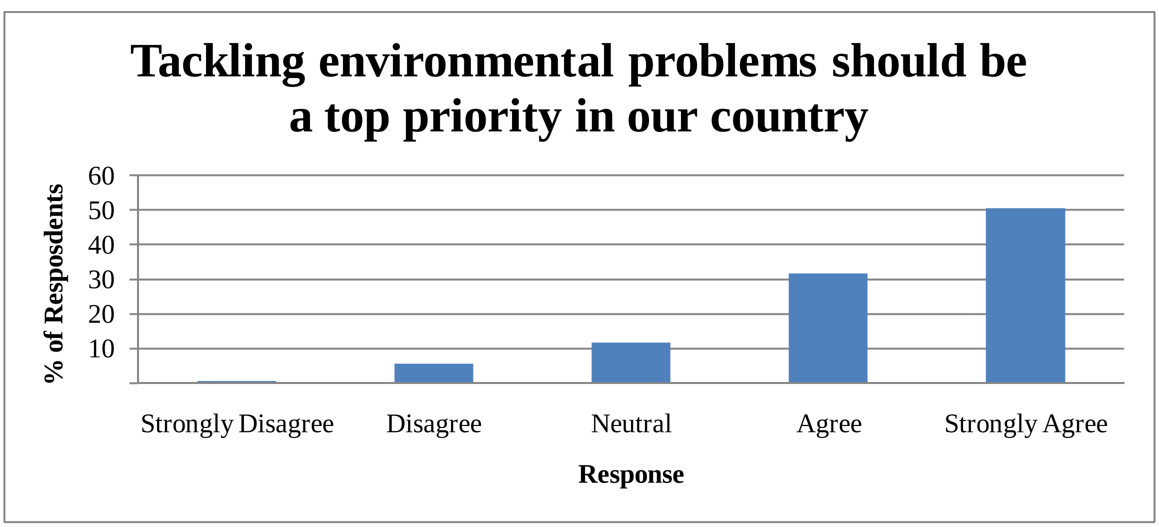







Environmental Organization Membership
% of Respondents
80
70
60
50
40
30
20
10
0
No
Yes
Don't Know
Response


Eco-certification of seafood products by a reputable body is important to me
% of Respondents
60
50
40
30
20
10
0
Strongly Disagree
Disagree
Neutral
Agree
Strongly Agree
Response


Tackling environmental problems should be a top priority in our country
% of Resposdents
60
50
40
30
20
10
Strongly Disagree
Disagree
Neutral
Agree
Strongly Agree
Response

Appendix O: Principal Component Analysis Tables

KMO and Bartlett's Test		
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.651
Bartlett's Test of Sphericity	Approx. Chi-Square	133.484
	df	21
	Sig.	.000

Total Variance Explained									
	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
Component	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	2.045	29.219	29.219	2.045	29.219	29.219	1.752	25.034	25.034
2	1.371	19.582	48.802	1.371	19.582	48.802	1.621	23.155	48.189
3	1.002	14.310	63.111	1.002	14.310	63.111	1.045	14.922	63.111
4	.793	11.323	74.435						
5	.658	9.404	83.839						
6	.589	8.410	92.249						
7	.543	7.751	100.000						

Appendix P: Prediction tables for binary probit analysis

Predictions for Binary Choice Model		Predicted Value		
		0	1	Total Actual
Actual Value	0	11 (6.5%)	32 (19.0%)	43 (25.6%)
	1	6 (3.6%)	119(70.8%	125 (74.4%)
	Total Predicted	17 (10.1%)	151 (89.9%)	168 (100.0%)

