Valuing Improvements to the Environmental Performance of Salmon Aquaculture in British Columbia: A Choice Modelling Approach

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Abstract

In recent years, alternative systems of aquaculture, including integrated multi-trophic aquaculture (IMTA) and closed-containment aquaculture (CCA), have been developed to address some of the environmental effects of conventional salmon aquaculture. Industry adoption of these technologies in British Columbia has been tentative, since there is little financial incentive for salmon aquaculture companies to improve their environmental performance. While previous studies have outlined the private economic benefits and costs associated with IMTA and CCA adoption, they did not address the benefits accrued to society associated with improvements to the environmental performance of the salmon aquaculture industry. Doing so would increase the economic value of these technologies, and provide justification for implementing policies that would encourage its widespread adoption.

This study used a discrete choice experiment administered via an online survey of 1321 residents of British Columbia to address three research questions: (i) how do residents of BC value improvements to the coastal environment that could be realized through the adoption of more sustainable aquaculture systems, (ii) how is this valuation affected by using different ‘status quos’ and (iii) are British Columbians supportive of alternative aquaculture technology adoption? Results demonstrate that British Columbians are WTP to improve the environmental conditions surrounding salmon farms, and that this WTP varies depending on the status quo conditions. By making assumptions regarding the potential environmental improvements that could arise from widespread adoption of IMTA or CCA technologies in British Columbia, the benefits to society from their adoption can be approximated. Based on these assumptions, British Columbians would be WTP between CDN $77.76 and $159.54 per household per year to support development and fund incentives for adoption of IMTA, and $133.28 to $173.00 per household per year to support development and fund incentives for adoption of CCA, depending on future status quo conditions. Opinions regarding IMTA vs. CCA technologies are mixed in British Columbia, with 32.4% of residents indicating a preference for CCA, and 25.5% preferring IMTA. Overall, results indicate that British Columbians are highly supportive of using government policy to improve the environmental performance of salmon aquaculture.

Keywords: Integrated Multi-Trophic Aquaculture; Close-Containment Aquaculture; environmental valuation; discrete choice experiment; willingness to pay

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I'd like to dedicate this piece of work to my late mentor, confidante and friend, Hudson Gefaell. We love you and miss you every single day.

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List of Acronyms

ASC	Alternative Specific Constant
BC	British Columbia
CCA	Closed-Containment Aquaculture
DCE	Discrete Choice Experiment
DFO	Fisheries and Oceans Canada
EB	Emamectin Benzoate
IMTA	Integrated Multi-Trophic Aquaculture
LCA	Latent Class Analysis
MCS	Medium-Case-Scenario Status Quo
MNL	Multinomial Logit
PCA	Principal Component Analysis
RAS	Recirculating Aquaculture Systems
WCS	Worst-Case-Scenario Status Quo
WTP	Willingness to Pay

Chapter 1: Introduction

1.1 Introduction

The salmon aquaculture industry is both a source of economic growth and environmental controversy for British Columbia (BC). As the world's fourth largest producer of farmed salmon, it is the province’s largest agricultural export, and has surpassed wild salmon in both production weight and value (Fisheries and Oceans Canada [DFO], 2011). Furthermore, it is an important source of employment and economic development in many small, coastal communities. As the industry continues to grow, so too has criticism over the industry's impact on coastal ecosystems surrounding salmon aquaculture facilities. This has served as a hindrance to the industry, as it has faced substantial opposition from environmental groups, First Nations, politicians and members of the BC public. As a result, both the government and the salmon aquaculture industry have begun to take steps towards addressing the environmental issues surrounding salmon farming. Solutions are needed that ensure environmental sustainability, while allowing this powerhouse industry to remain profitable on an increasingly large scale.

1.2 Problem Statement

In recent years, alternative systems of salmon aquaculture have been developed which address some of the environmental impacts of conventional marine net-pen systems. Closed-containment aquaculture (CCA) is a diverse grouping of aquaculture systems that place an impermeable barrier between the cultured species and the surrounding environment (Ayers & Tyedmers, 2009). Integrated multi-trophic aquaculture (IMTA) involves the cultivation of both salmon and extractive species, and uses bio-mitigation to reduce the impact of organic wastes (Ridler et al., 2007). However, the salmon farming industry has been very reluctant to adopt these new systems, due to uncertainty over their economic and technical feasibility. Previous financial analyses of these systems have found them to be less profitable than traditional net-pen systems (BCSFA, 2009; Boulet *et al.*, 2010). However, these analyses, which focus on private costs and benefits for producers and consumers, fail to take in to account the benefits accrued to society associated with reduced damages to the coastal environment that could arise from widespread adoption of these systems. Quantifying these benefits accrued to society using environmental valuation techniques will substantially increase the value (social benefit) of alternative aquaculture systems in future economic analyses[1]. This could promote industry adoption of these alternative technologies, and provide justification for government policies aimed at reducing the environmental impact of salmon aquaculture.

1.3 Research Questions

This research uses environmental valuation techniques to value changes to the coastal environment surrounding salmon aquaculture facilities in British Columbia. These values can be used by industry, government and other stakeholders to encourage the adoption of alternative aquaculture technologies that may result in improvements to the coastal environment when compared to the status quo. Given the controversial and well-publicized nature of this issue in the province, it will also provide an analysis of British Columbians' opinions, attitudes and perceptions of salmon aquaculture in the province.

My research questions are as follows:

1) How do British Columbians value (what are they willing to pay for) improvements to the environmental conditions surrounding salmon farms in B.C.?
2) Given the lack of scientific consensus around the environmental impacts of salmon farming, how is this willingness to pay (WTP) affected by differing future 'status quos'? How does a change is status quo affect the outcomes of a discrete choice experiment (DCE)?
3) Given the highly controversial, well-publicized nature of the salmon aquaculture debate in British Columbia, how does the public perceive salmon aquaculture in the province, and how supportive are they of different technologies and policies related to salmon aquaculture?

[1] Social benefit is a concept used in environmental economics to mean the total benefit to society of producing a particular good or service. This means any benefits accrued to producers and consumers, as well as any benefits/costs accrued to society as a whole (Hanley & Barbier, 2009, 3).

1.4 Research Methods and Approach

A web-based survey was developed and completed by over 1300 residents of British Columbia. The survey collected data on respondents' connection to the British Columbian coast, their prior knowledge and perceptions of salmon aquaculture, their opinions of different aquaculture technologies and government policies, and their overall environmental attitudes. It also included a discrete choice experiment (DCE) that was used to elicit respondents' WTP for improvements to the coastal environment that could be brought about through improvements to the salmon aquaculture industry's environmental performance. Two different status quo options were used within the DCE, yielding two different models that were subsequently compared to determine the impact that status quo has on WTP. Finally, Latent Class Analysis (LCA) was conducted to identify unobservable segments within the larger sample.

1.5 Scope of Study

The survey was administered exclusively to British Columbian residents, and the results may not necessarily be transferrable to other provinces or jurisdictions. This is especially true given the large influence of media and environmental groups on the discourse around salmon farming within British Columbia. The study was also limited in the environmental impacts that were considered. Thus, the values could change if other possible impacts were included in this analysis. It is also limited in its presentation of the status quo. Given the lack of scientific consensus regarding the extent and severity of impacts, two different status quo options were used. However, any number of status quos could have been used, which could yield different results. As the scientific discourse continues to grow in size and scope, a more accurate depiction of current environmental conditions may arise.

1.6 Report Organization

This report is divided in to seven chapters. Chapter 2 will provide background to this research, including an introduction to the salmon aquaculture industry in British Columbia, its potential environmental impacts, and alternative aquaculture technologies that have been developed to address these impacts. Chapter 3 provides a literature review of environmental valuation methods, existing studies on the economics of alternative aquaculture technologies, and a review of studies that have addressed status quo issues in DCEs. Chapter 4 provides a summary of the methodologies used in this research. Chapter 5 presents the results of the survey, and Chapter 6 provides a discussion of those results. Chapter 7 concludes the paper, and provides a summary of key findings.

Chapter 2: Background

Chapter 2 provides background information that is pertinent to this research. It includes a general overview of the salmon aquaculture industry in British Columbia and outlines the industry's potential environmental impacts. It also introduces two alternative technologies currently under development: integrated multi-trophic aquaculture (IMTA) and closed-containment aquaculture (CCA).

2.1 The Salmon Aquaculture Industry in British Columbia

Commercial salmon aquaculture first began in British Columbia during the 1970s on the Sunshine Coast. The industry largely consisted of small farms that experimented with raising Coho and Chinook salmon (DFO, 2013a). During the 1980s, plummeting global salmon prices and poor environmental conditions led many of these small farms to close or be bought out by larger companies (Noakes *et al.*, 2002; DFO, 2013a). These large companies were able to invest in improved technologies and infrastructure (Noakes *et al.*, 2002). Around the same time, there was also an industry-wide switch from rearing Pacific salmon to Atlantic salmon, which is considered to be a hardier species that grows faster and can withstand higher densities (Noakes *et al.*, 2002; Boulet *et al.*, 2010). Following these changes, the industry expanded rapidly, growing in value more than ten-fold within a few years (DFO, 2013a). At present, four large companies control the majority of farmed salmon production in British Columbia: Marine Harvest, Mainstream, Grieg Seafood Ltd. and Creative Salmon Company Ltd. (Watson, 2011). The companies are vertically integrated, largely controlling production through the hatchery, grow-out, processing, and marketing phases (Boulet *et al.*, 2010).

Approximately 130 salmon aquaculture operations hold licenses in British Columbia, though only 70-75 farms are operational at any one time (Watson *et al.*, 2011). The majority of these farms are operated using similar production methods and technologies. Salmon eggs are hatched in land-based hatchery facilities, where they remain for up to eighteen months. They are then transferred to marine net-pens as smolts (CAIA, 2012). The marine net-pens consist of a metal frame with a submerged mesh barrier between the cultured salmon and the marine environment. As shown in Figure 1, farms have several net-pens that are situated side-by-side in sheltered coastal waters (CAIA, 2012). The salmon live in these net-pens at high densities, and are fed a controlled diet to optimize growth. They remain in net-pens until they reach market size, normally around 4.5 kilograms (CAIA, 2012). Figure 1 shows a typical conventional salmon farm in British Columbia.

Figure 1: A Typical Net-Pen Configuration in British Columbia

Source: BC Salmon Farmers Association, 2006

In 2012, salmon farms in BC produced over 73,700 metric tonnes of salmon, representing 89% of total salmon production in the province (BC Ministry of Agriculture, 2013). This level of production generated $432.9 million in wholesale value for the province (BC Ministry of Agriculture, 2013). The industry's success has made farmed salmon British Columbia's largest agricultural export (BC Ministry of Agriculture, 2013). While the United States represents the largest export market for BC farmed salmon, it is also exported to Japan, China, Russia and South Korea (Stroomer & Wilson, 2012).

The aquaculture industry as a whole generates approximately 1,700 direct, full time jobs within British Columbia (Stroomer & Wilson, 2012). According to a 2009 report by PricewaterhouseCoopers LLP prepared for the BC Salmon Farmers Association, the salmon aquaculture industry directly employs 2,800 people if hatcheries, farm sites, administration and processing are taken in to account. Government studies have indicated that the industry directly employs 1500 FTE workers (Legislative Assembly of BC, 2007). Many of these positions are located in small, coastal communities where alternative employment is limited due to the decline of wild fisheries in the province.

2.1.1 Aquaculture Governance in British Columbia

Prior to 2009, finfish aquaculture was managed by the provincial government in British Columbia, through the Ministry of Agriculture and Lands (Watson, 2011). However, a 2009 BC Supreme Court Ruling (*Morton v. British Columbia*) found that finfish aquaculture should be considered a fishery, and thus be under the jurisdiction of Fisheries and Oceans Canada (Watson, 2011). As a result of this ruling, the federal government is now responsible for "licensing sites, production volumes, species to be produced, fish health, sea lice levels, fish containment and waste control (DFO, 2014a, first para.)." The provincial government is responsible for issuing marine and freshwater tenures, licensing marine plant culture and certain business aspects of the industry (DFO, 2014a). This differs from the rest of Canada, where aquaculture is principally managed at the provincial level (DFO, 2014a).

2.2 The Environmental Impacts of Salmon Farming in British Columbia

For decades, the salmon aquaculture industry in British Columbia has faced local and international criticism regarding the extent and severity of its environmental impacts. This criticism has resulted in often-changing, controversial environmental regulatory structures and policies (DFO, 2014a; Nguyen & Williams, 2013). The following section will outline some of the potential environmental impacts of salmon farming. While there are a diverse range of potential impacts, this section focuses on those that are pertinent to this research. It is important to note that much of the research on the environmental impacts of salmon farming remains highly contested and controversial. Furthermore, the impacts are highly site-specific and will differ based on several biological and oceanographic factors, operating procedures, and technologies used during production (Brooks & Mahnken, 2003; Beamish et al., 2007).

2.2.1 Disease and Parasite Transfer

Farmed salmon may incubate diseases and parasites (pathogens), increasing the risk that these pathogens spread to wild species. While farmed salmon enter the marine environment free of pathogens, they can be infected by pathogens through direct interaction with the marine environment (Morton *et al.*, 2004). Farmed salmon live in high densities and thus may be more susceptible to outbreaks of pathogens (Morton *et al.*, 2004). While these pathogens are controlled through monitoring and the use of antibiotics, vaccines and other drugs where necessary, the two-way transfer of pathogens between farmed and wild salmon is inevitable (DFO, 2013b). In BC, the question of whether farmed salmon are causing a decline in wild salmon stocks due to the increased spread of sea lice (*Lepeophtheirus salmonis* and *Caligus clemensi*) has been at the centre of government inquiries, scientific journal articles, and front-page news stories. While some studies have indicated that proximity to a salmon farm is correlated with the abundance of sea lice found on juvenile wild salmon (Morton *et al.*, 2004; Krkosek *et al.*, 2005; Price *et al.*, 2010; Saksida *et al.*, 2011), other studies have found little to no correlation (Beamish *et al.*, 2005). Many researchers point out the importance of confounding environmental factors that impact sea lice survival, and therefore abundance, such as temperature, salinity and currents (Brooks 2005; Beamish *et al.* 2007).

Scientists, NGOs and the media have also expressed concern over disease outbreaks amongst both farmed and wild salmon. The three salmon diseases that are currently monitored in Canada are infectious haematopoietic necrosis (IHN), infectious pancreatic necrosis (IPN) and infectious salmon anaemia (ISA) (CFIA, 2012). According to the Canadian Food Inspection Agency (2012), ISA and IPN have not been found in the Pacific Ocean off British Columbia, but there have been reported cases of IHN in both farmed and wild salmon. At present, little research is available on transmission dynamics between farmed and wild salmon with regards to these diseases in British Columbia.

2.2.2 Marine Habitat Quality

Salmon farms release feces and uneaten feed in to the surrounding marine environment, which can lead to increased carbon, nitrogen and phosphorous levels in the surrounding water column and benthic habitat (Brooks & Mahnken, 2003; Wang *et al.*, 2012). Ammonia, ammonium and sulfides are also released through salmon excretory processes (Brooks & Mahnken, 2003). The oxidation of organic wastes can reduce dissolved oxygen content in the surrounding habitat (Hargrave, 2003). However, in the Pacific Northwest, primary production is largely limited by the amount of sunlight, not nutrient availability, and therefore eutrophication is less of an issue in British Columbia (Brooks & Mahnken, 2003). While the severity of impacts to marine habitat has been controversial, studies have found a decrease in biodiversity and potential trophic effects in benthic communities in habitat near salmon farm (Giles, 2008; Callier *et al.*, 2013). The extent and severity of impacts associated with wastes are highly dependent on farm operating procedures as well as environmental and oceanographic factors, including water depth, currents and cloud cover (Brooks & Mahnken, 2003; Chang *et al.*, 2013).

Scientists have also looked in to the routine and periodic usage of parasiticides, disinfectants, antifouling agents, antibiotics and other agro-chemicals, and their localized impact on marine habitat (Burridge *et al.*, 2010). Emamectin Benzoate (EB), marketed as SLICE®, is an in-feed treatment for sea lice. Laboratory studies have demonstrated that it can increase mortality in non-target crustaceans (Haya *et al.*, 2001; Bright & Dionne, 2005). Further field research conducted by the DFO found that "(i) EB can remain and so potentially build up in benthic sediments close to salmon farms, depending on the frequency and extent of SLICE® usage and the local site conditions; and (ii) EB is bioavailable and can be measured in the muscle tissues of spot prawns collected near salmon farms treated with SLICE® (DFO, 2012, 6)." While extensive research has been conducted in to the effects of individual chemicals on non-target species and ecosystem health, the cumulative ecological impacts of chemicals has been cited as an important gap in knowledge (Burridge *et al.*, 2010; DFO, 2012).

2.2.3 Aesthetic Impacts

Salmon farms in British Columbia are often located in undeveloped or residential coastal areas, and complaints have been raised by homeowners and recreationalists regarding salmon farms' impacts on the aesthetics of an area. Within Canada, complaints have been lodged to provincial and federal governments regarding this issue (ESSA, 1992; Gough, 2010). Residents and recreationalists have cited disruption of pristine views, unpleasant odors, increased marine debris and decreased coastal access as evidence of diminished aesthetic value resulting from aquaculture development in BC (D'Anna, 2013). One recent survey conducted in Baynes Sound, BC on shellfish aquaculture found that 44% of local residents either agreed or strongly agreed with the statement 'shellfish farming spoils the beauty of Baynes Sound (D'Anna, 2013).' Furthermore, 51% of survey respondents found that the presence of aquaculture reduced enjoyment of local beaches, 50% of respondents thought aquaculture operations made too much noise and 76% of respondents were unhappy about marine debris originating from farms (D'Anna, 2013). While shellfish aquaculture is operationally different than finfish aquaculture, very little research has been conducted on aesthetics for finfish aquaculture in British Columbia.

2.2.4 Other Environmental Impacts

While this study will focus on valuing improvements to disease and parasite transfer risk, marine habitat quality and aesthetic quality around salmon farms in British Columbia, these are not the only environmental impacts associated with salmon farming. However, these additional impacts have not been included in this research because i) the impact has not been proven that they represent a significant impact in BC or ii) the impact is not directly related to the type of technology used. These impacts include:

- Farmed salmon consume feed that contains fish oils and meal from wild forage fisheries. As production volumes of carnivorous finfish species increases while forage fishery capture rates stagnate, it is possible that these fisheries will be overexploited (Naylor *et al.*, 2000). However, cultured salmon now have a highly efficient feed conversion ratio, normally between 1.2 and 1.4 (Tacon & Metian, 2008).
- Cultured salmon can escape their holdings, often due to infrastructure malfunction or adverse weather conditions. Since the vast majority of salmon farms culture Atlantic salmon, a non-native species, this could lead to a biological invasion. Atlantic salmon have been found in salmon rivers in BC, indicating the possibility that reproduction may be occurring (Fisher *et al.*, 2014; Volpe *et al.*, 2000). However, other evidence indicates that the likelihood of Atlantic salmon reproductive success on the Pacific coast is negligible (Noakes, 2011; Waknitz *et al.*, 2003).
- Marine mammals, particularly pinnipeds, can be attracted to aquaculture operations due to the highly concentrated presence of prey species. This can cause marine mammal deaths through net entanglement and drowning (Nash *et al.*, 2000). Furthermore, salmon farmers are authorized to kill some marine mammals (harbour seals and California sea lions) if their infrastructure is under threat (BCSFA, 2013). However, reported marine mammal deaths are not large enough to cause significant harm at the population level at this time (DFO, 2014b).

2.3 Alternative Aquaculture Technologies

In recent years, alternative salmon aquaculture systems have been developed to address some of the environmental impacts of conventional net-pen aquaculture. These systems include closed-containment aquaculture (CCA) and integrated multi-trophic aquaculture systems (IMTA). While neither system is widely used for salmon culture in Canada, there are several government, industry, and NGO-funded pilot projects, research initiatives, and small-scale, private farms operating at present.

2.3.1 Integrated Multi-Trophic Aquaculture

IMTA involves the cultivation of salmon (or other finfish species) and extractive species, such as shellfish, sea cucumbers and seaweeds, nearby to one another (see Appendix 2). These systems mimic coastal ecosystems' assimilative capacity by using bio-mitigation to reduce pollution from organic wastes (Chopin *et al.*, 2001; Ridler *et al.*, 2007; Macdonald *et al.*, 2011). Extractive animal species consume uneaten feed and feces released by the salmon, and seaweeds absorb inorganic nutrients (Chopin *et al.*, 2001). At present, no IMTA farms are culturing salmon in British Columbia. In recent years, a commercial IMTA farm cultured Sablefish, shellfish and seaweeds in Kyuquot, British Columbia[2].