Prediction Success	
Sensitivity = actual 1s correctly predicted	95.20%
Specificity = actual 0s correctly predicted	25.58%
Positive predictive value = predicted 1s that were actual 1s	78.81%
Negative predictive value = predicted 0s that were actual 0s	64.71%
Correct prediction = actual 1s and 0s correctly predicted	77.38%
Prediction Failure	
False pos. for true neg. = actual 0s predicted as 1s	74.42%
False neg. for true pos. = actual 1s predicted as 0s	4.80%
False pos. for predicted pos. = predicted 1s actual 0s	21.19%
False neg. for predicted neg. = predicted 0s actual 1s	35.29%
False predictions = actual 1s and 0s incorrectly predicted	22.62%

Appendix Q: Binary probit and ordered probit model descriptive statistics

	AVGORDER	FAC1	FAC2	FAC3	GENDER	AGE	EDUC	INC2	INC3	INC4	RESTOUR	HHSIZE
Mean	1.29883517	0.056792	0.02202	-0.04162	0.470238	38.6369	0.804	0.3	0.39	0.173	0.285714	2.3214
Standard Error	0.06944921	0.072549	0.076024	0.072906	0.038623	0.898999	0.031	0.04	0.04	0.029	0.034958	0.093
Median	1.09861229	0.119271	-0.19704	-0.18322	0	37	1	0	0	0	0	2
Mode	1.09861229	0.373519	1.58729	-0.22032	0	37	1	0	0	0	0	2
Standard Deviation	0.90016459	0.940346	0.98539	0.944966	0.500606	11.65236	0.398	0.46	0.49	0.379	0.453104	1.2054
Sample Variance	0.81029628	0.88425	0.970993	0.892961	0.250606	135.7776	0.159	0.21	0.24	0.144	0.205304	1.453
Range	3.91202301	5.510994	4.893247	4.804205	1	55	1	1	1	1	1	5
Minimum	0	-3.47991	-2.24816	-2.24549	0	22	0	0	0	0	0	1
Maximum	2.03108173	2.645087	2.558718	1	77	1	1	1	1	1	6	

Appendix R: Map of BC shellfish tenures

(Wilderness Committee, 2002)

Appendix S: Sample semi-structured interview questions

1) Where are the primary domestic and international markets for shellfish? 2) Who is in the position to set the price for B.C. shellfish? Is it the grower, the processor, the wholesaler, the consumer? Do all parties just accept the world price? 3) Is the price for B.C. shellfish sensitive to the supply/demand? 4) Who is in the position of power in the market, the grower, the processor, the wholesaler, or the consumer? 5) What is your opinion on the potential for growth in the B.C. shellfish industry? Which species has the greatest potential? 6) What are the new market channels that can be explored? 7) Do you foresee access to seed as the main obstacle to growing the industry? If not, what do you consider the most difficult hurdle to industry growth? 8) What percentage of B.C. shellfish production is exported to the United States? 9) What is the path that B.C. shellfish take from ocean to plate? 10) Is the price for B.C. shellfish sensitive to the supply/demand?

Reference List

Aguilar, F., & Vlosky, R. (2007). Consumer willingness to pay price premiums for environmentally certified wood products in the US. *Forest Policy and Economics, 9*, 1100-1112.

Alain, B. (2005). Taking stock: A profile of canada's aquaculture industry. *Statistics Canada - Vista on the Agri-Food Industry and the Farm Community, 21*(4), 1-6.

Alberini, A. (1995a). Optimal designs for discrete choice contingent valuation surveys: Single-bound, double-bound, and bivariate models. *Journal of Environmental Economics and Management, 28*(3), 287-306.

Alberini, A. (1995b). Willingness-to-pay models of discrete choice contingent valuation survey data. *Land Economics, 71*(1), 83-95.

Alvarado, P. (1996). *Diseno y dimensionamiento de un centro de cultivo mixto de peces y algas en el sur de chile: Analisis de prefactibilidad tecnico-economica.* Unpublished Aquaculture Engineering, Universidad de Los Lagos, Osorno,

Arrow, K., Solow, R., Portney, P., Leamer, E., Radner, R., & Schuman, H. (1993). *Report of the NOAA panel on contingent valuation*National Oceanic and Atmospheric Administration.

Asche, F., Guttormsen, A., Tveteras, & R. (1999). Environmental problems, productivity and innovations in norwegian salmon aquaculture. *Aquaculture Economics and Management, 3*(1), 19-30.

Barrington, K., Ridler, N., Chopin, T., Robinson, S., & Robinson, B. (2010). Social aspects of the sustainability of integrated multi-trophic aquaculture. *Aquaculture International, 18*, 201-211.

Batte, M., Hooker, N., Haab, T., & Beaverson, J. (2007). Putting their money where their mouths are: Consumer willingness to pay for multi-ingredient, processed organic food products. *Food Policy, 32*, 145-159.

BCSGA. (2011). *Shellfish culture: Raft systems.* Retrieved March/2, 2011, from http://bcsga.ca/about/industry-encyclopedia/raft-systems/

Becker, N., & Freeman, S. (2009). The economic value of old growth trees in israel. *Forest Policy and Economics, 11*, 608-615.

Bendell, L. (2010). Cadmium in oysters from the pacific northwest; british columbia, canada. *Proceeding of the Workshop; Cadmium in Shellfish from the Pacific Northwest: Status and Health Concerns,* Simon Fraser University, Burnaby, British Columbia, Canada. 11-13.

Bendell, L., & Feng, C. (2009). Spatial and temporal variations in cadmium concentrations and burdens in the pacific oyster (*crassostrea gigas)* sampled from the pacific north-west. *Marine Pollution Bulletin, 58*(8), 1137-1143.

Blaine, T., Lichtkoppler, F., Jones, K., & Zondag, R. (2005). An assessment of household willingness to pay for curbside recycling: A comparison of payment card and referendum approaches. *Journal of Environmental Management, 76*, 15-22.

Boccaletti, S., & Moro, D. (2000). Consumer willingness to pay for GM food products in italy. *AgBioForum, 3*(4), 259-267.

Bodvin, T., Indergaard, M., Norgaard, E., Jensen, A., & Skaar, A. (1996). Clean technology in aquaculture - a production without waste products? *Hydrobiologia, 326-327*(1), 83-86.

Boyle, K. (2003). Contingent valuation in practice. In P. Champ, K. Boyle & T. Brown (Eds.), *A primer on nonmarket valuation* (pp. 111-169). Dorddrecht, Boston, London: Kluwer Academic Publishers.

British Columbia Shellfish Growers Association. (2007). *Shellfish tenures location map* (http://www.bcsga.ca/about/industry-encyclopedia/shellfish-tenures-locations-map ed.)

Brown, J. (1988). Multivariate analyses of the role of environmental factors in seasonal and site-related growth variation in the pacific oyster *crassostrea gigas*. *Marine Ecology - Progress Series, 45*, 225-236.

Bunting, S., & Shpigel, M. (2009). Evaluating the economic potential of horizontally integrated land-based marine aquaculture. *Aquaculture, 294*(1-2), 43-51.

Buschmann, A., Troell, M., Kautsky, N., & Kautsky, L. (1996). Integrated tank cultivation of salmonids and gracilaria chilensis (rhodopyta). *Hydrobiologia, 326-327*, 75-82.

Cameron, T., & James, M. (1987). Estimating willingness to pay from survey data: An alternative pre-test-market evaluation procedure. *Journal of Marketing Research, 24*(11), 389-395.

Cheng, H., & Capps Jr., O. (1988). Demand analysis of fresh and frozen finfish and shellfish in the united states. *American Journal of Agricultural Economics, 70*(3), 533-542.

Chopin, T., Buschmann, A., Halling, C., Troell, M., Kautsky, N., Neori, A., et al. (2001). Integrating seaweeds into marine aquaculture systems: A key toward sustainability. *Journal of Phycology, 37*, 975-986.