IMTA has been shown to reduce the amount of organic waste released in to the coastal environment (Macdonald *et al.*, 2011). It has also been shown to increase the growth rate of shellfish species by 46% when compared to shellfish monocultures (Ridler *et al.*, 2007). The private economic implications of IMTA adoption have also been found to be tentatively positive, and include product diversification and risk mitigation (Whitmarsh *et al.*, 2006; Nobre *et al.*, 2010). However, these systems still allow a high level of interaction between cultured species and the surrounding marine ecosystem. Therefore, IMTA does not address all of the environmental impacts associated with conventional net-pen aquaculture.

[2] This farm was run by Dr. Stephen Cross, an Associate Professor at the University of Victoria, and the NSERC Industrial Research Chair in Sustainable Aquaculture. Kyuquot SEAfoods is a commercial IMTA farm (referred to as Sustainable Ecological Aquaculture or SEAfarm) and research station (SeaVision Group, 2015).

2.3.2 Closed-Containment Aquaculture

Closed-containment aquaculture (CCA) is a diverse grouping of aquaculture systems that place an impermeable barrier between salmon and the surrounding environment (Boulet *et al.*, 2010). These systems can be located on land or in the water, and involve varying degrees of environmental interaction (see Appendix 3). Land-based systems consist of large, solid-walled containers, while marine-based systems consist of soft-walled bag systems (Boulet *et al.*, 2010; Apostle, 2012). In both cases, water is either constantly re-circulated through the aquaculture system or treated before being released back in to the environment (Boulet *et al.*, 2010). As of 2015, at least one closed-containment salmon farm is operating in British Columbia: KUTERRA Land-Based Closed Containment Salmon Farm run by 'Nagmis First Nation in Alert Bay ('Nagmis First Nation, 2015).

By limiting interaction with the external environment, CCA has the potential to prevent fish escapes, reduce disease and parasite transfer between farmed and wild fish and prevent the release of organic wastes (Chadwick *et al.*, 2010; Ayers & Tyedmers, 2009). For this reason, it is strongly advocated for by environmental groups in British Columbia (Ecoplan International Inc., 2008) This technology also creates a highly controlled environment for cultured fish that can reduce certain production risks, such as disease outbreaks (Ecoplan International Inc., 2008). However, the commercial-scale economic feasibility of CCA for salmon has been called in to question by both industry and the federal government (BCSFA, 2009; Boulet *et al.*, 2010). A recent study conducted by DFO on the economic feasibility of closed-containment found that "the presence of higher capital costs, energy costs and labour requirements significantly affected its overall profitability (Boulet *et al.*, 2010, vi)." It has also been criticized for creating new environmental issues, including high energy consumption and the creation of solid organic wastes through water treatment (Ayers & Tyedmers, 2009; Chadwick *et al.*, 2010).

Chapter 3: Literature Review

This chapter provides an overview of relevant academic literature in order to identify gaps in existing research that will be answered by my research questions. This chapter will review economic studies of alternative aquaculture systems, stated-preference approaches to environmental valuation, and examine status quo issues related to DCEs.

3.1 Economic Studies of Alternative Aquaculture Systems

While the private costs and benefits of alternative aquaculture systems have been assessed through government, academic and industry research, very little research has been conducted on the social benefits and costs associated with different aquaculture technologies as a result of their differing environmental performances. The research discussed in this section provided an important foundation to build upon in the development of this study.

3.1.1 Economic Studies of IMTA

Financial analyses have been conducted on IMTA farms, with largely positive results. Since there are no commercial-scale IMTA farms producing salmon in Canada, the results of Canadian studies are largely based on a pilot project in the Bay of Fundy[3]. Ridler *et al.* (2007) conducted a capital budgeting model and found that IMTA farms have the potential to increase the net present value of a salmon monoculture by 24%. IMTA was also found to mitigate financial risk due to product diversification (Ridler *et al.,* 2007). Other economic studies have been conducted on IMTA globally. Whitmarsh *et al.* (2006) also used a capital budgeting model to examine integrated salmon-mussel systems on the west coast of Scotland. While this research also demonstrated an increase in net present value with integration, this increase was found to be highly dependent on the stability of global salmon prices. Another recent study conducted in South Africa used economic and ecological data to examine the social benefits of incorporating seaweeds in to abalone farming (Nobre *et al.*, 2010). Social benefits (in the

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[3] Between 2001 and 2006, DFO and industry scientists developed an industrial-scale IMTA pilot project that co-cultivated salmon, blue mussels and kelp in the Bay of Fundy, NB (DFO, 2013c).

form of positive externalities) were estimated using the cost of restoration of wild kelp beds. It was expected that by culturing seaweeds, pressure to wild seaweeds would be reduced. While this study did find that IMTA modestly increased private profits by 1.4%, the external environmental benefits considered in the study contributed 80% of the overall economic gains upon shifting to IMTA (Nobre *et al.*, 2010). Yip (2012) used a choice experiment to determine that consumers in major markets for BC salmon in the US are willing to increase their total consumption and pay a 9.8% price premium for IMTA salmon versus conventionally-farmed salmon, which could increase profitability for producers of IMTA products.

Martínez-Espiñeira *et al.* (2012) used contingent valuation to estimate the non-use benefits of IMTA in Canada, in the form of bio-mitigation of salmon farm waste. This study found that Canadians who do not eat salmon would be willing to pay between CDN $43 and 65 million per year for the environmental improvements brought about by IMTA. Martínez-Espiñeira *et al.* (2015) also conducted a study focused on Canadian salmon consumers that used the contingent behavior method to assess how their consumption choices would be affected by the availability of IMTA products. The aggregate benefit to Canadian salmon consumers was found to be CDN $280 million per year to CDN $1.5 billion per year, depending on the restrictiveness of assumptions.

3.1.2 Economic Studies of CCA

Closed-containment aquaculture, though widely used in the production of some fish species, is not currently used for large-scale commercial production in British Columbia. Several conflicting reports on the private economic and technical feasibility of CCA have been produced by government, industry and environmental groups (Ayers & Tyedmers, 2009; Boulet *et al.*, 2010; Wright & Arianpoo, 2010). The most widely cited of these reports was produced by Fisheries and Oceans Canada (Boulet *et al.*, 2010). This report preliminarily examined hypothetical costs for eight different types of closed-containment systems, though only land-based recirculating aquaculture systems (RAS) were found to have a positive return on investment after three years. RAS systems were found to be marginally profitable, though much less so than conventional net-pen aquaculture. RAS was also found to be more susceptible to market fluctuations over time. However, this study was based on hypothetical data, and did not include the potential social benefits of CCA in its economic analysis (Boulet *et al.*, 2010). Another report produced the same year for the SOS Marine Conservation Foundation found that while net-pen aquaculture was more profitable, closed-containment technology benefitted economically from price premiums and improved production methods (Wright & Arianpoo, 2010). Furthermore, Yip (2012) found that consumers in the major US markets for BC farmed salmon were willing to pay a price premium of 3.9% for CCA salmon. These studies indicate that CCA has the potential to be profitable, though significantly less so than conventional marine net-pens. However, the social benefits of CCA, including any reduced environmental impact on the coastal environment that it may cause, have not been included in any of these analyses.

3.2 Environmental Valuation

As demonstrated in the preceding sections, a large amount of economic analysis of alternative aquaculture systems has been conducted in order to assess their private profitability, but little examination of the social benefits derived from the improved environmental performance of these alternative systems[4]. These social benefits can be quantified using environmental valuation. By estimating the monetary value of an environmental good (or change in the provision of that good), environmental valuation allows environmental costs and benefits accrued to society to be included in traditional economic analyses (Hanley & Barbier, 2009, 3). Decision-makers are then equipped to generate more socially efficient outcomes from decision-making processes.

Numerous different methods of environmental valuation are currently in use, each with its own specific theoretical framework and uses, limitations and intricacies. Three broad-based approaches are used; stated-preference, revealed preference, and production function approaches. Stated-preference approaches, which include contingent valuation and discrete choice experiments, survey the public regarding their willingness to pay or willingness to accept compensation for a change to an environmental good or service (Champ *et al.*, 2003, 101-102). Conversely, revealed

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[4]In this study, improved environmental performance of alternative systems of salmon aquaculture (IMTA and CCA) may lead to social benefits in the form of a reduction in the negative externalities associated with conventional marine net-pen salmon aquaculture.

preference methods, which include the travel cost method and hedonic pricing, ascertain environmental values from the behavior in markets for related goods (Champ *et al.*, 2003, 259). Production function approaches value the environment as an input to economic production. Production function approaches examine the effect that an environmental change would have on consumer and producer surplus for a certain product or service (Barbier, 1994). This review will provide an overview of revealed preference and production function approaches, and a more detailed review on stated-preference methods, including contingent valuation and choice experiments.

3.2.1 Revealed Preference and Production Function Approaches

Revealed preference methods ascertain environmental values from the behavior in markets for related goods (Champ *et al.*, 2003, 259). These methods are best used to measure the consumptive or 'use' value of an environmental good or service. Production function approaches value the environment as an input to economic production. They examine the effect that an environmental change would have on consumer and producer surplus for a certain product or service (Barbier, 1994).

The travel cost method (TCM) is used to value an ecosystem or a recreation site not valued in traditional markets by examining the travel expenditures consumers make to get to that site (Clawson & Knetsch, 1966; Brown & Mendhelson, 1984). It is often used to value parks and other areas where tourism and recreation are common. The travel cost method establishes the statistical relationship between the number of visits an individual makes to a particular recreation site and the costs incurred from undertaking said visit, along with several other site-specific variables. These costs, which can be both monetary expenses and the opportunity cost of one's time, are directly related to the utility derived from visiting the site (Brown & Mendhelson, 1984). TCM has been used to value particular attributes of environmental goods and services within a site, such as a marine protected area (Font, 2000; Chae & Wattage, 2012). This relationship is used to determine the total value of a site for visitors. The random utility site choice travel cost method allows respondents to choose amongst multiple sites based on site characteristics and trip cost (Kaoru *et al*., 1995).

The other common method of revealed preference is the hedonic pricing method (HPM). Like choice experiments and the random utility site choice travel cost method, hedonic pricing is based on Lancaster's (1966) characteristics theory of value. HPM attempts to determine the effect that an environmental good has on home prices in order to estimate the value of a change in that environmental good (Tyrvainen, 1997). By determining the statistical relationship between a change in an environmental good and housing prices, the WTP for a marginal increase in that environmental good can be determined. This method is best used to value improvements in the environmental quality of urban areas, or to value environmental amenities such as urban parks or vistas (Tyrvainen, 1997; Ekeland, 2004).

The production function approach examines the environment as an input in the economic production process and uses the change in production cost and output, and its resulting effect on prices, as a proxy for the value of an environmental good (Barbier, 1994; Hanley & Barbier, 2009). The sum of the changes in producer and consumer surplus can be used to provide a WTP estimate for the change in the quality or quantity of an environmental good. It builds on traditional economic theory, which has been used to value the change in production that results from a change in any input/factor of production (Hanley & Barbier, 2009).

One of the major shortcomings of revealed preference approaches is their inability to measure non-use values for environmental goods (Carson, 2011, 8-9). Given that a great deal of the value derived from British Columbia's coast is hypothesized to be passive use and/or non-use in nature, revealed preference or production function approaches were not appropriate to be used in this study.

3.2.2 Stated-Preference Approaches

Stated-preference approaches to environmental valuation are used in situations where the value of an environmental good is not entirely derived from the direct use of that good (Champ et al., 99-100). Stated-preference approaches became widely used when Krutilla (1967) developed the concept of economic 'existence value': utility derived from simply knowing that an environmental good exists. It became clear that omitting this value from economic analyses would seriously underestimate the value of environmental goods. Since contingent valuation was the only method at the time able to estimate existence value, it rapidly grew in popularity (Carson, 2011, 8).

3.2.2.1 Contingent Valuation

The contingent valuation method (CVM) uses various forms of surveys to directly ask respondents for their WTP, or willingness to accept compensation (WTAC), for some change in the provision of an environmental good. In order to conduct a CVM study, respondents must be informed about the environmental change to be valued, why and how they would pay (or accept compensation) for the change, and the ramifications if the change is not implemented (Hanley, 1988; Hanneman, 1994). A hypothetical market is presented, including a realistic 'payment vehicle' by which respondents could pay for the environmental change (Champ et al., 2003, 129-130). Common payment vehicles include voluntary donations, taxes and increased costs for market goods (Champ et al., 2003, 130). Respondents are then asked to provide their WTP for the environmental good. WTP is elicited through the respondent selecting one amount from a series of options, providing an open-ended amount, or making a dichotomous choice between paying or not paying a certain amount (Hanley & Barbier, 2009). In doing so, it is possible to estimate the demand curve, and therefore the consumer surplus, of said environmental good (Hanley & Barbier, 2009).

3.2.2.2 Discrete Choice Experiments

Discrete choice experiments (DCE) are the other commonly used methodology within the stated-preference approaches to environmental valuation. DCEs allow not only for the estimation of the value of an environmental good, but also the value of the individual attributes associated with that good (Hanley *et al.,* 1998; Hanley *et al.*, 2001). In choice experiments respondents are asked to choose between a series of different alternatives, each of which is described in terms of its various attributes, and the levels that these attributes take. The first step in this process involves identifying the relevant attributes and levels for the environmental good under consideration, one of which is always price or cost (Hanley *et al.*, 2001). Once these have been determined, bundles of attributes are put together using the principles of experimental design. Each bundle of attributes is arranged in groups, referred to as choice sets, which are presented to respondents. One of these options is normally the 'status quo' option that involves no deviation from current practices (Hanley *et al.*, 2001). With each choice set presented, respondents are asked to choose their most preferred option based on each options' attributes, and the levels those attributes take (Hanley *et al.*, 2001). Once the responses have been collected, the marginal change in utility from a change in a certain attribute, and WTP for these marginal changes can be estimated (Hoyos, 2010). See Section 4 for details on the methodologies used in model estimation and WTP.

Like CVM, DCEs can be used to estimate both use and non-use values. However, choice experiments are considered by many to be better suited to dealing with multi-dimensional, complex issues that involve trade-offs between attributes (Hanley *et al.*, 2001; Boxall *et al.*, 1996). DCEs have a natural ability to separate alternatives in to their individual attributes, and determine the value of specific attribute changes, instead of valuing an alternative as a whole (Hanley *et al.*, 2001). Choice experiments can also be advantageous in dealing with some of the methodological issues associated with CVM. Since respondents can express their preferences over a range of payment amounts and attribute levels, DCEs have been demonstrated to be more sensitive to scope than in CVM (Foster & Mourato, 2003). This was demonstrated by Foster and Mourato (2003), who determined that CE was significantly more sensitive to scope than CVM in empirical tests. Furthermore, since WTP is not directly elicited, but instead inferred based on respondent choices, strategic behavior and 'yeah saying' may be reduced (Hanley *et al.*, 2001). As a result, DCEs are now widely used, and considered by many social scientists to be a more robust and accurate method of environmental valuation (Hanley *et al.,* 2001).

While choice experiments are considered by many to be superior to CVM for conducting environmental valuation, there are some valid criticisms that have been levied against this method. One of the most common criticisms is the underlying assumption that the value of an environmental good is equal to the sum of the value of its attributes (Hanley *et al*., 1998). This assumption can be problematic, since there is no way to include all of the potentially relevant attributes of a good within a choice experiment. Furthermore, previous studies have demonstrated that choice experiments overestimate the total value of an environmental good relative to CVM, which values the whole instead of the sum of its parts (Adamowicz et al., 1998; Foster & Mourato, 2003).

Therefore, CVM can be considered more useful when examining goods as a whole, versus marginal changes in their attributes.

Given the complexity involved in choice experiment design, there are many opportunities for the results to be affected by decisions made by the researcher. The attributes and levels chosen, experimental design methods, the number of choice sets respondents must deal with and other factors can have a substantial effect on the end results (Caussade *et al*., 2005). Furthermore, there is some degree of cognitive difficulty associated with making a large number of somewhat complex and detailed choices. This fatigue can lead respondents to pay less attention and make choices at random, which could reduce the validity of results (Hanley *et al.*, 2001; Savage & Waldman, 2008). Savage and Waldman (2008) investigated so-called fatigue effects in mail and online surveys, and found that it can have a significant effect on estimates of utility. Finally, CE share some of the same issues as CVM, including hypothetical market bias, though this is said to be somewhat reduced in the case of CE (Hanley *et al*., 2001).

3.3 Valuing Environmental Performance using DCEs

Improving the environmental performance of a municipality, company or industry's environmental performance can lead to benefits accrued to society at large. Members of the public benefit from reduced environmental damage, and/or improved environmental conditions when compared the status quo situation. Several studies have used DCEs to estimate the economic value of these environmental performance improvements, or the environmental conditions that result. Much of the research related to WTP for environmental performance improvements from a company or industry focuses on the consumer. Often, the payment vehicle used is an increase in the price of a certain product or service for a more 'green' product (Yip, 2012; Axsen *et al.*, 2009). However, some studies focus on eliciting values from residents that live within the region where production occurs. These studies focus on improvements to the environmental performance of an industry, or subsequent management programs aimed at minimizing environmental damage from a particular industry, as described below.

Numerous studies have focused on valuing reduced environmental damages from terrestrial agriculture industry. Loomis *et al.* (2000) used a DCE to value restoration of a river's five ecosystem services that had been damaged by agricultural pollution. Birol *et al.* (2006) conducted a similar DCE to value restoration of polluted wetlands in Greece. Colombo *et al.* (2005) examined the value of reducing off-farm effects of soil erosion. In this study, residents were found to be willing to pay to reduce desertification, but also placed a high value on local employment.

Furthermore, a significant amount of research has attempted to value the social costs and benefits associated with coastal wind farm development in Europe, as well as WTP for reduced environmental impacts from wind farms (Alvarez-Farino & Hanley, 2002; Dimitropoulos & Kontoleon 2009, Koundouri *et al*., 2009). While this industry is very different from salmon aquaculture, some of the environmental and aesthetic issues are similar, including reductions in pristine coastal views, and potential for marine wildlife impacts.

3.4 Valuing Improvements to the Environmental Performance of Salmon Aquaculture

A limited amount of research has estimated the value of environmental improvements in salmon aquaculture, though there is an extensive body of research valuing changes to coastal ecosystems resulting from improved environmental performance of other industries (Atkins *et al.*, 2007; Othman *et al.*, 2004; Birol *et al.*, 2006). Muir *et al.* (1999) outlined several possible methods that could be used to value the environmental impacts of salmon aquaculture. Muir *et al.* (1999) argue that while opportunity cost, replacement cost, hedonic pricing and travel cost could all be used as a method of valuation, contingent valuation has the most potential to create full and accurate valuation estimates for salmon farming. Though Muir *et al.* make no mention of choice experiments, this paper does discuss the importance of examining specific environmental attributes and trade-offs in conducting valuation. Several studies examine benefits accrued to farmed salmon consumers from improvements in environmental performance (Whitmarsh & Wattage, 2006; Johnston *et al.*, 2008, Yip, 2012). However, with the exception of Martínez-Espiñeira *et al.* (2012), there have been few attempts to value the resulting environmental improvements that accrue to those that do not necessarily consume farmed salmon. This study will build upon the WTP estimates derived from contingent valuation by Martínez-Espiñeira *et al.* (2012) in several ways.

Instead of using contingent valuation focusing exclusively on the bio-mitigation benefits of IMTA, it will use a DCE to examine other environmental benefits associated with improved environmental and economic performance of salmon aquaculture operations. In addition, this study will also include CCA in its analyses, given its notoriety in British Columbia. Finally, Martínez-Espiñeira *et al.* (2012) sampled Canadians who were non-consumers of farmed salmon. This study will focus on British Columbian residents, including both consumers and non-consumers of farmed salmon.

3.5 Status Quo Issues related to DCE

Most DCEs feature an option within each choice set that reflects no change from the current situation. This is most commonly presented as a 'status quo' profile that features attributes and levels pertaining to the current state, or as an 'opt-out' or 'no choice' option that provides no further information (Boxall *et al*., 2009 Dominguez-Torreiro & Solino, 2011). It can be difficult to establish a status quo option for a DCE when there is a lack of undisputed, objective data on which it can be based. Respondents' subjective perceptions may differ, and therefore delegitimize the status quo presented (Dominguez-Torreiro & Solino, 2011; Kataria *et al.*, 2012). It has been suggested that this could impact utility estimates (Dean, 2008; Marsh *et al.*, 2011). However, if an 'opt-out' option is presented due to a lack of data on the status quo, this option can be interpreted as being based on the respondents' interpretation of the status quo, without one singular meaning (Dominguez-Totteiro & Solino, 2011).