Chopin, T., Robinson, S., Troell, M., Neori, A., Buschmann, A., & Fang, J. (2008). Multi-trophic integration for sustainable marine aquaculture. In S. Jorgensen, & B. Fath (Eds.), *Encyclopedia of ecology* (pp. 2463-2475). Oxford: Academic Press. doi:DOI: 10.1016/B978-008045405-4.00065-3

Coopers and Lybrand. (1997). *Economic potential of the british columbia aquaculture industry*

Costa-Pierce, B. (2002). Ecology as the paradigm for the future of aquaculture. In B. Costa-Pierce (Ed.), *Ecological aquaculture: The evolution of the blue revolution* (pp. 339-372). Oxford: Blackwell.

Cranfield, J., & Magnusson, E. (2003). Canadian consumer's willingness to pay for pesticide free food products: An ordered probit analysis. *International Food and Agribusiness Management Review, 6*(4), 13-30.

Davenport Maps. (2009). *Vancouver island tourism regions.* Retrieved 04/01, 2009, from http://www.vancouverisland.com/Maps/?id=30

Daykin, A., & Moffat, P. (2002). Analyzing ordered responses: A review of the ordered probit model. *Understanding Statistics, 1*(3), 157-166.

DFO. (2010). *Aquaculture production quantities and values.* Retrieved 03/08, 2011, from http://www.dfo-mpo.gc.ca/stats/aqua/aqua-prod-eng.htm

Dillman, D. (2000). *Mail and internet surveys: The tailored design method* (2nd Edition ed.). New York, New York: John Wiley & Sons.

Donaldson, C., Thomas, R., & Torgerson, D. (1997). Validity of open-ended and payment scale approaches to eliciting willingness to pay. *Applied Economics, 29*(1), 79-84.

Doney, S., Fabry, V., Feely, R., Kleypas, J. (2009). Ocean acidification: The other CO_2 problem. *Annual Review of Marine Science*. *1*, 169-192.

Edwards, P., Pullin, R., & Gartner, J. (1988). Research and education for the development of integrated crop-livestock: Fish farming systems in the tropics. *ICLARM Studies and Reviews, 16*, 53.

FAO. (2010). *The state of world fisheries and aquaculture*FAO Food and Aquaculture Department.

FAO Fishstat Plus Database. (2010). *Aquaculture production (quantities and values): 1950-2008*

Ferreira, J., Hawkins, A., & Bricker, S. (2007). Management of productivity, environment effects and profitability of shellfish aquaculture - the farm aquaculture resource management (FARM) model. *Aquaculture, 264*(1-4), 160-174.

Folke, C., & Kautsky, N. (1992). Aquaculture with its environment: Prospects for sustainability. *Ocean & Coastal Management, 17*, 5-24.

Folke, C., Kautsky, N., & Troell, M. (1994). The costs of eutrophication from salmon farming: Implications for policy. *Journal of Environmental Management, 40*(2), 173-182.

Frankic, A., & Hershner, C. (2003). Sustainable aquaculture: Developing the promise of aquaculture. *Aquaculture International, 11*, 517-530.

Gazeau, F., Quiblier, C., Jansen, J., Gattuso, J., Middelburg, J., & Heip, C. (2007). Impact of elevated on CO_2 on shellfish calcification . *Geophysical Research Letters, 34*(L07603), 1-5.

Govindasamy, R., & Italia, J. (1999). Predicting willingness to pay a premium for organically grown fresh produce. *Journal of Food Distribution Research, 30*(2), 44-53.

Green, W. (2000). In Gujarati D. (Ed.), *Econometric analysis* (4th Edition ed.)

Gunduz, O., & Bayramoglu, Z. (2011). Consumer's willingness to pay for organic chicken meat in samsun province of turkey. *Journal of Animal and Veterinary Advances, 10*(3), 334-340.

Halwell, B. (2008). *Worldwatch report: Farming fish for the future* No. 176). Washington, DC: Worldwatch Institute.

Hanemann, M. (1984). Welfare evaluations in contingent valuation experiments with discrete responses. *American Journal of Agricultural Economics, 66,* 332-341.

Hoagland, P., Kite-Powell, H., Jin, D., Schumacher, M., Katz, L., & Klinger, D. (2007). *Economic sustainability of marine aquaculture: A report to the marine aquaculture task force*Marine Policy Center, WHOI.

Hoehn, J., & Randall, A. (1989). Too many proposals pass the benefit cost test. *American Economic Review, 79*, 544-551.

Interviewee #1. (2010).

Interviewee #2. (2010).

Interviewee #3. (2010).

Interviewee #4. (2010).

Interviewee #5. (2010).

Jolliffe, I. (2002). *Principal component analysis* (Second Edition ed.). New York: Springer.

Kanninen, B. (1993a). Design of sequential experiments for contingent valuation studies. *Journal of Environmental Economics and Management*, *25*(1), S1-S11.

Kanninen, B. (1993b). Optimal experimental design for double-bounded dichotomous choice contingent valuation. *Land Economics, 69*(2), 138-146.

Kanninen, B. (1995). Bias in discrete response contingent valuation. *Journal of Environmental Economics and Management*, *28*(1), 114-125.

Krystallis, A., & Chryssohoidis, G. (2005). Consumers' willingness to pay for organic food. *British Food Journal, 107*(5), 320-343.

Laroche, M., Bergeron, J., & Guido, B. (2001). Targeting consumers who are willing to pay more for environmentally friendly products. *Journal of Consumer Marketing, 18*(6), 503-520.

Lekhi, P., Cassis, D., Pearce, C., Ebell, N., Maldonado, M., & Orians, K. (2008). Role of dissolved and particulate cadmium in the accumulation of cadmium in cultured oysters (*crassostrea gigas*). *Science of the Total Environment, 393*(2-3), 309-325.

Loomis, J., Kent, P., Strange, L., Fausch, K., & Covich, A. (2000). Measuring the total economic value of restoring ecosystem services in an impaired river basin: Results from a contingent valuation survey. *Ecological Economics, 33*, 103-117.

Loureiro, M., & Bugbee, M. (2005a). Enhanced GM foods: Are consumers ready to pay for the potential benefits of biotechnology? *The Journal of Consumer Affairs, 39*(1), 52-70.

Loureiro, M., & Lotade, J. (2005b). Do fair trade and eco-labels in coffee wake up the consumer conscience? *Ecological Economics, 53*, 129-138.

MacKay, S., Peterson, F., & Rey, A. (2007). *Economic impacts and prospects of the salmon farming and wild salmon industries in british columbia* No. Volume 2). Victoria: Special Committee on Sustainable Aquaculture.

Mankiw, G., Kneebone, R., McKenzie, K., & Rowe, N. (2002). *Principles of microeconomics* (Second Edition ed.). United States, Canada, Australia: Nelson.

Ministry of Environment. (2007). *British columbia's fisheries and aquaculture sector* No. 2007 Edition). Victoria: BC Stats - Ministry of Environment.

Ministry of Environment. (2008). *British columbia seafood industry: Year in review 2008.* Victoria: Oceans and Marine Fisheries Branch - Ministry of Environment.

Misra, S., Huang, C., & Ott, S. (1991). Consumer willingness to pay for pesticide-free fresh produce. *Western Journal of Agricultural Economics, 16*(2), 218-227.

Mitchell, R., & Carson, R. (1981). *An experiment in determining willingness to pay for national water quality improvements. draft report to the US environmental protection agency*. Washington, DC:

Mohamed, S., & Ibrahim, M. (2007). Preliminary study on willingness to pay for environmentally certified wood product among consumers in malaysia. *Journal of Applied Sciences, 7*(9), 1339-1342.