Very few previous studies have attempted to address the issue of choice under uncertain status quo conditions in DCEs. One potential option that has been used is to allow respondents to specify their own status quo, or to base the status quo on the respondents own experiences specified in responses to other questions (Glenk, 2011). Taylor (2011) used a variable status quo as a context variable when presenting future possible scenarios for coral reefs in Hawaii. A variable status quo was used in order to determine whether the present situation would influence choices amongst future scenarios. The context variable was found to be significant in affecting respondent preferences. Another DCE study that examined consumer preferences for water utilities in England also examined the role of the status quo option. A split sample was used that varied the description of the status quo. It was determined that while different status quos did affect the probability of the status quo being chosen, it had little impact on preferences for service provision (Lanz & Provins, 2012). This research will attempt to extend existing DCE and environmental valuation research to determine the impact that a heterogeneous status quo has on WTP for improved environmental performance in the salmon aquaculture industry.

Chapter 4: Methodology

This chapter provides an overview of the methodologies applied in this study. The topics discussed include selecting an environmental valuation method, survey and DCE development, focus group testing of the survey, and data collection and subsequent analysis.

4.1 Identification of the Appropriate Study Method

While a DCE was ultimately selected as the method of environmental valuation to assess the BC public's WTP for improvements to the environmental conditions around salmon farms, first a number of different methods were reviewed to determine their suitability. The following section provides justification for the use of a DCE for the purposes of this study.

4.1.1 Choice of Stated vs. Revealed Preference Approach

As discussed in Section 3.2, three broad-based approaches are used in ascertaining environmental values; stated-preference, revealed preference and production-function approaches. Stated-preference approaches, which include contingent valuation and discrete choice experiments, survey the public regarding their willingness to pay, or willingness to accept compensation, for a change to an environmental good or service (Champ *et al.*, 2003, 101-102). Conversely, revealed preference methods, which include travel cost method and hedonic pricing method, ascertain environmental values from the behavior in markets for related goods (Champ *et al.*, 2003, 259). Production function approaches value the environment as an input to economic production. They examine the effect that an environmental change would have on consumer and producer surplus for a certain product or service (Barbier, 1994).

One of the weaknesses of revealed preference and production function approaches is their inability to measure non-use value. Non-use value is the value derived from an environmental good or service that is unrelated to a person's direct or indirect use of that good or service. Stated-preference approaches have been designed to capture both use and non-use values (Hanley *et al.,* 2001; Carson, 2011, 8-9).

A large proportion of British Columbia's coast is very remote and, given that the majority of British Columbians live in urban areas, it was hypothesized (then confirmed by the results of this study) that the majority of residents have little to no interaction with the coastal environment around salmon farms. There are likely indirect use values derived from a healthy coastal environment, but those may not be well known or understood by the general public. Therefore, only stated-preference methods would be appropriate in this particular context, since revealed preference or production function approaches could lead to an underestimate of the total economic value of a change to the coastal environment by ignoring existence or non-use benefits (Krutilla, 1967).

4.1.2 Contingent Valuation Method VS Choice Experiments

CVM could have been used if a change in only one particular environmental attribute, or a specific change in multiple attributes at the same time, was being valued. This was demonstrated by Atkins *et al.* (2007), who examined the non-use benefits of reduced coastal eutrophication caused by agricultural practices exclusively. However, given the multi-dimensional and complex nature of the environmental and economic effects of salmon farming, and the possibility of tradeoffs between them, CVM could potentially oversimplify the issue (Hanley *et al.*, 2001). It would require that the valuation be limited to one particular attribute, or that all attributes be valued together as one package. CVM was used by Martínez-Espiñeira *et al.* (2012), who exclusively valued the bio-mitigation benefits of IMTA, omitting analysis of any other environmental changes. However, this study aimed to examine multiple environmental impacts that could be affected by a change in salmon farming production technology, and determine the relative WTP to reduce these impacts. Therefore, in order to capture both use and non-use values, and value changes to multiple environmental attributes, a DCE was chosen as the preferred method for this valuation study.

4.2 Discrete Choice Experiment (DCE)

The methodology used for developing a DCE is largely based on guidance from Hanley *et al.* (1998), Hanley *et al.* (2001), Champ *et al.* (2003), and Hensher *et al.* (2005). Major challenges in developing this DCE included developing an understandable choice scenario given the scientifically complex and controversial nature of the environmental impacts of salmon farming, as well as the lack of a widely-accepted status quo based on the current environmental conditions to use within the DCE.

4.2.1 Theoretical Basis for DCEs

Choice experiments apply both the Characteristics Theory of Value (Lancaster, 1966; Hanley et al., 1998), and Random Utility Theory (Hanley *et al*.,1998). While DCEs were not developed until 1982, their theoretical basis is the Characteristics Theory of Value (Lancaster, 1966; Hanley et al., 1998; Carson, 2011). This theory states that the value or utility of any good consists of the utility of characteristics or attributes that make up the good, and the levels that these attributes take (Lancaster, 1966; Hanley et al., 1998). This theory has since been extended to include both market and non-market environmental goods and services.

Random Utility Theory is used to describe how individuals derive utility from consuming a good. Like Characteristics Theory of Value, Random Utility Theory can be extended to both market and non-market goods. Random Utility Theory states that the utility derived from consuming a particular good is made up of both a deterministic element (V) based on the attributes of that good, as well as a random, unobservable element ($\mathcal{E}$) (Hanley *et al*.,1998; Adamowicz *et al.*, 1998) . Therefore, the utility (U) to an individual i for a particular choice alternative j can be determined as follows (Adamowicz *et al.*, 1998):

$$U_{ij} = V_{ij} + \varepsilon_{ij} \qquad (1)$$

While utility can not be measured in accurate terms, due to unobservable element Ɛ, the probability that an individual will choose alternative j over alternative k can be estimated based on the assumption that an individual will choose alternative j over alternative k as long as Ui_j is greater than Ui_k (if $j \neq k$). In a DCE, when an individual respondent is faced with choice scenario C, the probability that the individual i will select alternative j is as follows (Adamowicz *et al.*, 1998):

$$Prob\,\{j\ is\ chosen\} = Prob\left\{V_{ij} + \varepsilon_{ij} \geq V_{ik} + \varepsilon_{ik}\ ;\ for\ all\ k \in C\right\} \qquad (2)$$

If one assumes that Ɛ are independently and identically distributed across individuals with a Type 1 extreme value distribution, a scale parameter that equals 1 and independence between choice scenarios for each individual, the probability of choosing alternative *j* over *k* can be modelled using the following formula (Adamowicz *et al.*, 1998):

$$Prob\ \{j\ is\ chosen\} = e^{v_{ij}} / \sum_k e^{v_{ik}}\ ; for\ all\ k\ \epsilon\ C \qquad (3)$$

This means that the probability that an individual will choose *j* is equal to the exponent of the deterministic element of utility (V_{ij}) based on the attributes of good *j* divided by the sum of the exponent of the deterministic elements of utility for the other options in a given choice set (V_{ik}). As established in the Characteristics Theory of Value, the utility of a good is made up of the sum of the individual utilities of each attribute of the good. The deterministic component of utility can be derived from the attributes of the good in question, and the levels that those attributes take (Adamowicz et al., 1998). Once parameter estimates have been obtained, a WTP compensating variation measure of welfare can be obtained (Hoyos, 2010)

4.2.2 Developing the Hypothetical Market

In order to value improvements to the environmental conditions surrounding salmon farms in BC, a hypothetical market scenario was developed in which respondents to the survey could realistically be expected to pay for such improvements (Champ et al., 2003, 129-130). One common scenario used in environmental valuation is one in which respondents are presented with a potential policy or program that would necessitate a tax increase or other payment type (Loomis, 2000; Hanley *et al.*, 2001). In this survey, respondents were first presented with basic information about salmon farming and its environmental effects. After receiving this information, respondents were presented the following scenario (Figure 2):

Figure 2: Hypothetical Market Scenario Presented to Survey Respondents

> **"The potential environmental impacts of salmon farming could be reduced if the B.C. government implemented a program that provided financial incentives for salmon farmers to develop and adopt environmentally friendly technologies. The eventual impact of such a program would depend on the number of companies that participate in the program and the types of technologies they adopt. However, without such a program environmental conditions may deteriorate.**
>
> **In the following exercise, you will be presented with potential outcomes of such a program in terms of employment, marine habitat quality, likelihood of disease/parasite transfer, and coastal aesthetic quality in 10 years. *The program would be funded by additional annual taxes paid by each household in B.C.***
>
> **Please select the program that you would be most likely to support"**

There is some precedent in British Columbia for using government-funded subsidies to encourage green technology adoption by both companies and consumers. This has included provincial funds subsidizing electric vehicle purchases and retrofitting buildings to improve energy efficiency (LiveSmart BC, 2014). Therefore, it was expected that respondents in British Columbia would be somewhat familiar with the idea of government-funded subsidies such as the one presented in Figure 2.

4.2.3 Selection of Attributes and Levels

Based on the above possible future scenario, DCE attributes were selected to represent the environmental and economic outcomes of a government program aimed at promoting the use of alternative aquaculture technologies. It was decided early on that the attributes would not focus on the environmental performance of different aquaculture technologies. Instead, the environmental attributes should represent different states of the environment, since improving the environmental performance of salmon aquaculture would be valued largely due to its effect on the environmental conditions surrounding salmon farms.

Attributes were identified and selected based on a review of existing literature on the environmental impacts of conventional net-pen salmon farming and alternative aquaculture technologies (see Section 2.2). They were further refined based on feedback from three focus groups. Choice sets must include all attributes relevant to the decision being made by the respondent in order to minimize random error. However, if too many attributes are included, the cognitive burden on respondents can also increase respondent errors (Swait & Adamowicz, 2001). Therefore, only the most significant potential environmental impacts of salmon farming were included in this analysis.

The first step was to identify the potential environmental impacts of salmon farming and determine which of these potential impacts should be considered in developing attributes. It was decided that the environmental attributes chosen should a) be supported by scientific literature and b) be sensitive to a change in technology. For example, one potential impact considered was farmed salmon escapes. However, there is no scientific literature that has demonstrated this to be an issue in British Columbia. Another potential impact is the use of wild fish for feed. However, this issue is not strongly impacted by the type of aquaculture technology used. For this reason, neither of these potential impacts was ultimately included.

The potential environmental attributes that were considered for inclusion in the DCE are described in in Table 1. Those that were included are discussed in more detail below.

Table 1: Environmental Attributes Considered for the DCE

Potential Environmental Impact of Salmon Farming	Related Environmental Condition	Included/ Excluded	Reason for Exclusion
Disease/parasite incubation	Disease/parasite risk for wild species	Included	NA
Farmed Salmon Escapes	Health/biological productivity of wild species	Excluded	Scientific research has not demonstrated this to be a serious issue in the Pacific Northwest
Chemical Usage	Marine Habitat Quality	Included	NA
Release of organic wastes	Marine Habitat Quality	Included	NA
Use of wild fish in feed	Wild fish populations	Excluded	Not majorly affected by a change in technology
Creation of view/noise/smell issues	Aesthetic Quality	Included	NA
Marine mammal interactions	Marine mammal populations	Excluded	Scientific research has not demonstrated this to be a serious issue in the Pacific Northwest

In order to ensure that the survey was balanced and included important tradeoffs, economic attributes of the program were considered as well. Economic attributes served two purposes: as a potential tradeoff for environmental attributes, and as a payment vehicle for the DCE. The finalized attributes included in the study are described below. For a full list of attributes and levels used in the DCE, as well as the definitions provided to respondents, see Table 2.

- **Disease/Parasite Risk:** This attribute presents the likelihood that diseases or parasites (e.g. sea lice) will be transferred between farmed and wild species in BC. Concerns over effects to wild salmon from sea lice have been highly publicized in British Columbia in the last decade (Morton et al., 2004; Noakes, 2011; Dill, 2011).
- **Marine Habitat Quality:** This attribute presents the impact of organic wastes from food and fecal matter, as well as agro-chemicals on the marine habitat surrounding the province's salmon farms.

- **Aesthetic Quality:** The presence of obstructed views and issues with noise, smell and marine debris in coastal regions where salmon farms are present. Aesthetic quality has been identified as a major issue for people who live and engage in recreation in areas that have a high density of aquaculture operations (D'Anna, 2013).
- **Employment in Salmon Farming:** Previous studies have indicated that one of the key benefits of aquaculture is job creation. There are approximately 1500 direct, FTE jobs in salmon aquaculture in the province (Legislative Assembly of BC, 2007). While the total number of jobs created by aquaculture is small, these jobs are often located in small, coastal communities where there are declining rates of employment. It was included to determine whether the number of jobs would be an important factor in respondents' choice of program.
- **Annual Tax Increase:** The amount that each household in BC will pay in additional taxes each year for the next 10 years to support research and development of alternative aquaculture systems. Taxes are a commonly used payment vehicle for non-market valuation (Champ et al., 2003, 129-130).

Table 2: Definitions of Final Attributes and Levels Used in the DCE

Attribute	Levels[5]
Parasite and Disease Transfer - The likelihood that diseases or parasites (e.g. sea lice) will be transferred between farmed and wild species in BC	**No Risk** - No likelihood of parasite or disease transfer between farmed and wild species **Low Risk** - Low likelihood of parasite and disease transfer between farmed and wild species **Moderate Risk** - Some likelihood of parasite and disease transfer between farmed and wild species **High Risk** - Significant likelihood of parasite and disease transfer between farmed and wild species
Marine Habitat Quality - The impact of organic waste and agro-chemicals on the marine habitat surrounding the province's salmon farms.	**Very Good Quality** – Negligible impacts from organic wastes and agro-chemicals at all farm sites **Good Quality** - Minimal impacts to marine habitat from organic wastes and agro-chemicals at less than 25% of active farm sites **Fair Quality** - Minimal to moderate impacts on marine habitat from organic wastes and agro-chemicals at 25-50% of active farm sites **Poor Quality** - Moderate impacts on marine habitat from organic wastes and agro-chemicals at 50-75% of active farm sites
Coastal Aesthetic Quality - The presence of obstructed views and issues with noise, smell and marine debris in coastal regions where salmon farms are present.	**Very Good Quality** - Views are unobstructed, and there are no issues with noise, smell or marine debris. **Good Quality** – Views are minimally obstructed, and there are minor issues with noise, smell and marine debris **Fair** Quality - Views are somewhat obstructed, and there are occasional issues with noise, smell and marine debris **Poor** Quality - Views are highly obstructed.

[5] Note that the lowest level for the three environmental variables only appeared in the status quo option.

	Regular issues with noise, smell and marine debris
Employment in Salmon Farming - The total number of people directly employed in the coastal salmon farming industry in BC	0, 500, 1000, 1500, 2000, 2500
Additional annual taxes per household - The amount that each household in BC would pay in additional taxes each year for the next 10 years to support the program.	$5, $10 $20 $40 $60 $80

4.2.4 Choice of Experimental Design

Once attributes were established, they were combined into choice sets to be presented to respondents following statistical design theory (Hanley et al., 2001). A complete factorial design is one that uses all possible combinations of attributes and levels. However, this often leads to an impractically large number of potential combinations. Fractional factorial designs reduce the number of combinations while maintaining orthogonality, though some estimating power is lost when compared to complete factorial designs (Hanley et al., 2001). A design was produced using SAS software consisting of 72 possible choice sets and a d-efficiency of 91.0494 (Kuhfeld, 2010). Instead of using blocking, randomization tables were used to produce random, non-repeating combinations of choice sets to be produced.

4.2.5 Status Quo Treatment

A status quo was included as an alternative in each choice set. The status quo alternative represented an opportunity to ‘opt out’ or ‘do nothing’, in contrast to the other two alternatives which represented a change in policy. As stated by Champ et al. (2003, 186), “we believe that choice scenarios should include opt-out options because in most real world choice situations, individuals are not in a situation of ‘forced choice’ and they have the option to choose not to choose.” The utility of this status quo option is estimated by the coefficient for the alternative specific constant (ASC; Boxall *et al.,* 2009). It became apparent through focus group testing of the survey that respondents weren’t satisfied with a simple ‘opt out’ option, since they wanted to know what the conditions would be if they chose the status quo option. However, as mentioned in Section 3.5, it can be difficult to establish a ‘status quo’ option for DCEs in situations that lack undisputed, objective data on which it can be based. Given the lack of scientific consensus on the extent and severity of the environmental impacts of salmon farming in the province, it was difficult to determine a single status quo that could accurately reflect the current conditions. Furthermore, there is limited research that addresses the issue of choice under uncertain status quo conditions in DCEs. This study attempted to determine how WTP is affected by differing future 'status quos', and how a change in status quo could affect the outcomes of a DCE. Two different status quos were used. The sample was split in two, with each sub-sample of respondents seeing one status quo throughout the DCE’s six choice sets. While the economic attributes remained the same in both status quos (set at CDN $0 annual tax increase per household and 1500 FTE employees), the environmental attributes differed between status quos. Half the respondents evaluated the ‘worst-case-scenario’ (WCS) status quo, which had all environmental attributes set to the worst possible level. The other half evaluated what was referred to as the ‘medium-case-scenario’ (MCS), which had all environmental attributes set to a level one better than the worst possible level (see Table 3). In order to ascertain whether there was a significant difference in preferences between the two models, the data from both DCEs was combined and run as a single known class model, with the status quo treatment representing the ‘known classes’. The results of this analysis are reported in Section 5.7.3.

Table 3: Status Quo Attribute Levels Shown to Respondents in DCE

Attribute	‘Medium-Case-Scenario’ Status Quo	‘Worst-Case-Scenario’ Status Quo
Employment	1500	1500
Disease and Parasite Transfer Risk	Moderate Risk	High Risk
Marine Habitat Quality	Fair Quality	Poor Quality
Aesthetic Quality	Fair Quality	Poor Quality
Annual Tax Increase per Household	$0	$0

4.2.6 Information Treatment

Information treatments can be used in stated-preference valuation studies to determine what effect, if any, the type and amount of information provided to respondents will have on respondent WTP (Champ et al., 2003, 124-126). It was hypothesized that respondents' choices could be influenced by the amount of information they had on future environmental conditions. Respondents may be more likely to be precautionary and conservative with their choices in situations where the information provided is limited. For example, respondents may be less willing to face 'moderate risk' of parasite and disease transfer between farmed and wild salmon if they do not have a complete understanding of what a moderate versus low risk entails. To test this hypothesis, the sample was split in two. All respondents were provided with definitions of each attribute, to ensure a full understanding of each scenario. However, only half of the sample was provided with an explanation of the different levels within each environmental attribute. The results were analyzed to determine what effect, if any, such an information treatment would have on respondent choice.

4.3 Survey Design

The survey instrument was designed to set up and effectively administer the choice experiment and to elicit further information from respondents. Non-DCE questions served two purposes. They improved the analysis of the DCE by providing information about respondents that could be used as covariates in modelling exercises (see Section 5.7.2.1). They also served to answer our third research question, how does the public perceive salmon aquaculture in the province and how supportive are they of different technologies and policies related to salmon aquaculture? Certain questions, specifically those pertaining to demographics, salmon consumption and salmon farming technology, were taken with permission directly from Winnie Yip's 2012 survey of farmed salmon consumers in major West Coast markets in order to allow for future comparison studies to be conducted (Yip, 2012). The survey consisted of eight sections, which are detailed in Table 4. The full survey can be found in Appendix 1.

Table 4: Description of Sections of the Survey

Survey Section	Number of Questions	Purpose of Section
Relationship to the Marine Environment	5	• Introduce respondents to the survey • Determine whether respondents engage/interact with the marine environment
Prior Knowledge of Salmon Farming	6	• Determine whether respondents had prior knowledge or preconceived notions of salmon farming • Assess salmon consumption behavior • Provide a brief introduction to the salmon farming industry in British Columbia
Salmon Farming and the Environment	4	• Introduce respondents to the potential environmental impacts of net-pen salmon farming • Determine whether respondents had prior knowledge or preconceived notions about the environmental impacts of salmon farming
Choice Experiment	6	• To elicit WTP for improvements in the environmental performance of salmon aquaculture • To determine how this WTP is affected by differing future status quos
Salmon Farming Policy	6	• To determine whether respondents would support various policy instruments that could be used to improve the environmental performance of salmon aquaculture
Salmon Farming Technology	6	• To introduce closed-containment and integrated multi-trophic aquaculture technologies • To assess respondents' opinions and preferences for alternative aquaculture technologies
Demographics/ Environmental Views	13	• To gain an understanding of the demographic profile of respondents for future comparisons with the BC population • To determine whether respondents' environmental views impacted their DCE choices.

Following the initial stages of survey design, a series of focus groups were conducted to ensure adequate survey comprehension, develop attributes more fully, and have focus group respondents indicate whether they had any issues with content or bias. Participants for focus groups were recruited through the online marketing research company Research Now. Research Now provided a list of potential participants from the Metro Vancouver Area who had indicated that they were interested in participating in a focus group at the specified date and time. From the list provided, participants were selected at random, and contacted with focus group details. For their time and effort, each participant was paid CDN $50.00.These focus groups were conducted on July 8th, July 24th and August 22nd 2013. All focus groups were located in Vancouver, due to budgetary constraints.

Respondents began the focus group by completing a paper copy of the draft survey. They were then asked specific questions to elicit feedback on different components of the survey. Participant feedback at each focus group was taken in to account, and survey components were changed accordingly. Many minor changes in content and wording were made as a result of focus group feedback. Major changes that resulted from feedback from the three focus groups included:

- Inclusion of a status quo. It became clear from the first focus group that survey respondents were uncomfortable making a choice without knowing what the future ‘status quo’ conditions would be.
- Refinement of the hypothetical market. Initially, the hypothetical market did not specify what type of government program would be implemented. However, it was clear that the type of program was an important component of choice. Ultimately, a subsidy program was chosen to provide more specificity (See Figure 2).

4.4 Sampling Strategy and Data Collection

The survey was designed to be completed by residents of British Columbia. While previous online surveys pertaining to salmon aquaculture have sampled across Canada (Martínez-Espiñeira *et al.*, 2012, 2015), British Columbians were chosen due to the high volume of farmed salmon produced in BC, and the controversial nature of the salmon farming industry in the province. It was decided that the coastal areas outside of Metro Vancouver should be oversampled, in order to ensure that enough respondents came from the areas where salmon farming is most prevalent. The sampling strategy also targeted an even split of male and female respondents, and an age range representative of the current BC population, based on data from BC Stats and Statistics Canada. Demographic data from the sample was then compared to population data to assess representativeness (see Table 6). Geographic areas were designated based on forward sorting areas. The targeted geographic breakdown of our sample was as follows (Table 5):

Table 5: Targeted Geographic Area Breakdown of Sample

Geographic Area	Target Sample Proportion
Metro Vancouver Area	50%
Victoria	10%
Coastal BC (excluding Vancouver and Victoria)	25%
Interior BC	15%

The online survey was designed and developed using Adobe Dreamweaver (Version 11, CS5) software. The back-end survey programming was completed by Paulus Mau, who was also responsible for hosting the survey at the domain <https://remsurvey.rem.sfu.ca/>. Participants to the survey were recruited using the market research firm Research Now. Research Now recruits survey respondents using a rewards-based system. Potential survey respondents sign up with Research Now, and provide them with demographic, attitudinal information, as well as information on their consumer behavior. Based on this information, Research Now is able to recruit respondents to fill out online surveys and questionnaires, based on demographic or other requirements. In return for participating in online surveys, respondents receive rewards points from Research Now. These rewards points can then be redeemed for various goods and services (Research Now, 2015).

Two pre-tests were conducted to ensure that the technical aspects of the survey were working properly, and to ensure that the initial results didn’t indicate any major issues with particular questions. As discussed above, the survey targeted respondents who were residents of British Columbia. Therefore, respondents were screened out immediately if they did not identify themselves as BC residents. The final survey was fielded between January 17th and March 10th 2014.

4.5 Data Analysis

Data analysis was conducted using the statistical analysis software Latent Gold for choice modelling and IBM SPSS software (Version 22) for analysis of non-DCE questions. DCE analysis was conducted with assistance from Ryan Trenholm[6].

4.5.1 Principal Component Analysis

Principal component analysis (PCA) was used to transform a set of potentially correlated variables in to a smaller set of linear, orthogonal (uncorrelated) values. According to Jolliffe (2002), PCA can reduce dimensionality of data, but maintain its variation, in cases where there are a large number of variables that may be interrelated in some way. Using the PCA function in SPSS (Version 22), highly correlated variables related to respondent characterization were reduced to a single variable. Eigenvalues, which measure the amount of variation explained by each principal component, were used to assess whether a particular principal component should be included in the DCE (Boxall & Adamowicz, 2002). If an eigenvalue is above 1, it means that it is able to account for more variance than the original variables (Jolliffe, 2002). Several variables were reduced to three principal components that were included as covariates in the DCE.

4.5.2 Multinomial Logit Model - Use and Limitations

A multinomial logit (MNL) model was used to estimate part-worth utilities using Latent Gold statistical software package. The theoretical basis for MNL models is discussed in Section 4.2.1. MNL models are advantageous due to their relative simplicity, the ability to develop ‘good’ models based on goodness-of-fit tests, and prediction accuracy given large sample sizes (Louviere, Hensher and Swait, 2000). However, these models are based on a large number of assumptions that can reduce the accuracy of the results. Assumptions include error terms that are independently and identically distributed across individuals with a Type I extreme value distribution, a scale

[6] Ryan Trenholm provided significant advice and guidance in analyzing the results of the discrete choice experiment, including the Multinomial Logit and Latent Class models, and developed the compensating variation estimates. He also produced the experimental design used for the DCE.

parameter that is normalized to 1, and independence among choice scenarios for each individual (referred to as independence of irrelevant alternatives or IIA[7]). It also assumes that respondent's preferences are homogenous (McFadden, 1986; Louviere, Hensher and Swait, 2000).

4.5.3 Latent Class Analysis

To address the somewhat limiting assumptions of homogenous preferences and IIA, a latent class model was also calibrated[8]. While a number of models have been developed that incorporate heterogeneity via *a priori* characteristics of the respondents, such as socio-demographic variables, latent class models sorts and separates respondents into discrete groupings based on their choices during the DCE (Boxall & Adamowicz, 2002). Latent class models are based on the theory that the probability of an individual *i* choosing choice alternative *j* is a function of two components: the probability that an individual will belong to latent class *x*; and the probability that an individual will choose a certain alternative, given that he or she is a member of a certain class:

$$P_{ij} = (P_{ix})(P_{ij|x}) \tag{4}$$

If the assumptions for the MNL model discussed above hold, this equation can be expanded as follows (Boxall & Adamowicz, 2002; Yip, 2012):

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[7] IIA is the assumption that the introduction of additional alternatives in to a choice set would not affect the probabilities of choosing the original alternatives within the choice set. This is considered to be a somewhat unrealistic and therefore limiting assumption of MNL models (Luce, 1959; McFadden, 1986). There are statistical tests that can be conducted to test for IIA, however these tests were not conducted during data analysis. If these tests demonstrate that IIA is violated, a Multinomial Probit model can be used (McFadden, 1986). Alternatively, the MNL model can be used, but without the assumption that the scale parameter is equal to 1 (McFadden, 1986). The IIA assumption may be a limitation to this research, and further tests to determine its validity should be conducted.

[8] While a latent class model was used to address the assumptions of homogeneity and IIA, there are additional model specifications that could have been used as well. Mixed logit models, including random parameters logit models allow for model parameters to vary randomly across individuals. However, while accounting for heterogeneity, these model specifications are limited in their ability to explain the sources of heterogeneity (Greene & Hensher, 2003; Shen, 2009).

$$P_{ij} = \sum_{x=1}^{x} \left[\frac{e^{\alpha_x S_i}}{\sum_{x=1}^{x} e^{\alpha_x S_i}}\right] \left[\frac{e^{\beta_x Z_j}}{\sum_{a \in C} e^{\beta_x Z_a}}\right] \quad (5)$$

Where α_x is the estimated coefficient associated with the effects of specific characteristics (*S*) specific to the latent class *x*. β_x is the estimated coefficient for class *x* for alternative *j*. *Z*, in the case of this study, represents characteristics of the environmental good, in this case the specific attributes associated with each alternative *a* in choice set *C*. The probability of an individual *i* choosing alternative *j* is a function of a) the probability that one particular individual would be would be observed in latent class *x*, given certain socio-demographic or attitudinal characteristics and b) the probability that an individual will choose option *j*, given that they are a member of latent class *x* (Boxall & Adamowicz, 2002).

Once placed in distinct groups based on their innate preferences, respondents can then be characterized based on their *a priori* characteristics, which incorporates heterogeneity and increases the amount of information that can be derived from a MNL model (Boxall & Adamowicz, 2002). Different part-worth utilities can then be derived for each latent class (see Section 5.7.2).

4.5.4 Environmental Valuation (Estimating WTP)

Using the part-worth utilities produced by the two MNL models, willingness to pay parameters can be estimated. This section discusses two measures of WTP: compensating variation and implicit prices

According to Hanley, Mourato and Wright (2001), parameter estimates from an MNL model can be used to calculate a WTP compensating variation measure that will conform to demand theory. WTP estimates derived from DCEs can be obtained using the following formula (Hoyos, 2010):

$$CS = \frac{1}{\mu} \left[\ln\left(\sum exp(\beta Y^0\right) - \ln\left(\sum exp(\beta Y^1\right)\right] \quad (6)$$

In this formula, μ equals the marginal utility of income (coefficient of the payment attribute), β is the coefficient of an environmental attribute, and Y^0 and Y^1 represent vector of attribute levels at the intial status quo level and following a change in levels, respectively. According to Hoyos (2010, 1598), "compensating variation measures a change in the level of provision in the attribute or attributes by weighting this change by the marginal utility of income." In other words, the compensating variation measures the amount of income that must be taken away from a consumer at the new attribute levels so that they are as well off as they were at the old attribute levels.

This equation was used to develop a 'decision-support tool' that can be used to forecast preferences under different policies or management scenarios (Semeniuk *et al.*, 2009). In this case, it was used to estimate WTP for an improvement in conditions from the status quo, represented by the estimated parameter coefficient of the ASC (Boxall *et al.,* 2009). This tool allowed for monetary values to be derived from a change in the levels of multiple attributes at the same time by finding the difference between respondents' measurement of utility under the status quo (which was negative), and then new measurement of utility under a change in multiple attribute levels away from the status quo.

Implicit prices are estimates of the respondents' WTP for a discrete improvement in one attribute level within the model. For example, respondent WTP for an improvement in marine habitat quality from 'good' to 'very good', holding all other attribute levels constant can be estimated using the following formula:

$$Mean\,WTP = \frac{-(\beta q1 - \beta q0)}{\mu} \qquad (7)$$

This formula takes the ratio between the negative of the difference between the estimated parameter coefficients (β_n) for different levels of attribute *q* (in this case marine habitat quality) to the parameter coefficient of the price attribute μ (used to measure marginal utility of income). This provides the 'implicit price' for the improvement. However, implicit prices do not account for WTP for a move away from the status quo.

Chapter 5: Results

This chapter provides a summary of the results of the online survey (see Appendix 1 for full survey). It concludes with results of the DCE, and the estimated willingness to pay for improvements in the environmental conditions around salmon farms in British Columbia.

5.1 Sample Characteristics

In total, 3,602 respondents opened the survey during the two sampling phases (pre-test and final phase).[9] This analysis uses only data from the final phase to avoid any possible discrepancies between the two phases. A total of 3,281 respondents opened the survey during the final phase, with 2,462 respondents it. This represents a completion rate of 75.0%. Of those who did not complete the survey, 53.6% dropped out within the first five pages. The rest dropped out in small numbers throughout the remainder of the survey, though a significant number (10.7%) dropped out during the discrete choice experiment. A respondent's record was considered to be invalid if the respondent did not live in British Columbia, if the survey was completed in less than 6 minutes or more than an hour, or if suspicious choice behavior was detected in their discrete choice experiment answers. Suspicious choice behavior meant that a respondent chose the same option either 5 or 6 times out of 6 choice sets.[10] After removing these invalid responses, 1653 respondents left that were left for use in analysis[11].

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[9]From November 19th to November 27th 2013, a pre-test of the survey was conducted. A total of 321 respondents opened the survey, with 256 completing it. Following the pre-test, some minor changes and question additions were made. The final survey was implemented between January 20th and March 9th 2014, when 1,653 complete, valid responses were collected.

[10] It was determined during the pre-test that the average survey response time was 12 minutes. A cut-off completion time of 6 minutes was to ensure that respondents were completing the survey diligently.

[11] Of the respondents who completed the final survey (n = 2,462), 754 respondents were removed due to suspicious answers during the choice experiment (5 out of 6 responses were the same, or 6 out of 6 responses were the same), and responses from respondents were removed who completed the survey in under 6 minutes or over an hour.

These respondents were divided between three different survey versions. Version 1, which presented the 'middle-case-scenario' status quo, had 644 valid, completed responses. Version 2a, which presented the WCS status quo, had 676 valid, completed responses. Version 2b, which presented the WCS status quo with alternate wording of attribute levels and sampled only from the Lower Mainland, had 332 completed, valid responses. This analysis will focus only on the sample that participated in version 1 or 2a (referred to hereafter as version 2), for a total of 1321 responses that will be analyzed in this chapter.

5.1.1 Socio-Demographics

As mentioned in Section 4.4, the survey sample was meant to be as demographically representative of the general population of BC as possible. Therefore, the socio-demographic data collected in this survey is meant to assess the representativeness of the sample as compared to the general population of BC. Aside from a requirement that respondents reside in British Columbia, no additional filters were applied to the sample. Socio-demographic information is compared to statistics collected by BC Stats and/or Statistics Canada (see Table 6), unless otherwise noted. Some notable differences between the survey sample and the BC population were detected in the results. For example, the survey had a higher proportion of female respondents than is found in the general population (61.7% versus 50.4%). Overall survey respondents were older than the general population, with 19-24 year olds being underrepresented (1.7% versus 9.0%), and 45-54 year olds being overrepresented (31.1% versus 19.3%) in the survey sample. The survey sample was also more educated than the population of British Columbia, with a much smaller proportion of respondents not having any post-secondary education (15.0% versus 48%). Average income level in the sample was similar to that of the BC population, both falling within the CDN $75,000 to $99,999 range.

Table 6: Demographic Characteristics of Sample in Comparison to Data from BC Stats

Demographic Categories	Total Sample % Frequency	BC Stats Data
Gender		
Male	37.1%	49.6%
Female	61.7%	50.4%
No Response	1.3%	NA
Age		
19-24	1.7%	9.2%
25-34	16.1%	17.3%
35-44	17.4%	20.4%
45-54	31.1%	20.4%
55-64	17.0%	14.7%
65+	16.9%	17.9%
No Response	0.7%	
Educational Attainment[12]		
Elementary School	0.2%	20%
High School	14.8%	28%
Some Post-Secondary	16.0%	5%
College Diploma	29.6%	28%
Bachelors Degree	26.4%	12%
Graduate/Professional Degree	12.6%	8%
No Response	0.3%	NA
Region of Residence		
Lower Mainland/Southwest	50.0%	61%
Vancouver Island/Central Coast	30.0%	17.8%
North Coast	1.9%	1.3%

[12] The provincial data for educational attainment is adapted from the Research Universities Council of British Columbia's BC Labour Market Profile (January 2013)

Kootenay	2.4%		3.4%
Thompson-Okanagan	11.2%		12%
Caribou	3.1%		3.5%
Northeast	1.2%		0.9%
Nechako	0.2%		1.5%
Income Level			
Less than $24,999	Average/median income of sample = $75,000-$99,999	7.3%	Median after-tax family income in BC = $67,915 Average after-tax family income = $78,580
$25,000-$34,999		9.7%	
$35,000-$49,999		14.4%	
$50,000-$74,999		22.0%	
$75,000-$99,999		21.5%	
$100,000-$149,999		18.7%	
$150,000-$199,999		4.3%	
$200,000 plus		2.2%	
Average Household Size			
	Mean=2.45 SD=1.29 NA		2.5

Survey participants were purposely oversampled in non-Lower Mainland coastal areas, and therefore there is a smaller proportion Lower-Mainland residents in the sample than in the British Columbia population (50% vs 61%), and a higher proportion of Vancouver Island residents (30% vs. 17.8%). Other regions are proportionally represented in the sample within two percentage points of the British Columbia population.

Demographic differences can largely be explained by the method chosen for survey participant recruitment. Research Now tends to attract older, more affluent survey participants (Research Now, personal communications, January 2014). Research Now survey respondents need to have regular access to a computer and internet service, which likely results in a slight bias the sample towards more affluent participants. This survey may also have been more interesting or appealing to salmon consumers, who have been shown to have higher incomes than non-salmon consumers (Yip, 2012).

Given that the sample was not perfectly aligned with the demographic characteristics of BC residents, the results of the survey and DCE may not be entirely representative either. For example, given the higher income levels and higher proportion of coastal residents in the sample, it is likely that the results provide a slight overestimation of WTP for improvements in the environmental performance of salmon aquaculture.

5.1.2 Connection to the British Columbia Coast

It was hypothesized that those respondents who spent more time working or recreating in coastal areas of British Columbia, or who felt a strong mental or emotional connection to the British Columbia coast, would be willing to pay more to improve environmental conditions around salmon farming operations.

Respondents who identified themselves as residents of one of the coastal regions (Lower-Mainland Southwest, Vancouver Island/Central Coast or North Coast) were asked whether they considered themselves to be residents of the coastal region of British Columbia. This particular question was asked for two reasons: Given that coastal regions are geographically large, it is likely that some portion of people who live in these coastal regions are actually located quite far inland. Furthermore, those who live close to the coastline but cannot or choose not to access it on a regular basis may not identify themselves as living on the coast. Out of the 1078 respondents who live in coastal regions, 89.4% self-identified as coastal residents (see Table 7).

Table 7: Inhabitants of Coastal Regions who Self-Identify as Residents of the BC Coast

Response	Frequency	N
Yes	89.4%	964
No	5.2%	56
I Don't Know	5.4%	58
Total	100.00	1078

Respondents were also asked whether they had recently spent time on the coast of British Columbia for work or pleasure, and in which activities or industries they had participated in. Approximately one quarter of respondents spent more than 100 days on the Pacific Coast, either on the water or within 100 metres of the shoreline, which may be due to the large proportion of respondents who live in coastal areas, and therefore can easily access coastal areas with relatively low cost and/or effort. A large majority of respondents (76.6%) had engaged in some form of coastal recreation, with the most common activities being land-based coastal recreation, sightseeing and swimming. A small proportion (6.5%) identified as having worked in a marine-related employment sector. However, according to a 2007 report released by the provincial government on the economic contribution of the oceans sector, only 1% of British Columbians were directly employed in a marine-based job (Ocean Coordinating Committee, 2007)[13]. The higher proportion of respondents who had been employed in a marine-related industry may be attributable to the higher proportion of coastal residents that participated in the survey. For detailed results related to respondent's use of and connection to the BC coast, see Appendix 4.

5.1.3 Environmental Ethic

Respondents were asked a series of questions about their environmental values, opinions and beliefs. It was hypothesized that respondents who aligned themselves more strongly with environmentalism and sustainability, or who were active in the environmental movement, would be more likely to support improving the sustainability of the salmon farming industry. Very few respondents were found to actively participate in organized environmental activities (see Table 8). The vast majority of respondents (92.7%) were not members of or donors to environmental organizations or groups. Most respondents (89.6%) had not attended an environment-related meeting, lecture or protect in the preceding two years.

[13] This report included the following industries in the oceans sector: seafood, ship and boat building, ocean construction, ocean high tech, ocean recreation, ocean transport, federal and provincial government, research and environmental non-governmental organizations.

Table 8: Respondents' Participation in Environmental Groups/Activities

Response	Member/donor to an Environmental Group	Attendee of an Environmental Lecture/Meeting/Protest
Yes	4.8%	8.2%
No	92.7%	89.6%
I don't know	2.0%	1.5%
No response	0.5%	0.8%

Respondents were also asked their level of agreement with certain statements related to their environmental worldview. These statements were adapted from the revised New Ecological Paradigm (NEP) questionnaire (Dunlap *et al.*, 2000), originally developed in 1978 and revised in 2000 as a measure of a person's environmental beliefs or worldview. The NEP scale consists of fifteen statements about the relationship between humans and the environment. Respondents to the NEP questionnaire are asked whether they strongly agree, mildly agree, are unsure, mildly disagree or strongly disagree with each statement. It has been widely used since its development in sociological and environmental research (Dunlap *et al.*, 2000).