Monterey Bay Aquarium. (2011). *Oysters.* Retrieved 10/20, 2010, from http://www.montereybayaquarium.org/cr/SeafoodWatch/web/sfw_factsheet.aspx?gid=82

Moon, W., & Balasubramanian, S. (2003a). Willingness to pay for non-biotech foods in the US and UK. *The Journal of Consumer Affairs, 37*(2), 317-339.

Moon, W., & Balasubramanian, S. (2003b). Is there a market for genetically modified food in europe? contingent valuation of GM and non-GM breakfast cereals in the UK. *AgBioForum, 6*(3), 128-133.

Moon, W., Florkowski, W., Bruckner, B., & Schonhof, I. (2002). Willing to pay for environmental practices: Implications for eco-labeling. *Land Economics, 78*(1), 88-102.

Muir, J. (2005). Managing to harvest? perspectives of the potential of aquaculture. *Philosophical Transactions of the Royal Society B, 360*, 191-218.

Muth, M., Karns, S., Anderson, D., Murray, B. (2002). *Agricultural and Resource Economics Review, 31*(2), 171-186.

Naylor, R., Goldburg, R., Primavera, J., Kautsky, N., Beveridge, M., Clay, J., et al. (2000). Effect of aquaculture on world fish supplies. *Nature, 405*, 1017-1024.

Neori, A., Chopin, T., Troell, M., Buschmann, A., Kraemer, G., Halling, C., et al. (2004). Integrated aquaculture: Rationale, evolution and state of the art emphasizing seaweed biofiltration in modern mariculture. *Aquaculture, 231*(1-4), 361-391. doi:DOI: 10.1016/j.aquaculture.2003.11.015

Neori, A., Troell, M., Chopin, T., Yarish, C., Critchley, A., & Buschmann, A. (2007). The need for a balanced ecosystem approach to blue-revolution aquaculture. *Environment, 49*(3), 37-43.

Nobre, A., Robertson-Anderson, D., Neori, A., & Sankar, K. (2010). Ecological-economic assessments of aquaculture options: Comparison between abalone monoculture and integrated multi-trophic aquacultre of abalone and seaweeds. *Aquaculture, 306*(1-4), 116-126.

Orians, K. (2010). Sources of cadmium to BC oysters. *Proceeding of the Workshop; Cadmium in Shellfish from the Pacific Northwest: Status and Health Concerns,* Simon Fraser University, Burnaby, British Columbia, Canada. 14-16.

Paltzat, D., Pearce, C., Barnes, P., McKinley, R. (2008). Growth and production of California sea cucumbers (*Parastichopus californicus*) co-cultured with suspended Pacific oysters (*Crassostrea gigas*). *Aquaculture*, 275, 124-137.

Pendleton, L., David Suzuki Foundation, & Coastal Alliance for Aquaculture Reform. (2005). *Closing in on environmentally sound salmon aquaculture*. Vancouver, B.C.: David Suzuki Foundation. Retrieved from http://libaccess.mcmaster.ca/login?url=http://site.ebrary.com/lib/oculmcmasterpubpolicy/Doc?id=10084285

Petrell, R., & Alie, S. (1996). Integrated cultivation of salmonids and seaweeds in open systems. *Hydrobiologia, 326-327*(1), 67-73.

Radam, A., Yacob, M., Bee, T., & Selamat, J. (2010). Consumer's perceptions, attitudes and willingness to pay towards food products with "no added MSG" labeling. *International Journal of Marketing Studies, 2*(1), 65-77.

Renwick and Associates. (1996). *Market competitiveness analysis of the BC shellfish industry*

Ridler, N., Wowchuck, M., Robinson, B., Barrington, K., & Chopin, T. (2007). Integrated multi-trophic aquaculture (IMTA): A potential strategic choice for farmers. *Aquaculture Economics and Management, 11*(1), 99-110. doi:http://www.tandf.co.uk/journals/titles/13657305.asp

Ryan, M., Scott, D., & Donaldson, C. (2004). Valuing healthcare using willingness to pay: A comparison of the payment card and dichotomous choice methods. *Journal of Health Economics, 23*, 237-258.

Salmon, R., & Kingzett, B. (2002). *Profile and potential of the BC shellfish aquaculture industry*. Nanaimo: Kingzett Professional Services Ltd. for Vancouver Islan Economic Developers Association.

Shang, Y. (1973). Comparison of the economic potential of aquaculture, land animal husbandry and ocean fisheries: The case of Taiwan. *Aquaculture, 2,* 1987-195.

Shuve, H., Caines, E., Ridler, N., Chopin, T., Reid, G., Sawhney, M., et al. (2009). Survey finds consumers support integrated multitrophic aquaculture. *Global Aquaculture Advocate, 12*(2), 22-23.

Soloman, B., & Johnson, N. (2009). Valuing climate protection through willingness to pay for biomass ethanol. *Ecological Economics, 68,* 2137-2144.

Soto, D., Aguilar-Manjarrezz, J., Brugere, C., Angel, D., Bailey, C., Black, K., et al. (2008). Applying an ecosystem-based approach to aquaculture: Principles, scales and some management measures. *Building an Ecosystem Approach to Aquaculture. FAO/Universitat De Les Illes Balears Expert Workshop,* Palma de Mallorca, Spain. 15-35.

Statsoft, I. (2011). *Electronic statistics textbook.* Tulsa, Oklahoma: Statsoft.

Tibbetts, J. (2001). Aquaculture: Satisfying the global appetite. *Environmental Health Perspectives*, 109 (7), A318 - A323.

Troell, M., Joyce, A., Chopin, T., Neori, A., Buschmann, A., Fang, J. (2009). Ecological engineering in aquaculture - Potential for integrated multi-trophic aquaculture (IMTA) in marine offshore systems. *Aquaculture*. *297.* 1-9.

Troell, M., Halling, C., Nilsson, A., Buschmann, A., Kautsky, N., & Kautsky, L. (1997). Integrated marine cultivation of gracilaria chilensis (gracilariales, rhodophyta) and salmon cages for reduced environmental impact and increased economic output. *Aquaculture, 156*(1-2), 45-61. doi:DOI: 10.1016/S0044-8486(97)00080-X

Tsakiridou, E., Zotos, Y., & Mattas, K. (2006). Employing a dichotomous choice model to assess willingness to pay for organically produced products. *Journal of Food Products Marketing, 12*(3), 59-69.

Turnbull, B. (1976). The empirical distribution function with arbitrarily grouped, censored and truncated data. *Journal of the Royal Statistical Society, B38*(3), 290-295.

Wang, J. (1990). Managing shrimp pond water to reduce discharge problems. *Aquacultural Engineering, 9*(1), 61-73.

White, K., O'Neill, B., & Tzankova, Z. (2004). *At a crossroads: Will aquaculture fulfill the promise of the blue revolution?*SeaWeb Aquaculture Clearinghouse.

Whitmarsh, D., Cook, E., & Black, K. (2006). Searching for sustainability in aquaculture: An investigation into the economic prospects for an integrated salmon–mussel production system. *Marine Policy, 30*(3), 293-298. doi:DOI: 10.1016/j.marpol.2005.01.004

Wilderness Committee. (2002). *BC fish farm map*

Wurts, W. (2000). Sustainable aquaculture in the twenty-first century. *Reviews in Fisheries Sciences, 8*(2), 141-150.

Zheng, W., Shi, H., Chen, S., & Zhu, M. (2009). Benefit and cost analysis of mariculture based on ecosystem services. *Ecological Economics, 68*(6), 1626-1632. doi:DOI: 10.1016/j.ecolecon.2007.12.005

Zimet, D., & Smith, J. (2000). *Results of oyster survey presentation*. North Florida Research and Education Center. University of Florida: Institute of Food and Agriculture Sciences.