Given the time constraints in my survey, a subset of three questions were selected and/or adapted from those introduced by Dunlap *et al.* (2000). A fourth question about the government's involvement in addressing environmental issues was also included. The statements chosen can be seen in Table 9. Levels of agreement for each statement were coded from 1 to 5, where 1 indicated strong agreement and 5 indicated strong disagreement[14]. Results indicate that despite not being very engaged in environmental organizations or activities, a strong majority do demonstrate preliminary indications of a pro-ecological worldview (see Table 9). For example, 93.0% of respondents agreed or strongly agreed that the government should play an active role in protecting the environment, while only 15.0% indicated that humans have the right to

[14] 1 = strongly agree, 2 = agree, 3 = undecided 4 = disagree, 5 = strongly disagree. Responses of I don't know/no response were removed for average calculations.

modify nature to suit their own needs. Responses to some of the questions in Table 9 were used as a covariate in the DCE (see Section 5.5.2).

Table 9: Respondents' Level of Agreement with Statements adapted from the NEP

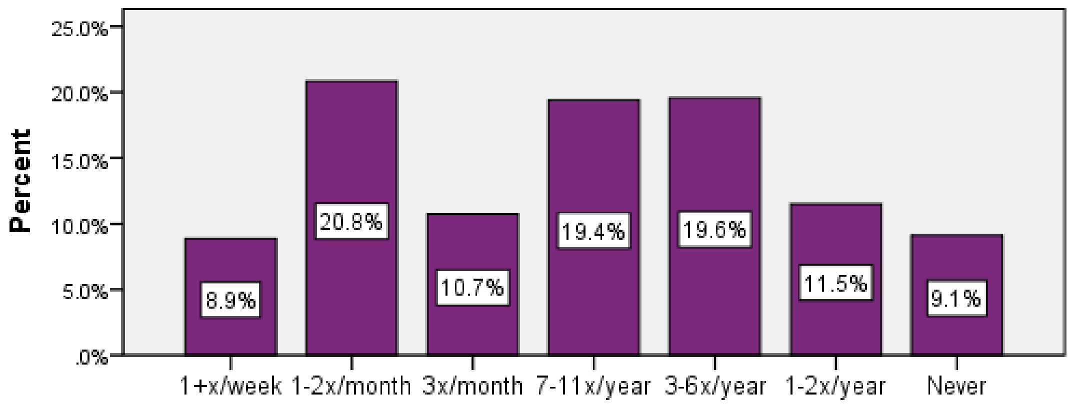
Statement	Strongly Agree (1)	Agree (2)	Undecided (3)	Disagree (4)	Strongly Disagree (5)	I Don't Know	Sample Mean/SD
I think the government should play an active role in protecting the environment	56.7%	37.3%	3.5%	0.6%	0.0%	1.6%	4.51/0.61 N=1302
I believe that humans are having a serious and irreversible effect on the environment	43.3%	39.4%	10.6%	3.9%	0.8%	1.5%	4.22/0.86 N=1297
Humans have the right to modify nature in order to suit their needs	2.1%	12.9%	18.6%	37.2%	26.8%	2.0%	2.25/1.05 N=1302
The earth has plenty of natural resources if we just learn how to develop them responsibly.	18.4%	45.3%	15.4%	12.9%	5.5%	2.0%	2.40/1.10 N=1289

While most applications of the NEP are geared towards a specific sub-set of the population (such as specific professions, age groups etc.), some studies have assessed responses to these questions for the general public (Dunlap *et al.*, 2000). The responses above demonstrate that the overall pro-ecological worldview found in this sample is in line with other recent studies conducted on the general public of British Columbia that used the NEP (Meuser, 2011; Gates, 2007).

5.2 Salmon Consumption Patterns

Respondents were also asked questions about their personal salmon consumption habits, i.e. how frequently they had consumed salmon in the prior 12 months, either at home or in restaurants (see Figure 3). While the number varied substantially, respondents had consumed salmon an average of 15 times in the past 12 months, though the high standard deviation indicates that a lot of variation in consumption habits (SD = 15.1)[15]. Over 90% of respondents had eaten salmon at least once in the last 12 months, though less than half of respondents (40.4%) ate salmon more than once a month (see Figure 3). Only 9.1% had not eaten salmon at all. These results are consistent with a 2011 survey prepared for the Canadian Aquaculture Industry Alliance, which indicated that 88% of Canadians had consumed seafood in the past three months, and 74% had consumed salmon. The survey also indicated that British Columbians ate the most seafood when compared to other provinces (Coletto *et al.*, 2011).

Figure 3: Respondent's Salmon Consumption Frequency during the Last 12 Months



Most respondents who had not eaten salmon in the past twelve months indicated that it did not appeal to them because of personal taste and/or dietary restrictions (see Table 10). A very small proportion (1.64%) of respondents chose not to eat salmon at least in part because they did not consider it to be environmentally friendly.

[15] Respondents were asked to select from different ranges of salmon consumption (once or twice a month, seven to eleven times per year etc.). The middle value in each range was used to calculate the average. For example, once or twice a month was considered 1.5 times per month, or 18 times in the last year.

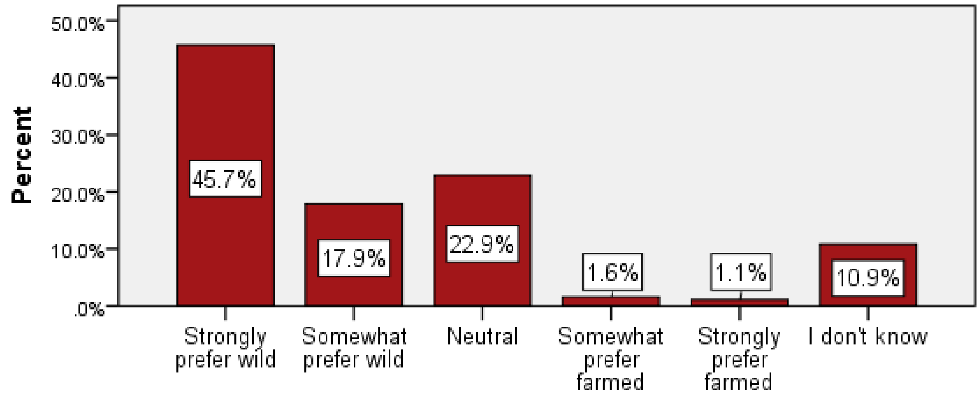
Table 10: Salmon Non-Consumers - Reasons for Not Consuming Salmon

Reason	N	Frequency
I don't like fish	53	43.44%
I don't like salmon	37	36.07%
I'm a vegetarian	18	14.75%
Salmon is too expensive	11	9.02%
I don't know how to cook salmon	3	2.46%
Salmon is unsafe	1	0.82%
Salmon is unhealthy	1	0.82%
Salmon is not environmentally friendly	2	1.64%
Salmon is not available where I live	0	0.00%
Salmon smells bad in the house	7	5.74%
Other[16]	13	10.66%

Those respondents who had eaten salmon at least once in the last year were asked whether they preferred farmed or wild salmon. Nearly two-thirds (63.6%) stated that they either strongly or somewhat preferred wild salmon (see Figure 4). A very small proportion (2.7%) indicated that they either strongly or somewhat preferred farmed salmon. Approximately one-third of respondents (33.8%) indicated they were unsure what type of salmon they generally ate, or were neutral as to whether they ate farmed or wild salmon. For more detailed data on salmon consumption patterns, see Appendix 5.

[16] Other reasons specified by respondents included food allergies and veganism.

Figure 4: Salmon Consumers' Preferences for Farmed vs. Wild Salmon



5.3 Respondent Familiarity with Salmon Farming

Respondents were asked a series of questions to determine their familiarity with the salmon farming industry in British Columbia, and where/how they had acquired this information. These questions served two purposes: to provide insight into individuals' knowledge about the salmon farming industry, given how well publicized it is, and to determine whether their prior knowledge of salmon farming would impact their choices in the DCE (for full results, see Appendix 6).

Respondents were first asked how familiar they were with the practice of salmon farming. A rating scale was used, that ranged from 1 (not familiar at all) to 5 (very familiar), with 3 representing 'somewhat familiar'. The average was 2.68 (SD = 1.00), with a median and mode of 3. Over 60% of respondents identified themselves as at least somewhat familiar with salmon farming. A small proportion (14.91%) knew nothing about salmon farming prior to participating in the survey (see Table 11).

Table 11: Respondent's Prior Familiarity with Salmon Farming

Level of Familiarity	Frequency	N
1 (Not familiar at all)	14.91%	197
2	22.63%	299
3 (Somewhat familiar)	46.03%	608
4	12.49%	165
5 (Very familiar)	3.94%	52
Total	100.00%	1321
Mean	2.68	
Standard Deviation	1.00	
Mode	3	
Median	3	

Respondents were asked whether they had seen or spent time near a salmon farm. This question was meant to determine whether respondents had any first-hand experience with salmon farms, or whether their knowledge of salmon farms had come from other secondary sources such as the news media. As expected, a majority of respondents (60.1%) had never been to or seen a salmon farm. A little over one-quarter of respondents (27.6%) had been to or seen one, and a proportionately large number of respondents weren't sure (11.7%). Since the majority of British Columbia's residents live in urban areas, only those who spend time travelling to the remote, coastal areas where salmon farms are located would have seen or spent time near one.

Respondents were then asked about where and how often they saw, heard or read about salmon farming. Respondents were asked to identify what their main source of information on salmon farming had been in the last 12 months. A majority of respondents (59.2%) identified news stories/journalism as their main source of information (see Appendix 6 for full list of information sources). Respondents were also asked to estimate how much they had seen, heard or read about salmon farming in the media in the past 12 months, where 1 = 'nothing at all' and 5 = 'a large amount' (see Table 12). The mean response was 2.51 (SD = 0.995), indicating that the average respondent had been exposed to a small to moderate amount of media on the topic of salmon farming. While very few respondents (3.2%) had come in contact with a large amount of media (identified in the survey as several pieces per week), only 15.8% of respondents had seen nothing at all.

Table 12: Rating Scale of How Often Respondents Saw, Heard or Read about Salmon Farming in the Media in the past 12 months

Response	Frequency	N
1 Nothing at all	15.8%	209
2	35.0%	462
3 A moderate amount – approx. 1 media piece per month	33.8%	447
4	11.4%	150
5 A large amount – several media pieces per week	3.2%	42
No Response	0.8%	11
Total	100.0%	1321

5.3.1 Prior Knowledge of Salmon Farming and the Environment

After being asked a series of questions about their prior knowledge of salmon farming in general, respondents were asked whether they were familiar with the potential impacts of salmon farming on the marine environment. Given the large amount of media coverage salmon farming has received in British Columbia over the past decade, it was expected that a strong majority would identify themselves as at least ‘somewhat familiar’ with the environmental controversy surrounding it. While a majority (58.5%) identified themselves as at least somewhat familiar, over 40% of respondents indicated that they had little to no prior knowledge of the potential effects of salmon farming on the marine environment (see Table 13). On average, respondents were just slightly less aware (Mean = 2.51, SD = 1.10) of the environmental impacts of salmon farming than salmon farming in general (Mean = 2.68).

Table 13: Respondent Familiarity with the Potential Environmental Impacts of Salmon Farming

Scale	N	Frequency
1(Not Familiar at all)	258	19.7%
2	285	21.8%
3 (Somewhat Familiar)	524	40.1%
4	175	13.4%
5 (Very Familiar)	66	5.0%
Total	1308	100.0%

After being presented with brief descriptions of three potential impacts of salmon farming (disease and parasite transfer risk, effects to marine habitat quality, effects to aesthetic quality), respondents were asked their own view on the current status quo environment surrounding salmon farms. This was meant to provide evidence for the lack of an accepted status quo, and to introduce respondents to the different levels that future DCE attributes could take.

Respondents were split on whether there was a high (32.1%) or moderate (32.4%) risk of disease and parasite transfer between farmed and wild salmon, which may be attributable to the large amount of press coverage that sea lice has received in British Columbia over the past few years. The most common answer for marine habitat and aesthetic quality was that they were currently 'fair quality', with a smaller proportion of respondents choosing the worst-case option in both cases. In all three cases, between 25 and 30 percent of respondents indicated that they 'didn't know' what the current conditions are (for full results, see Appendix 7).

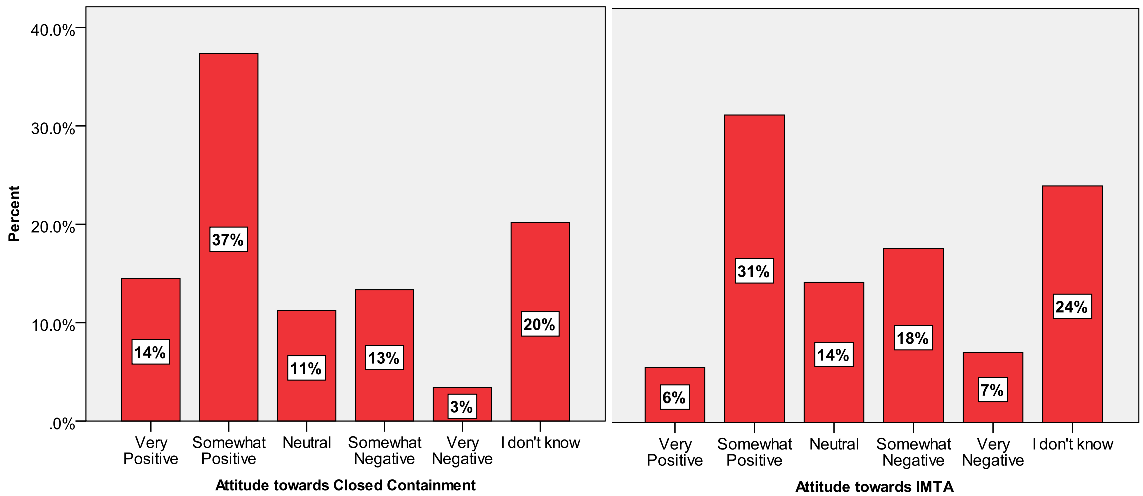
5.4 Respondent's Preference for IMTA vs. CCA

Respondents were asked a series of questions about their opinions about and preferences for IMTA and CCA technologies. It was expected that given strong support for CCA technology by environmental organizations in the province, as well as high profile figures such as David Suzuki and Alexandra Morton, that CCA would be very popular among respondents (Burrows, 2011; David Suzuki Foundation, 2014). For the full results from this section, see Appendix 9.

After being provided with a short, balanced description of each technology[17], respondents were asked whether they a) had prior knowledge of the technology, and b) what their (initial or preconceived) opinion of the technology was. These questions were meant to capture respondents' opinions of these technologies independent from one another, prior to asking respondents for their preferences between the two. While the majority of respondents had no prior knowledge of either IMTA or CCA, a larger proportion of respondents had prior knowledge of CCA (33.0%) than IMTA (14.2%). Respondents were also asked to rank their opinion of each technology on a scale from 1 (very negative) to 5 (very positive)[18]. The mean response was 3.13 for IMTA (SD = 1.13) and 3.58 for CCA (SD = 1.09), which indicates that on average, respondents had a neutral to somewhat positive opinion of both technologies (see Figure 5). A paired t-test was conducted which demonstrated that on average there was a significant difference between the means for CCA vs. IMTA[19]. A little over one-third (37.0%) of respondents had a somewhat or very positive opinion of IMTA, whereas over half (51.9%) had a somewhat or very positive opinion on CCA. A larger proportion had a negative opinion of IMTA (24.8%) compared to CCA (17.7%).

[17] Descriptions were taken from Yip (2012) in order to allow for a direct comparison between the results of the two studies. They can be found in Appendix 1 (full survey).
[18] 'Don't know' responses were coded as 'missing-system' in SPSS
[19] ($t(1302) = -20.69$, $p < 0.0005$)

Figure 5: Attitudes towards IMTA and CCA Technology when Assessed Independently



A Spearman's correlation[20] test was used to determine whether there were correlations between respondents' prior knowledge of a technology and their attitude towards it. For CCA, a weak, statistically significant, positive relationship between prior knowledge of CCA and favorable opinion of CCA was found (r_s=0.340). For IMTA, a statistically significant, very weak, negative relationship was found between prior knowledge of IMTA and favorable opinion of IMTA (r_s=-.153). This indicates that respondents who indicated they were familiar with CCA were more likely to have a favorable opinion of it. Respondents who indicated they were familiar with IMTA were less likely to have a favorable opinion of it. The results of the Spearman correlation test can be found in Appendix 9.

5.4.1 Preferences for CCA vs. IMTA

After being asked for their opinion of the two technologies in isolation from one another, respondents were then asked to compare their relative preference for one technology over the other. Respondents were asked which technology they would prefer

[20] For this test, the yes/no responses to respondent's prior familiarity with the alternative technologies was dummy coded (No = 0 Yes = 1 Not Sure = missing-system).

if only one of the technologies were to be widely adopted in British Columbia. Approximately one-third (34.7%) of respondents indicated that they somewhat or strongly preferred CCA, while only 25.5% preferred IMTA. In order to allow for comparisons, the results were coded from -2 (strongly prefer CCA) to 2 (strongly prefer IMTA) using the same numbering as Yip (2012)[21]. The results indicate a slight preference for CCA (Mean = -0.22, SD = 1.17). Preferences for IMTA vs. CCA are shown in Table 14.

Table 14: Respondent Preference for IMTA vs. CCA Technologies

Preference	N	Frequency
Strongly Prefer IMTA (2)	65	4.9%
Somewhat Prefer IMTA (1)	272	20.6%
Neutral (0)	280	21.2%
Somewhat Prefer CCA (-1)	276	20.9%
Strongly Prefer CCA (-2)	182	13.8%
I Don't Know (NA)	246	18.6%
Total	1321	100.0%

Common reasons for respondents to prefer IMTA included: it seemed more natural (41.8%), it was more environmentally friendly (32.9%) it was more effective at addressing salmon farming's environmental issues (28.5%). Respondents preferred CCA because it separates farmed salmon from the marine environment (65.1%) and it is more effective at addressing salmon farming's environmental issues (60.1%). See Table 15 for the full list of reasons.

[21] Strongly prefer IMTA = 2, Somewhat prefer IMTA = 1, Neutral = 0, Somewhat prefer CCA = -1, Strongly Prefer CCA = -2, I don't know = missing system

Table 15: Reasons for IMTA/CCA Preferences

Reasons for IMTA preference (N = 337)	Reasons for CCA preference (N = 459)
41.8% thought it seemed more natural 32.9% thought it seemed more environmentally friendly 28.5% thought it was more effective at addressing salmon farming's environmental issues 24.9% thought IMTA seemed more sustainable 20.2% liked the fact that it cultured multiple species 17.2% thought it was more efficient at producing seafood 13.1% thought it used less resources 11.3% thought it was more innovative	65.1% liked the fact that it separates farmed salmon from the marine environment 60.1% thought it was more effective at addressing salmon farming's environmental issues 50.1% thought it seemed more environmentally friendly 19.6% thought CCA was more sustainable 13.1% thought it was more efficient at producing seafood 10.5% thought CCA was more innovative 9.6% thought it seemed more natural 6.8% thought it seemed to use less resources

5.5 Attitudes towards Government Policy

Respondents were also asked about their support of different types of government policy related to salmon aquaculture. It was hypothesized that respondents who were supportive of using tax dollars to subsidize R&D or adoption of green technologies would also be willing to pay more for sustainable aquaculture systems within the DCE. A large proportion of respondents (45.6%) believed that the government should be responsible for ensuring that the marine environment around salmon farms is in good condition, while 31.3% believe it should be the responsibility of salmon farming companies. Respondents were also asked to express their support or opposition for different types of policies, as they relate to salmon aquaculture (see Table 16). Answers were then coded from 1 (strongly oppose) to 5 (strongly oppose). Respondents exhibited strongest levels of support for enacting stricter regulations and using green taxes to improve industry sustainability[22]. Most respondents were opposed to industry-developed voluntary guidelines (full results of these questions can be found in Appendix 10).

[22] Green taxes are taxes imposed upon producers or consumers as a method of reducing pollution or discouraging the consumption of environmentally damaging goods.

Table 16: Level of Support for Policy Options related to Salmon Aquaculture

Policy Type	Strongly Support (5)	Support (4)	Undecided (3)	Oppose (2)	Strongly Oppose (1)	I don't know	Mean /Standard Deviation
Stricter mandatory regulations	48.4%	39.1%	7.4%	0.6%	0.2%	3.9%	Mean = 4.28 SD = 0.80
Industry-developed guidelines	2.4%	11.9%	19.8%	34.3%	26.9%	3.9%	Mean = 2.25 SD = 1.08
Green taxes	43.8%	38.9%	10.4%	2.3%	0.7%	3.3%	Mean = 4.27 SD = 0.80
Government funding of green technology R&D	24.8%	43.9%	20.1%	4.3%	2.1%	3.9%	Mean = 3.89 SD = 0.92
Subsidies for green technology adoption	23.3%	42.6%	18.5%	7.3%	4.2%	3.5%	Mean = 3.77 SD = 1.04

5.6 Principal Component Analysis

As supported in Section 4.6.1, principal component analysis was used to transform a set of potentially correlated variables in to a smaller set of linear, orthogonal (uncorrelated) values to be used as covariates in the DCE (Jolliffe, 2002; Boxall *et al.,* 2009). Included in this analysis were three questions related to respondent environmental ethic, three questions related to their prior knowledge of salmon farming, and two questions related to their support of government-funded programs that subsidize R&D or green technology adoption. A total of 8 responses to survey questions were reduced in to 3 components or 'factors', representing the above categories. As indicated in Table 17, these three uncorrelated factors cumulatively account for 66.1% of variance in the data (i.e. they account for two-thirds of the variation in the original data).

It also shows that the principal components account for more variance than the initial variables (eigenvalues <1). Table 18 provides ‘principal component loadings’, which serve as a measure of correlation between the original variables and the rotated components (Boxall *et al.,* 2009). Not surprisingly, highly-related questions (such as support for government-funded R&D in to green technologies, and government-funded subsidies for green technology adoption) were loaded in to components together.

Table 17: Eigenvalues[23] derived from Principal Component Analysis

Component	Component Name	Initial Eigenvalue	% of Variance	Cumulative Variance %
1	Prior knowledge of salmon farming	2.29	28.62%	28.62%
2	Support of government-funded programs	1.78	22.20%	50.82%
3	Environmental Ethic	1.22	15.28%	66.10%

Table 18: Rotated Principal Component Loadings (Rotated Component Matrix)

Component Name	Survey Question Topic	Components		
		1	2	3
Environmental Ethic	Belief that humans are having an irreversible effect on the environment	-0.019	0.770	0.137
	Belief that humans have the right to modify the environment	0.017	-0.697	0.177
	Belief that the environment should be protected by government	0.177	0.668	0.272
Support for Government-funded Programs	Support for government subsidized R&D for green technologies	0.033	0.176	0.813
	Support for government-subsidized green technology adoption	-0.098	-0.039	0.836
Prior knowledge of Salmon Farming	Prior knowledge of salmon farms	0.864	-0.013	0.012
	Level of Media Exposure about Salmon Farming	0.821	0.043	-0.055
	Prior knowledge of the environmental impacts of salmon farms	0.879	0.083	-0.021

[23] Eigenvalues are a measure of the amount of variance that can be explained by each component

5.7 DCE Results

Two MNL (one-class) models were estimated in Latent Gold, using the choice results from the two different samples (Model 1: MCS and Model 2: WCS). In each model, the data was segmented using latent-class analysis, which generated a three-class model. Several different potential covariates were tested throughout data analysis, including socio-demographic information such as income, age and education. However, no significant relationship was found between demographics and respondent choice that was common to both models. The three PCA components from Section 5.4 were included as covariates, and were found to have significant explanatory power.

5.7.1 Multinomial Logit Models (Part-Worth Utility)

Two MNL (1-class) models were estimated, with each one providing part-worth utility estimates for each attribute level given an MCS and WCS status quo. For the MNL model, the tax attribute was coded linearly, while the employment attribute was coded both linearly and in quadratic form. The results of both models are compared in graphic form in Appendix 11.

Model 1 was based on choice results from respondents who saw the MCS status quo. This MNL Model is based on the choice responses of 644 respondents. The results in Table 19 present the part-worth utility (estimated coefficient), standard error, as well as other indicators of significance of each attribute, including z-value and Wald statistic.

Table 19: Utility Estimates for 'Medium-Case-Scenario' status quo sample (MNL Model)

Attribute	Level	Coefficient	Standard Error	z-value	Wald p-value[24]
Disease and Parasite Transfer Risk	No risk	0.576***	0.036	16.229	<0.01
	Low risk	0.102***	0.036	2.791	
	Moderate risk	-0.678***	0.039	-17.512	
Marine Habitat Quality	Very good quality	0.335***	0.040	8.425	<0.01
	Good quality	0.153***	0.037	4.133	
	Fair quality	-0.480***	0.039	-12.629	
Aesthetic Quality	Very good quality	0.101***	0.037	2.719	<0.01
	Good quality	0.086**	0.038	2.271	
	Fair quality	-0.187***	0.038	-4.977	
Employment (linear)	NA	0.148***	0.018	8.220	<0.01
Employment (quadratic)	NA	-0.046***	0.012	-3.816	<0.01
Tax (linear)	NA	-0.308***	0.016	-18.868	<0.01
ASC (Intercept)[25]	NA	1.055***	0.049	21.557	<0.01

***significant at 0.01, **significant at 0.05, *significant at 0.1

The estimated coefficients for all attributes in the MCS MNL model were found to be highly significant (based on Wald p-values <0.01). A highly positive estimated coefficient indicates a strong preference for the corresponding attribute level. Conversely, a highly negative estimated coefficient indicates that a particular attribute level was not preferred. A large difference between levels indicates that a large amount of utility is gained from moving from the less preferred level to the more preferred level. The very high coefficient for the ASC (1.055) demonstrates that respondents had a significant preference for implementing a government program, no matter what the outcome of that government program would be. For environmental attributes, the part-worth utility of a reduction in risk of disease and parasite transfer was found to be highest, particularly for the improvement from moderate (-0.678) to low risk (0.102).

[24] Wald p-value indicates the significance of the attributes
[25] A positive ASC value indicates that respondents gain utility by moving away from the status quo. The ASC was coded such that a 1 indicated a choice of the two alternatives, and 0 for the status quo.

Aesthetic quality and employment were found to have lower part-worth utilities than the other environmental attributes.

Model 2 was based on choice responses from respondents who saw the WCS status quo. It was predicted that preferences for improvements to environmental attributes would be lower in this model, but that the parameter coefficient for the ASC would be higher. It was expected that respondents would be willing to pay substantial money for initial movements away from the WCS status quo, but then less for further improvements. This MNL Model is based on the choice responses of 677 respondents. The results in Table 20 present the part-worth utility (estimated coefficient), standard error, as well as other indicators of significance of each attribute, including z-value and Wald statistic.

Table 20: Utility Estimates for 'Worst-Case-Scenario' status quo sample (MNL Model)

Attribute	Level	Coefficient	Standard Error	z-value	Wald p-value[26]
Disease and Parasite Transfer Risk	No risk	0.491***	0.035	14.138	<0.01
	Low risk	0.142***	0.036	3.983	
	Moderate risk	-0.633***	0.038	-16.905	
Marine Habitat Quality	Very good quality	0.243***	0.038	6.384	<0.01
	Good quality	0.114***	0.036	3.223	
	Fair quality	-0.358***	0.036	-9.979	
Aesthetic Quality	Very good quality	0.063*	0.036	1.721	0.23
	Good quality	-0.035	0.037	-0.939	
	Fair quality	-0.027	0.035	-0.774	
Employment (linear)	NA	0.093***	0.017	5.485	<0.01
Employment (quadratic)	NA	-0.045***	0.012	-3.915	<0.01
Tax (linear)	NA	-0.321***	0.016	-19.800	<0.01
ASC (Intercept)	NA	2.093***	0.035	29.950	<0.01

***significant at 0.01 **significant at 0.05 *significant at 0.1

The estimated coefficients for all attributes in the WCS MNL model were found to be significant (based on Wald p-values <0.01), with the exception of aesthetic quality. In this model, any choice other than the status quo will represent an improvement in

[26] Wald p-value indicates the significance of the attributes

conditions. Therefore, the coefficient for ASC (2.093) for the WCS model is much larger than the ASC for the MCS model, since it demonstrates respondents preference from moving away from the WCS status quo for environmental attributes to alternatives where the environmental attributes were at least one level higher. Given that the status quo is the 'worst-case scenario', results indicate that a large number of respondents didn't select this option under any circumstances. For environmental attributes, like the MCS model, the part-worth utility of a reduction in risk of disease and parasite transfer was highest, particularly for the improvement from moderate (-0.633) to low (0.142) risk. Aesthetic quality and employment were found to have lower part-worth utilities than the other attributes.

5.7.2 Latent Class Analysis

Latent class models were run for 2 to 6 classes for both the MCS and WCS data samples to determine whether heterogeneous preferences were present in the two samples, as well as to determine the number of classes that would be the best fit for each sample. To allow for direct comparison between the latent class models, the same number of classes were used for the MCS and WCS samples.

A number of statistics provided by Latent Gold Software to assess a model's 'goodness-of-fit' can be useful in choosing the number of classes in a latent class model. These statistics include BIC(LL), AIC(LL) and AIC3(LL), and differ in how they handle the number of parameters in a particular model (Magidson & Vermunt, 2002). In general, the lower the information criteria measure, the better the model. While 4 and 5 class models showed slightly lower AIC and AIC3 levels for both MCS and WCS, the three-class yielded similar or lower BIC and CAIC levels. Ultimately, the 4, 5 and 6 class models were not used, since resulting models were unstable, and some classes contained large standard errors for the coefficient for the ASC under the WCS sample. Therefore, the three-class model was selected for both models, which also allows for some comparison. Another commonly used statistic for overall model fit is the pseudo-R^2. A higher R^2 is considered better, with measures above 0.2 considered to be well fitted (Hoyos, 2010, Louviere, Hensher & Swait, 2000). The 3-class models for MCS and WCS have R^2 of 0.380 and 0.426, respectively, which indicates a well-fitted model (Magidson & Vermunt, 2002). The fit statistics for these models can be found in Appendix 12.

5.7.2.1 Latent Class Analysis – Covariates

Covariates are variables which are external to the DCE that can be included in latent class analysis in order to provide further information with which to classify respondents in to latent classes, to describe latent classes based on exogenous variables, such as demographics or attitudinal data and to improve overall model fit (Magidson & Vermunt, 2003; Boxall *et al.,* 2009). While numerous demographic variables were included as covariates in earlier iterations of the latent class models, none were found to be significant for at least two of the three classes across both the MCS and WCS models. However, the three components extracted during PCA analysis (see Section 5.6) were included as covariates, and found to be significant across most classes for both MCS and WCS (see Tables 21 and 22). The three components were extracted from eight potentially-correlated variables, all of which were responses to attitudinal questions. These three components can be described as follows:

- **Environmental Ethic**: This component was largely extracted from responses to three questions regarding respondents' environmental ethic, adapted from the NEP scale (see Section 5.1.3)
- **Support for Government Funding of Alternative Aquaculture Technologies**: This component was largely extracted from responses to two questions regarding respondents' level of support of government-funded R&D in to alternative aquaculture technologies, and support for government-funded subsidies for farmers adopting alternative aquaculture technologies.
- **Prior Knowledge of Salmon Farming**: This component was largely extracted from responses to three questions regarding respondents' prior knowledge of salmon farming and its environmental impacts

5.7.2.2 Latent Class Model – MCS Status Quo

Table 21 provides the output for the LCA model for the MCS status quo. Like the MNL model, the LCA model provides estimated coefficients for each attribute level. However, respondents are grouped in to latent classes based on their choices made during the DCE, and their heterogeneous preferences are demonstrated through differing parameter coefficients between the classes. Table 22 provides a description of the three classes based on the covariates included in the model. A higher estimated coefficient for a covariate indicates that respondents in a particular class are more likely to exhibit the characteristic demonstrated by the covariate. For example, there is a significant correlation between membership in Class 1, and support of government-funded development of green technologies (parameter coefficient = 0.245, z-value = 2.663). The parameter coefficient for Class 2 is significantly negative, which indicates that respondents in this class are less likely to support government-funded development of green technologies.

Table 21: Utility Estimates for 'Medium-Case-Scenario' status quo sample (3-Class Model)

Attributes and levels	Class 1 (SD)	Standard Error	Class 2 (TC)	Standard Error	Class 3 (SE)	Standard Error	Wald p-value	Wald= p-value
Disease and Parasite Transfer							<0.001	<0.001
No risk	0.399***	0.092	0.464***	0.085	2.071***	0.293		
Low risk	0.071	0.075	0.173**	0.081	0.433***	0.145		
Moderate risk	-0.470***	0.109	-0.637***	0.091	-2.504***	0.350		
Marine Habitat Quality							<0.001	<0.001
Very good quality	0.539***	0.092	0.100	0.090	0.734***	0.184		
Good quality	0.168**	0.070	0.265*	0.083	0.236	0.127		
Fair quality	-0.706***	0.101	-0.364***	0.091	-0.970***	0.174		
Aesthetic Quality							<0.001	0.50
Very good quality	0.174***	0.073	0.058	0.085	-0.048	0.15		
Good quality	0.052	0.069	0.220	0.088	0.339**	0.167		
Fair quality	-0.227***	0.073	-0.278**	0.085	-0.291**	0.135		
Employment (linear)	0.244***	0.036	0.214***	0.047	0.010	0.092	<0.001	0.074
Employment (quadratic)	-0.062***	0.023	-0.042	0.032	-0.115**	0.050	<0.001	0.46
Tax (linear)	-0.229***	0.041	-0.951***	0.075	-0.022	0.089	<0.001	<0.001
ASC	2.692***	0.274	-0.504***	0.165	3.461***	0.426	<0.001	<0.001
Covariates								
Intercept	0.331***	0.166	0.087	0.102	-0.418**	0.185		
Support for govt. funding	0.245***	0.092	-0.271***	0.068	0.026	0.094		
Prior knowledge of salmon farming	-0.122	0.077	-0.193***	0.071	0.315***	0.090		
Environmental ethic	-0.159	0.088*	-0.363***	0.076	0.521***	0.108		

***significant at 0.01 **significant at 0.05 *significant at 0.1

Within the MCS model, all attributes were found to be significant (Wald p-value <0.001), while differences between attribute levels were significant for all attributes except aesthetic quality and employment. The MCS yielded three distinct classes. By examining the coefficients for attribute levels and covariates estimated for each class, information can be inferred about the characteristics of each class. The three classes that emerged in this model were labeled ‘Serious Environmentalists’ (SE), ‘Tax-Conscious’ (TC) and ‘Sustainable Development Supporters’ (SD)[27]. Their classifications were based on the choices made by each respondent in the DCE. A demographic breakdown of each latent class can be found in Appendix 13.

Serious Environmentalists: The serious environmentalists made up 23.6% of the sample. These respondents wanted to see an improvement in environmental conditions regardless of the tax burden imposed upon them. This group had the highest part-worth utility for all three environmental attributes. These respondents also had lower utility for improvements in salmon farming employment much lower than the other two latent classes. These respondents were found to have the highest environmental ethic (based on the survey questions regarding their environmental beliefs), and were more knowledgeable about salmon farming and its environmental impacts prior to responding to the survey.

Tax-Conscious: The tax-conscious made up 34.5% of the sample. As demonstrated by the negative value of their ASC, these respondents were much more likely to choose the status quo, ‘no program’ option, irrespective of program outcome. The most important factor in their decision making was not paying additional taxes to fund these government programs. However, they still demonstrated that they gain some utility from improvements in the environmental attributes, though to a lesser extent than the serious environmentalists. They also showed that they valued increasing employment levels, though this was less important to them than to the ‘sustainable development supporters’. These respondents were found to have the lowest environmental ethic, were largely opposed to government policies providing funding for green technologies and knew less about salmon farming prior to the survey when compared to the other two latent classes.

Sustainable Development Supporters: The sustainable development supporters made up 41.8% of the sample. This group gained more utility from improvements in coastal salmon farming employment more than the other two classes. They demonstrated that

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[27] It is important to note that while each individual respondent is assigned to a latent class, this is not done with complete certainty. Instead, each respondent is placed in the class in which there is the highest probability of membership. Therefore, each respondent may belong to multiple classes, with differing probabilities (Vermunt & Magidson, 2002, 91).

they valued improvements in all environmental attributes, though unlike the serious environmentalists, this group valued improvements in marine habitat quality more than reductions in disease and parasite transfer risk. Unlike the other two classes, this group demonstrated significant support for government-funded green technology subsidies. This may be why this group was more likely to choose one of the government-funded programs than the status quo, irrespective of the program's outcomes.

5.7.2.3 Latent Class Model – WCS Status Quo

Table 22 provides the output for the LCA model for the WCS status quo. Within the WCS model, all attributes were found to be significant (Wald p-value <0.001) with the exception of aesthetic quality. Differences between attribute levels were significant for all attributes except aesthetic quality and employment (quadratic only).

Table 22: Utility Estimates for 'Worst-Case-Scenario' status quo sample (3-Class Model)

Attributes and levels	Class 1 (SE)	Standard Error	Class 2 (SD)	Standard Error	Class 3 (TC)	Standard Error	Wald p-value	Wald = p-value
Disease and Parasite Transfer							<0.001	<0.001
No risk	0.961***	0.089	0.439***	0.094	0.033	0.152		
Low risk	0.196***	0.075	0.135	0.087	-0.162	0.164		
Moderate risk	-1.157***	0.090	-0.574***	0.099	0.129	0.155		
Marine Habitat Quality							<0.001	<0.001
Very good quality	0.662***	0.092	0.059	0.092	-0.109	0.165		
Good quality	0.282***	0.076	0.130	0.086	-0.123	0.164		
Fair quality	-0.944***	0.096	-0.189**	0.090	0.232	0.147		
Aesthetic Quality							0.21	0.50
Very good quality	0.130*	0.074	0.130	0.074	0.244	0.162		
Good quality	0.037	0.073	0.037	0.073	-0.079	0.166		
Fair quality	-0.168**	0.076	-0.168	0.076	-0.165	0.157		
Employment (linear)	0.143***	0.040	0.250***	0.044	-0.013	-0.079	<0.001	0.018
Employment (quadratic)	-0.105***	0.026	-0.055 *	0.029	-0.057	0.056	<0.001	0.43
Tax (linear)	0.008	0.038	-0.751***	0.073	-0.858***	0.095	<0.001	<0.001
ASC	5.129***	0.516	4.261***	0.527	-0.442**	0.216	<0.001	<0.001
Covariates								
Intercept	0.493***	0.116	0.498***	0.111	-0.991***	0.150		
Support for govt. funding	0.243	2.983	0.011	0.085	-0.254**	0.110		
Prior knowledge of salmon farming	0.224	2.734	-0.303***	0.088	0.079	0.112		
Environmental ethic	0.463	5.599	-0.065	0.078	-0.398***	0.097		

***significant at 0.01 **significant at 0.05 *significant at 0.1

Three classes similar to those seen in the MCS model emerged in the WCS model. However, the number of respondents in each group was different, and the choice behavior exhibited by each group was somewhat different, as outlined below. However, it should be noted that since two discrete samples were used in the two DCEs, the classes may also vary due to exogenous factors. A demographic breakdown of each class can be found in Appendix 13.

Serious Environmentalists: Faced with the 'worst-case scenario' status quo, the number of respondents that fell in to the 'Serious Environmentalist' class increased by over 20%, from 23.6% in the MCS model to 45.2% in the WCS model. This group demonstrated that they were highly unlikely to choose the status quo, despite the outcomes of the government programs presented. The slightly positive, insignificant value of the coefficient for this class indicates that taxes were not a factor in their decision, and they may have made choices without taking in to consideration any additional taxes that they would be required to pay. This class found the highest utility in disease and parasite transfer and marine habitat quality. This group showed strong support for subsidies, a high environmental ethic and strong prior knowledge of salmon farming.

Tax Conscious: Under the WCS status quo, this group of 'Tax Conscious' respondents was reduced in size considerably from 34.5% of the sample to just 11.4% of the sample. When faced with these WCS status quo conditions, the majority of respondents that may have fallen in to the Tax Conscious class under more favorable status quo conditions (such as the MCS status quo) shifted to the other, more environmentally-concerned classes. Unlike the tax-conscious class in the MCS model, this group only found significant utility in paying lower taxes, and showed no interest in any other attribute. They were highly likely to choose the 'no program' option. This group showed demonstrable opposition to government subsidies of green technologies, and were more likely to have a lower environmental ethic based on their responses to survey questions.

Sustainable Development-Supporters: This class made up 43.4% of the sample. While they valued improvements in the environmental attributes (though to a lesser extent than the serious environmentalists), they were highly concerned about increases in taxes. They also valued increases in employment the most. This group did not value improvements in aesthetic quality. This group was not likely to have substantial knowledge of salmon farming prior to the survey.

5.7.3 The Impact of Status Quo

To determine whether a significant difference in part-worth utility between the two models was present as a result of the status quo, the data from both samples (MCS and WCS) were pooled, and the status quo treatment was run as a known class using Latent Gold (Vermunt, 2005, 18-19). The Wald(=) test can then be used to determine if the coefficients significantly differ by status quo treatment. Not surprisingly, the ASC was significantly different (Wald(=) p-value <0.001). This was expected, given that one status quo was much worse than the other in terms of environmental conditions. Therefore, the difference between the part-worth utilities for the two models indicates that respondents have a stronger preference for not choosing the status quo when status quo conditions are worse.

The difference in part-worth utility for increased employment in salmon farming was found to be significant between the two models (Wald(=) p-value <0.001), as was marine habitat quality (Wald(=) p-value = 0.043) and aesthetic quality (Wald(=) p-value = 0.0060). Neither part-worth utility for the tax attribute nor the disease and parasite transfer risk attribute were found to be significantly different between the two models. The results of this known class model are found in Appendix 14.

The results of the known-class model demonstrate that while status quo did have as significant effect on respondent preferences for certain attributes, particularly those that were found to be less important overall in both models. However, it did not result in a significant difference in part-worth utilities for the two attributes found to be the two most important in both models, namely the taxes attribute and the disease and parasite transfer risk attribute. The results of this analysis are discussed further in Section 6.2.

5.8 WTP Estimates for Environmental Changes

As discussed in Section 4.6.4, WTP estimates that conform with demand theory can be derived from parameter estimates of a choice model. WTP estimates are presented in Canadian tax dollars per household per year for 10 years. They indicate WTP for improvements in the environmental and employment attributes. Estimated marginal WTP for each of the latent class models is provided in Appendix 15. It is important to note that the marginal WTP estimates seen in Table 23 do not take in to account the utility gained from moving away from the status quo option, which was captured by the parameter coefficients of the ASC in each model (Boxall *et al*., 2009). Instead represent the increase in utility gained from discrete improvements in the three attribute levels that were included

Table 23: WTP for Incremental Improvements in Environmental and Employment Attributes

Attribute	Level Change	Model 1 – MCS	Model 2 - WCS
Disease & Parasite Transfer	Mod. Risk - Low Risk	$37.99	$36.17
	Low Risk to No Risk	$23.08	$16.29
Marine Habitat Quality	Fair - Good Quality	$30.83	$22.02
	Good – V. Good Quality	$8.86	$6.01
Aesthetic Quality	Fair - Good Quality	$13.30	$2.92
	Good – V. Good Quality	$4.92	-$0.35*
Employment in Salmon Farming	+500 jobs	$5.00	$5.00

*Attribute level was not found to be significant (p>0.1)

WTP estimates for a change in the 'state of the world' were derived from the sum of the part-worth utilities in the MNL models, taking in to account the negative utility derived from the status quo option (indicated by the ASC value)[28]. The two 'decision-support tools' developed (one for each model) allowed us to predict the impact to utility, and subsequent WTP, of one or many changes in levels of attributes within the MNL models. These WTP estimates represent compensating variation measures. As indicated in Section 4.5.4, these estimates represent "a change in the level of provision in the attribute or attributes by weighting this change by the marginal utility of income (Hoyos, 2010, 1598)", where marginal utility of income is measured by the parameter coefficient for the price (tax) attribute. An example of this is shown in Table 24, which estimates the WTP for an improvement in both habitat quality and disease risk, under the MCS status quo.

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[28] The Characteristics Theory of Value indicates that the value of a particular good (including environmental goods) is made up of the value of its individual attributes.

Table 24: Annual WTP for an improvement in Disease and Parasite Risk and Marine Habitat Quality in the area surrounding salmon farms

ATTRIBUTE	NEW LEVEL	SQ LEVELS	NEW UTILITY	SQ UTILITY[29]
Jobs	1500	1500	0.444	-1.865
Wildlife	Good	Fair	0.153	
Risk	Low	Moderate	0.102	
Aesthetic	Fair	Fair	-0.187	

TOTAL	2.377
WTP	$115.75

This tool can also be used to estimate willingness to pay for alternative aquaculture technologies, based on different predictions of their environmental performance. For example, if CCA was widely implemented, it could improve marine habitat quality by removing any organic or agro-chemical waste released by conventional salmon farms. It could also significantly lessen disease transfer risk by preventing contact with wild salmon. However, it could reduce the number of coastal salmon farming jobs available in the industry due to the high capital costs required and the more mechanized nature of this technology. If the status quo was at MCS levels, WTP for this change would be $133.28 per household (see Table 25). If the status quo was WCS, WTP would be $173.00 per household (see Table 26).

[29] Mean centering was used in the alternatives file (one of the three files used for latent gold) for numeric attributes (employment, taxes and ASC). Due to the mean centering used for the numeric attributes in the alternatives file, the ASC values had to be adjusted slightly to ensure that they represented the correct status quo values. This was done based on advice from Ryan Trenholm.

Table 25: Estimated Annual WTP for Predicted Outcomes of Widespread CCA Adoption in British Columbia (MCS)

ATTRIBUTE	NEW LEVEL	SQ LEVELS	NEW UTILITY	SQ UTILITY
Jobs	500	1500	0.148	-1.865
Wildlife	Very Good	Fair	0.335	
Risk	None	Moderate	0.576	
Aesthetic	Fair	Fair	-0.187	

TOTAL	2.737
WTP	$133.28

Table 26: Estimated Annual WTP for Predicted Outcomes of Widespread CCA Adoption in British Columbia (WCS)

ATTRIBUTE	NEW LEVEL	SQ LEVELS	NEW UTILITY	SQ UTILITY
Jobs	500	1500	0.093	-2.907
Wildlife	Very Good	Poor	0.2431	
Risk	None	High	0.491	
Aesthetic	Fair	Poor	-0.0274	

TOTAL	3.707
WTP	$173.00

Two of the benefits of IMTA are that it reduces organic pollution, and thus improves marine habitat quality through bio-mitigation, and it diversifies production and improves profitability, which could lead to an expansion of the industry. If the status quo was MCS, WTP for an improvement in marine habitat quality and an increase in employment that could reflect the outcomes of IMTA development would be $92.18 (see Table 27). If the status quo was WCS, WTP would be $131.90 for the same environmental conditions (see Table 28).

Table 27: Estimated Annual WTP for Predicted Outcomes of Widespread IMTA Adoption in British Columbia (MCS)

ATTRIBUTE	NEW LEVEL	SQ LEVELS	NEW UTILITY	SQ UTILITY
Jobs	2500	1500	0.74	-1.865
Wildlife	Good	Fair	0.153	
Risk	Moderate	Moderate	-0.678	
Aesthetic	Fair	Fair	-0.187	

TOTAL	1.893
WTP	$92.18

Table 28: Estimated Annual WTP for Predicted Outcomes of Widespread IMTA Adoption in British Columbia (WCS)

ATTRIBUTE	NEW LEVEL	SQ LEVELS	NEW UTILITY	SQ UTILITY
Jobs	2500	1500	0.465	-2.907
Wildlife	Good	Poor	0.1144	
Risk	Moderate	High	-0.633	
Aesthetic	Fair	Poor	-0.0274	

TOTAL	2.826
WTP	$131.90

Chapter 6: Discussion

This chapter will provide a discussion of the results presented in Chapter 5, and responses to the research questions outlined in Chapter 1. It will conclude with limitations to this research, and suggestions for future research.

6.1 WTP for Improvements to the Environmental Conditions around Salmon Aquaculture Operations in BC

The results of the DCE demonstrate that British Columbians are willing to pay (via an increase in taxes) a substantial amount for improvements to the environmental conditions around salmon farms in the province. Furthermore, their WTP is significantly affected by the status quo environmental conditions.

6.1.1 Marginal WTP for Changes to Attribute Levels

Overall, the two MNL models (MCS and WCS) demonstrated that respondents hold the highest value for a marginal reduction in the risk of disease and parasite transfer between farmed and wild species ($36.17-$37.99 per household per year for an improvement from moderate risk to low risk). This high willingness to pay may be attributed to the large amount of media coverage and controversy around the spread of sea lice to wild salmon in British Columbia, and the potentially related effects on wild salmon populations in the province. This media coverage was particularly pronounced during the *Cohen Commission* of *Inquiry into the Decline of* Sockeye *Salmon in the Fraser River,* an official government investigation that led to a number of news stories about whether sea lice could be partially responsible for this decline[30].

Respondents were also willing to pay for marginal improvements to marine habitat quality around salmon farms that could be brought about from a reduction in organic wastes and agro-chemicals used during the production process (CDN $22.02-$30.83 per household per year for ten years to improve from moderate habitat quality to

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[30] During this government inquiry, two different scientists were asked to examine the effect that salmon farms were having on Fraser River sockeye salmon populations. The two scientists, Dr. Larry Dill and Dr. Don Noakes, were given the same data to analyze. However, the results of the two studies led to two very different findings (Noakes, 2011; Dill 2011).

good habitat quality). While this lower WTP amount indicates it may be less important to respondents than reducing disease and parasite transfer risk, it still indicates that marine habitat quality is a key issue that British Columbians would like to see improved. These marginal WTP estimates can be compared to Martínez-Espiñeira *et al.* (2012), who found that for the average household in Canada, WTP (non-use value) for the bio-mitigation benefits as a result of adoption of IMTA aquaculture systems is CDN $25.50 and $51.00 per household per year over a five year period. Given this five-year accounting period, the full WTP amount estimated by Martínez-Espiñeira *et al.* (2012) ranged from CDN $127.50 to $255.00 per household. Given the 10-year accounting period used for this study, the full WTP amount is slightly higher at CDN $220.20 to $308.30. The difference here may be attributable to the demonstrated lack of sensitivity to the length of a payment schedule that can be seen in stated-preference valuation exercises (Kahneman & Knetsch, 1992).

Respondents to the survey gained significantly less utility from improvements to the aesthetic quality around salmon farms in British Columbia when compared to the other environmental attributes. This demonstrates that the value in improvements to environmental conditions around salmon farms appears to be either non-use or indirect use in nature, since aesthetic quality is an attribute that would largely affect a person's direct use of the coastal environment around salmon farms. This is attributable to the fact that only one-quarter of respondents (27.6%) had even seen or visited a salmon farm, and most respondents lived in regions that have no salmon farming at all. This study can be contrasted with D'Anna (2013), who found that in areas where aquaculture is prevalent, such as Baynes Sound on Vancouver Island, residents' primary concern with aquaculture relates to aesthetic issues (D'Anna, 2013). The WTP estimates (CDN $13.30 [MCS] and $2.92 [WCS] per household per year for an improvement from fair aesthetic quality to good aesthetic quality) indicate that under MCS status quo conditions, respondents were at least somewhat interested in improving aesthetic quality. However, under the WCS status quo, this attribute was not significant, as respondents clearly made choices that reflected their preferences for improvements in the other two environmental attributes.

Respondents demonstrated that they value an improvement in environmental conditions much higher than an increase in salmon farming employment. Their willingness to pay for an increase in 500 salmon farming jobs was approximately CDN $5.00 per household per year (less than CDN $0.01 dollars per job) under both MNL models. A very small proportion of respondents had recently worked in the aquaculture industry (0.5%), so it is highly unlikely that respondents would be directly affected by an increase or decrease in salmon farming employment. Given the high proportion of urban residents in this sample, value derived from increases in coastal salmon farming employment may be considered 'non-use' in nature. Other DCE studies have demonstrated that when improvements in employment are 'non-use' in nature (i.e. – the respondent won't benefit directly or indirectly from this increase in jobs), it is the least important factor in respondent choice (Birol *et al.*, 2006).

6.1.2 WTP for Alternative Aquaculture Technologies

The WTP for an improvement in the environmental conditions surrounding salmon farms can also be extrapolated to estimate British Columbians' WTP for the adoption of alternative aquaculture systems. Given remaining scientific uncertainties regarding a) the current environmental conditions and b) the exact environmental improvements that could be brought about by new technologies, the results demonstrate a wide range of potential WTP for these alternative systems.

Our valuation estimates for the potential outcomes of IMTA development (Tables 27 and 28) range from CDN $92.18 (MCS) to $131.90 (WCS) per household year, based on certain assumptions regarding the environmental conditions and the level of coastal employment in salmon farming that would result. For example, these estimates make the assumption that IMTA adoption would lead to an increase in salmon farming jobs. If employment were to remain stable at 1500 FTE jobs, WTP decreases to CDN $77.76 (MCS) to $123.33 (WCS) per year. Conversely, research is currently conducted to determine whether IMTA can reduce sea lice numbers through bivalve ingestion of planktonic larvae (CIMTAN, 2015). If IMTA can reduce disease and parasite transfer risk to 'low risk', holding all other attributes at the levels presented in Tables 27 and 28, then WTP increases to CDN $115.75 (MCS) to $159.54 per household per year.

Our valuation estimates for the potential outcomes of CCA development (Tables 25 and 26) are based on the concept that this technology completely separates farmed salmon from the marine environment, thus removing any impacts to marine habitat quality and risk of disease and parasite transfer. It was also assumed that if the aquaculture industry in BC were to transition completely to using CCA technology, it would contract in size, based on current economic research of CCA regarding its costs and reduced staffing requirements (see Section 3.1.2). Under these assumptions, WTP estimates range from CDN $133.28 to $173.00 per household per year. Aesthetic quality was assumed to remain the same, since it is uncertain whether CCA would cause similar aesthetic issues or not. However, if aesthetic quality were to improve to 'good quality', WTP would increase to CDN $146.58 per household per year under MCS status quo, but remain the same under WCS status quo.

Specific WTP values for alternative technologies are predicated on assumptions made regarding the environmental outcomes that could result from their widespread adoption. However, British Columbians clearly place significant value on these environmental improvements. Implications for the salmon aquaculture industry and policy regarding salmon aquaculture are discussed in Section 6.3.

6.1.3 Lexicographic Preferences in Latent Classes

Marginal WTP estimates for each latent class (both MCS and WCS) are presented in Appendix 15. It is clear from examining the part-worth utilities and subsequent marginal WTP estimates that respondents of two of the latent classes, Serious Environmentalists and Tax Conscious, may have exhibited discontinuous, or lexicographic preferences, leading to unusable implicit price estimates (Campbell et al., 2008). According to Hoyos (2010), there is a basic assumption made in DCEs that there is unlimited substitutability between attributes. Lexicographic preferences occur when a respondent clearly values one attribute above all others, and is unwilling to make tradeoffs with other attributes (Spash, 2000). Therefore, even large improvements in attributes considered to be less important by a particular respondent would not be considered when making a choice amongst alternatives (Spash, 2000) Rosenberger *et al.* (2003, 63) stated that "[s]ome people may form their values in the context of a hierarchy; the structure of which being dependent upon the strength of the attitudes, beliefs, or dispositions they hold and the valuation context…she may express her preferences lexicographically—a general unwillingness to trade or accept compensation for changes in an environmental good." Under the WCS LCA model, lexicographic preferences were particularly pronounced. Serious Environmentalists dominantly valued improvements to disease and parasite transfer risk and marine habitat quality, with little to no consideration for the cost (via annual taxes). This led to a slightly positive, insignificant part-worth utility for the tax attribute. Conversely, the Tax Conscious latent class expressed a singular, dominant preference for no additional taxes, with insignificant part-worth utilities for all other attributes. This group clearly made choices based on the alternative that exhibited the lowest tax increase.

The causes and consequences of lexicographic preferences are varied. Lexicographic or discontinuous preferences have been attributed to several causes. One commonly cited cause is the complexity of choice experiments. Focusing on one or two attributes may be respondents' way of simplifying the choice task (Sælensminde, 2006; Hoyos, 2010). It could also be due to a DCE design where differences between attribute levels, or differences between alternatives, are too great (Sælensminde, 2006). However, as indicated by Rosenberger *et al.* (2003), a respondent may also exhibit true lexicographic preferences that are independent of the DCE. The presence of lexicographic preferences violates several key assumptions made in choice modelling, including the assumption that in each choice task, tradeoffs are made between all attributes, and irrespective of the presence of other alternatives. This means that there is a clear violation of the assumption of IIA (Sælensminde, 2006). Ultimately, the presence of lexicographic preferences can lead to incorrect valuation estimates, particularly in the case of environmental valuation since the choice task may be considered ethical versus economic in nature (Spash, 2000). According to Spash (2000, 196), where lexicographic preferences are present, "monetary values will fail to represent the values individuals associate with the environment, and interpreting responses as trade prices will result in misrepresentation of the motives that lay behind the stated WTP." Sælensminde, (2006) and Campbell et al. (2008) have attempted to address lexicographic or 'discontinuous' preferences using a multinomial error component logit model that allowed for the scale parameter to vary between continuous and discontinuous preferences (Campbell et al., 2008). The results demonstrated that the model performed much better, and provided WTP estimates that were sensitive to 'discontinuous' preferences. An extension of this research would be to use the alternative model specifications outlined by Sælensminde,

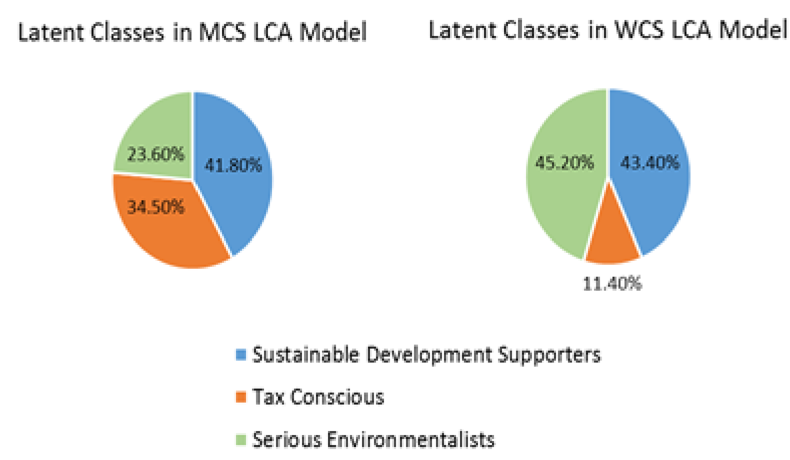
(2006) and Campbell et al. (2008) and determine how it affects model performance and WTP estimates.

6.2 The Impact of Status Quo on DCEs

Based on the results of the known-class analysis (Appendix 14), the status quo affects part-worth utilities significantly, but only for certain attributes. It was hypothesized that respondents who saw the WCS status quo would be willing to pay a high amount to move away from the status quo (indicated by a high ASC value), and less for subsequent improvements than those who saw the MCS status quo. The WCS status quo demonstrates to respondents that conditions could potentially be worse than anything captured within the model. For example, survey respondents who saw the WCS status quo (poor marine habitat quality) would be willing to pay less for a change in marine habitat quality from fair to good quality than would the respondents who saw the MCS status quo. Since the ‘fair quality’ attribute level already represented an improvement from the status quo in the WCS model, respondents didn’t value additional improvements quite as much as they would have had they seen the MCS status quo. Under the WCS status quo, it was determined that respondents value (are willing to pay) for improvements to aesthetic quality and employment numbers significantly less than they do under the MCS status quo. Respondents who were faced with the WCS status quo focused more strongly on those attributes they found to be the most important (based on part-worth utility), namely disease and parasite transfer risk and marine habitat quality.

While similar classes emerged in the two latent class models, the proportion of respondents placed in to each of the three classes shifted substantially between them. Under the WCS model, the ‘Serious Environmentalists’, who demonstrated the highest value for improvements in environmental attributes, class size increased from 23.6% to 45.2% of the sample. The opposite happened to those within the ‘Tax Conscious’ latent class. Under the MCS model, 34.5% of the sample were in the ‘Tax Conscious’ group, indicating that their main concern was preventing an increase in their taxes. However, under this model, the Tax Conscious latent class also showed some value in environmental improvements. Under the WCS model, most respondents fall within the other two latent classes, and only 11.4% of the sample remain in the class that principally values low taxes. Unlike the Tax Conscious group in the MCS model, this smaller group holds almost no value in environmental improvements. This demonstrates that even when faced with poor environmental conditions (such as were demonstrated in the WCS model), there remains a small proportion of a given population that still does not value any improvements in these environmental conditions. As status quo environmental conditions improve, the proportion of respondents who are WTP for further improvements decreases substantially.

Figure 6: Proportion of Respondents with Membership in Latent Classes – MCS vs. WCS Status Quo



6.3 Policy and Industry Implications for IMTA and CCA Technology Adoption in BC

The results of the DCE, as well as responses to questions about different policy options, have indicated that British Columbians would strongly support salmon aquaculture policy geared towards improving the industry's sustainability. While the most favored policy option among respondents was to create more stringent regulations, they were also highly supportive of government-funded initiatives that research, develop and encourage adoption of alternative aquaculture technologies.

The federal government has recognized this support, and has implemented a renewed Sustainable Aquaculture Program through Fisheries and Oceans Canada, which includes $54 million dollars in funding from 2013 to 2018 to improve the regulatory and governance system for the aquaculture industry in Canada (DFO, 2014c). The goal is to "create a transparent and efficient governance and regulatory system for Canadian aquaculture that has the confidence of the public, investors and markets as safeguarding public interest, protecting the environment and advancing industry competitiveness and sustainable growth (DFO, 2014c, 3rd para.)." It has also begun to support government-funded, collaborative research and development in to alternative aquaculture technologies. This research provides strong evidence for continued government funding of this research, as well as significant regulatory reform within the industry. It also justifies the revival of Fisheries and Oceans Canada's Aquaculture Innovation and Market Access Program (2008-2013), which provided funding for non-profit organizations and private companies to develop and adopt innovate technologies and management techniques (DFO, 2014c).

This research has indicated that the average adult British Columbian is at least somewhat aware of salmon aquaculture in British Columbia, and the environmental issues associated with the industry. Furthermore, most British Columbians have learned about salmon aquaculture through news stories and other media, rather than first-hand experience with salmon farms, or via information disseminated by the salmon farming industry. Results also indicate that British Columbians believe that salmon aquaculture is currently having a negative impact on the current environmental conditions around salmon farms, based on their perception of the status quo.

As previously mentioned, the salmon farming industry has faced strong criticism and opposition in the province, including large-scale, organized protests, boycotts and sabotage. This research has demonstrated that over two-thirds (69.5%) of British Columbians currently believe that there is a moderate to high risk of disease and parasite transfer between farmed and wild salmon, and over half (55.4%) described the marine habitat quality around salmon farms as poor or fair. In an FAO report on aquaculture governance, it is stated that "Long-term prosperity is predicated on fulfilling the four prerequisites for sustainable aquaculture development: technological soundness, economic viability, environmental integrity and social licence (Hishamunda *et al.*, 2012, 236)." The salmon aquaculture industry in British Columbia is struggling to obtain a social licence in British Columbia, largely due to the negative perception that British Columbians have regarding the industry's potential environmental impacts.

Therefore, there exist clear incentives for the salmon farming industry to adopt alternative aquaculture technologies in order to improve their stability and profitability, and for the government to provide funds to help them do so.

This research could also be used in future financial analyses for alternative aquaculture systems, to include any positive externalities generated by the improvements in environmental conditions that they may bring about. To-date, financial analyses of these systems have only included private costs and benefits accrued to the aquaculture companies that implement these systems (Ridler *et al.*, 2007; DFO, 2010). Recent research has demonstrated that IMTA increases benefits to producers through product diversification (Ridler, 2007; Kitchen, 2011), increases consumers WTP for the more sustainable product (Yip, 2012). This research, as well as the contingent valuation study conducted by Martínez-Espiñeira *et al.* (2012, 2015), estimate the social benefits of a reduction in the potential environmental effects of conventional net-cage salmon farms. If the results of these studies were incorporated in to future financial analyses, it would demonstrate an increase both the private profitability of IMTA, and in the social benefits of its implementation. This could encourage adoption of alternative technologies for companies who are concerned about the profitability of these systems.

6.4 Limitations of Research

One of the major limitations of this research, from a valuation standpoint, was the lack of a scientifically-accepted status quo for the environmental conditions surrounding salmon aquaculture operations. While this research examined the effect that status quo had on part-worth utility, our WTP values are based on hypothetical future status quos, versus the actual current environmental conditions. Status quo can have a major impact on WTP/utility estimates in DCEs (Marsh *et al.*, 2011; Dean, 2008).

There is also uncertainty regarding how adoption of alternative technologies will actually influence the surrounding coastal environment. Therefore, WTP estimates are based on a number of assumptions regarding the positive environmental improvements caused by different policy options aimed at encouraging adoption of alternative aquaculture technologies. If those improvements are not realized upon adoption of these technologies, then these valuation results can’t be considered valid.

Another limitation of this research related to the scientifically-complex nature of the environmental effects of salmon aquaculture. It was necessary to strike a balance between a) conveying enough information to allow for a full understanding of the issue, and b) increasing the cognitive burden of the DCE, and the survey instrument as a whole. The levels of each environmental attribute within the DCE were defined qualitatively (e.g. poor quality, fair quality, good quality, very good quality). This can result in less accurate valuation results, since there is some level of interpretation/ subjectivity in respondent’s interpretation of each level.

A marketing research company, Research Now, was used for survey participant recruitment. While they are able to provide a sample that is close to representative of the survey’s target population, the respondents represent a subset of the BC population that are willing to spend their free time participating in online surveys. The demographic differences, which are outlined in Section 5.1.1, could be addressed through the use of sampling weights to ensure the sample matches the population from a demographic standpoint. The use of Research Now may also have introduced bias or errors in to the survey results, since there were likely respondents who chose answers at random for the sole purpose of gaining ‘rewards points’ given out by Research Now. A number of these respondents were removed based on time restrictions and response patterns, however there were likely some that remained within the useable sample.

6.5 Recommendations for Future Research

One of the major barriers to IMTA and CCA adoption is uncertainty regarding the private profitability of alternative aquaculture systems. However, this research demonstrates that there are social benefits to alternative aquaculture systems that need to be considered. A more holistic cost-benefit analysis for alternative aquaculture systems that incorporated these benefits, as well as other financial parameters in to its analysis, would likely provide a much more positive result then if these systems are looked at exclusively from a private profitability standpoint.

Based on the results of this survey, there is clear indication that British Columbians would like to see a change in the policy and governance structures currently in place for salmon aquaculture in the province. A more in-depth analysis of policy options for salmon aquaculture would be a useful tool for future regulatory change.

Finally, a more in-depth analysis of the effects to WTP from the two different status quos could be conducted. The known class analysis conducted in this study provides preliminary results, but a more comprehensive methodology would provide more clarity and detail regarding status quo effects. One alternative method of examining the effect of status quo would be to use respondents' identified perception of the status quo as the status quo used in the DCE (Glenk, 2011). Doing so would address issues related to an uncertain status quo, and allow respondents' perceptions to play a role in establishing preferences.

Chapter 7: Conclusion

Salmon farming has been an engine of economic development for the province of British Columbia. However, its growth has been hindered by the controversy surrounding its potential environmental impacts. Alternative aquaculture systems, including IMTA and CCA, present an opportunity for the industry to improve its sustainability and achieve social license. However, the private profitability of these systems has been called in to question. While recent research has demonstrated that IMTA may provide additional benefits to both producers and consumers of IMTA products, this research attempted to address whether there were additional external benefits accrued to society resulting from the adoption of alternative aquaculture systems such as IMTA. This research used a DCE to determine what British Columbians are WTP for the environmental improvements that could result from this adoption. Given the controversy surrounding the current environmental impact of salmon farming, it also examined the effect that the status quo has on WTP. Finally, it examined British Columbians preferences and perceptions of alternative aquaculture systems in the province.

Based on assumptions regarding the environmental outcomes of their widespread adoption, it can be inferred that British Columbians are WTP between CDN $77.76 and $159.54 per household per year to fund IMTA development, and $133.28 to $173.00 per household per year to fund CCA development, Using the more conservative figures, this translates to a provincial WTP of CDN $143 million dollars and 245 million per year for IMTA and CCA for the province of British Columbia, based on current population estimates[31].

The two status quos used in the DCE produced significantly different results for certain attributes. The ASC, as well as the attribute for employment in salmon farming and aesthetic quality were all found to be significantly different using a known class model. Furthermore, the large difference in the coefficients for the ASC led to significantly different WTP results. Finally, the status quo was found to have a significant effect on latent class membership, and affected the choice behavior of each class.

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[31] This is based on a population of 4.6 million British Columbians, with an average household size of 2.5.

Based on the results of this study, British Columbians are concerned about the potential environmental impacts of salmon farming in the province, and are in favor of government policy aimed at improving the industry's sustainability. This includes funding research and development of alternative aquaculture technologies, and subsidizing companies that adopt these alternative technologies. Furthermore, while respondents are favorable about both IMTA and CCA technologies, British Columbians are currently more knowledgeable and more supportive of CCA technology when compared to IMTA technology.

This research provides incentive for the government and the salmon farming industry to work together towards the adoption of more sustainable aquaculture technologies in British Columbia. Doing so would ensure that industry can continue to expand with increased support of British Columbians, and ensure that the province's coastal environment is protected for future generations.

Work Cited

Adamowicz, W., Boxall, P., Williams, M., & Louviere, J. (1998). Stated-preference approaches for measuring passive use values: choice experiments and contingent valuation. *American journal of agricultural economics*, *80*(1), 64-75.

Álvarez-Farizo, B., & Hanley, N. (2002). Using conjoint analysis to quantify public preferences over the environmental impacts of wind farms. An example from Spain. *Energy policy*, *30*(2), 107-116.

Apostle, R. (2012). Closed–containment aquaculture in Atlantic Canada. *Maritime Studies*, *11*(1), 1-17.

Atkins, J. P., Burdon, D., & Allen, J. H. (2007). An application of contingent valuation and decision tree analysis to water quality improvements. *Marine pollution bulletin*, *55*(10), 591-602.

Axsen, J., Mountain, D. C., & Jaccard, M. (2009). Combining stated and revealed choice research to simulate the neighbor effect: The case of hybrid-electric vehicles. *Resource and Energy Economics*, *31*(3), 221-238.

Ayers, Nathan W. and Peter H. Tyedmers (2009). Assessing alternative aquaculture technologies: life cycle assessment of salmonid culture systems in Canada. *The Sustainability of Seafood Production and Consumption* 17(3): 362-373.

Barbier, E. B. (1994). Valuing environmental functions: tropical wetlands. *Land economics*, 155-173.

BC Ministry of Agriculture (2013). 2012 British Columbia Seafood Industry Year in Review. Retrieved from <http://www.agf.gov.bc.ca/stats/YinReview/Seafood-YIR-2012.pdf>

BC Salmon Farmers Association (BCSFA) (2013). Report on the Marine Mammal Workshop: March 19th 2013. Retrieved from < http://www.salmonfarmers.org/sites/default/files/marine_mammal_workshop_ report.pdf>

BC Salmon Farmers Association (BCSFA) (2009). Closed Containment. *BC Salmon Farmers Association Website*. Retrieved from < http://www.salmonfarmers.org/sites/default/files/research-resources/closed_containment.pdf>

Beamish, R.J., Neville, C.M., Sweeting, R.M., Ambers, N.J. (2005). Sea lice on adult Pacific salmon in the coastal waters of Central British Columbia. *Fisheries Research* 76, 198-208

Beamish, R.J., Neville, C.M., Sweeting, R.M., Jones, S.R.M., Ambers, N., Gordon, E.K., Hunter, K.L., and McDonald, T.E. (2007). A proposed life history strategy for the salmon louse, Le-peophtheirus salmonis, in the subarctic Pacific. *Aquaculture*, 264(1–4), 428–440.

Birol, E., Karousakis, K., & Koundouri, P. (2006). Using a choice experiment to account for preference heterogeneity in wetland attributes: the case of Cheimaditida wetland in Greece. *Ecological economics*, *60*(1), 145-156.

Boulet, David, Alistair Struthers and Eric Gilbert (2010). Feasibility Study of Closed-Containment Options for the British Columbia Aquaculture Industry. *Fisheries and Oceans Canada Website*. Retrieved from <http://www.dfo-mpo.gc.ca/aquaculture/lib-bib/nasapi-inpasa/BC-aquaculture-CB-eng.pdf>

Boxall, P. C., Adamowicz, W. L., Swait, J., Williams, M., & Louviere, J. (1996). A comparison of stated-preference methods for environmental valuation. *Ecological economics*, *18*(3), 243-253.

Boxall, P. C., & Adamowicz, W. L. (2002). Understanding heterogeneous preferences in random utility models: a latent class approach. *Environmental and resource economics*, *23*(4), 421-446.

Bright, Doug and Scott Dionne (2005). Use of Emamectin Benzoate in the Canadian Finfish Aquaculture Industry. *Environment Canada*. Retrieved from < http://publications.gc.ca/collections/Collection/En4-51-2005E.pdf>

Boxall, P., Adamowicz, W. L., & Moon, A. (2009). Complexity in choice experiments: choice of the status quo alternative and implications for welfare measurement*. *Australian Journal of Agricultural and Resource Economics*, *53*(4), 503-519.

Brooks, K.M. (2005). The effects of water temperature, salinity, and currents on the survival and distribution of the infective copepodid stage of sea lice (Lepeophtheirus salmonis) originating on Atlantic salmon farms in the Broughton Archipelago of British Columbia. *Canadian Reviews in Fisheries Sciences* 13(3), 177–204.

Brooks, K. M., Stierns, A. R., Mahnken, C. V., & Blackburn, D. B. (2003). Chemical and biological remediation of the benthos near Atlantic salmon farms. *Aquaculture*, *219*(1), 355-377.

Brown Jr, G., & Mendelsohn, R. (1984). The hedonic travel cost method. *The review of economics and statistics*, 427-433.

Burridge, Les, Judith S. Weis, Felipe Cabello, Jaime Pizarro, Katherine Bostick (2010). Chemical use in salmon aquaculture: A review of current practices and possible environmental effects. *Aquaculture* 306(1-4), 7-23.

Burrows, Matthew (2011). Alexandra Morton applauds B.C.'s first closed fish-farming tank. *Georgia Strait*. Retrieved from: <http://www.straight.com/article-368815/vancouver/alexandra-morton-applauds-bcs-first-closed-fishfarming-tank>

Callier, M. D., Lefebvre, S., Dunagan, M. K., Bataille, M. P., Coughlan, J., & Crowe, T. P. (2013). Shift in benthic assemblages and organisms' diet at salmon farms: community structure and stable isotope analyses. *Marine ecology. Progress series*, *483*, 153-167.

Colombo, S., Hanley, N., & Calatrava-Requena, J. (2005). Designing Policy for Reducing the Off-farm Effects of Soil Erosion Using Choice Experiments. *Journal of Agricultural Economics*, *56*(1), 81-95.

Campbell, D., Hutchinson, W. G., & Scarpa, R. (2008). Incorporating discontinuous preferences into the analysis of discrete choice experiments.*Environmental and resource economics*, *41*(3), 401-417.

Canadian Aquaculture Industry Alliance (CAIA; 2012). Canadian Farmed Salmon*. Canadian Aquaculture Industry Alliance Website.* Retrieved from <http://www.aquaculture.ca/files/species-salmon.php>

Canadian Food Inspection Agency (CFIA; 2012). Salmon Disease Surveillance in British Columbia – Backgrounder. *Canadian Food Inspection Agency Website*. Retrieved from <http://www.inspection.gc.ca/animals/aquatic-animals/diseases/reportable/isa/backgrounder/eng/1330100651673/1330100817464>

Carlsson, Fredrik and Peter Martinsson (2001). Do Hypothetical and Actual Marginal Willingness to Pay Differ in Choice Experiments? *Journal of Environmental Economics and Management* 41, 179-192.

Carson, R. (2011). Contingent valuation: a comprehensive bibliography and history. UK: Edward Elgar Publishing.

Caussade, Sebastian, Juan de Dios Ortúzar, Luis I. Rizzi, David A. Hensher (2005). Assessing the influence of design dimensions on stated choice experiment estimates. *Transportation Research Part B: Methodological* 39(7), 621-640.

Chadwick, E.M.P., Parsons, G. Jay, Sayavong, Boumy (2010). Evaluation of closed-containment technologies for saltwater salmon aquaculture. Ottawa: National Research Council of Canada Research Press.

Chae, Dong-Ruyl Premachandra and Sean Pascoe Wattage (2012) Recreational benefits from a marine protected area: A travel cost analysis of Lundy. Tourism Management 33(4): 971-977.

Champ, Patricia and Richard Bishop (2006). Is Willingness to Pay for a Public Good Sensitive to the Elicitation Format? Land Economics 82(2):162-173.

Champ, P.A., K.J. Boyle, and T.C. Brown, editors. (2003). *A Primer on Non-market Valuation*. Netherlands : Kluwer Academic Publishers.

Chang, B. D., Page, F. H., & Losier, R. J. (2013). Variables affecting sediment sulfide concentrations in regulatory monitoring at salmon farms in the Bay of Fundy, Canada. *Aquaculture Environment Interactions*, *3*(4), 67-79.

Chopin, T., Buschmann, A. H., Halling, C., Troell, M., Kautsky, N., Kraemer, G. P., Zertuche-gonzález, J. A., *et al.* (2001). Integrating Seaweeds in to Marine Aquaculture Systems: A Key Toward Sustainability. Science 986, 975-986

Coletto, David, Di Francesco, Lydia and Morrison, Jaime (2011). Seafood Survey: Public Opinion on Aquaculture and a National Aquaculture Act. Prepared for the Canadian Aquaculture Industry Alliance (CAIA). Retrieved from <http://www.aquaculture.ca/files/CAIA-PUBLIC-REPORT-May-2011.pdf>

Canadian Integrated Multi-Trophic Aquaculture Network (CIMTAN, 2015). Research Projects: Can filter-feeding bivalves ingest planktonic sea lice, leading to reduced lice numbers on cultivated salmon? (D1P6). *CIMTAN Website*. Retrieved from: <http://www.cimtan.ca/project_d1p6>

Clawson, Marion and Jack Knetsch (1966). Economics of Outdoor Recreation. Baltimore, Maryland: The John Hopkins Press.

D'Anna, Linda (2013). Baynes Sound Opinion Survey on Shellfish Aquaculture: Findings. Vancouver Island University: Institute for Coastal Research. Retrieved from <http://www.viu.ca/icr/files/2012/06/Baynes-Sound-Opinion-Survey-on-Shellfish-Aquaculture-Report-20130927.pdf>

David Suzuki Foundation (2014). Closed Containment is Affordable. *David Suzuki Foundation Website.* Retrieved from <http://www.davidsuzuki.org/issues/oceans/science/sustainable-fisheries-and-aquaculture/closed-containment-is-affordable/>

Dean, M. (2008). Status quo bias in large and small choice sets. *Job Market Paper*. Retrieved from <http://www.econ.brown.edu/fac/mark_dean/Working_Paper_4.pdf>

Dimitropoulos, A., & Kontoleon, A. (2009). Assessing the determinants of local acceptability of wind-farm investment: A choice experiment in the Greek Aegean Islands. *Energy policy*, *37*(5), 1842-1854.

Dill, L.M. (2011). Impacts of salmon farms on Fraser River sockeye salmon: results of the Dill investigation. *Cohen Commission Technical Report 5D*.

Domínguez-Torreiro, M., & Soliño, M. (2011). Provided and perceived status quo in choice experiments: Implications for valuing the outputs of multifunctional rural areas. *Ecological Economics*, *70*(12), 2523-2531.

Dunlap, R. E., Van Liere, K. D., Mertig, A. G., & Jones, R. E. (2000). New trends in measuring environmental attitudes: measuring endorsement of the new ecological paradigm: a revised NEP scale. *Journal of social issues*, *56*(3), 425-442.

Ecoplan International Inc. (2008). Global Assessment of Closed System Aquaculture. Prepared for the Coastal Alliance for Aquaculture Reform. Retrieved from <http://www.farmedanddangerous.org/wp-content/uploads/2011/01/ClosedSystemAqua-FINAL.pdf>

Ekeland, I., Heckman, J. and Neshelm, L. (2004). Identification and Estimation of Hedonic Models. *Journal of Political Economy*, 112, No. S1, Papers in Honor of Sherwin Rosen: A Supplement to Volume 112 (February 2004), S60-S109

ESSA Ltd. (1992). A Review of Salmon Farming in British Columbia. Prepared for the Ministry of Agriculture, Fisheries and Food. Retrieved from <http://www.for.gov.bc.ca/hfd/library/documents/bib92835.pdf>

Fisher, A. C., Volpe, J. P., & Fisher, J. T. (2014). Occupancy dynamics of escaped farmed Atlantic salmon in Canadian Pacific coastal salmon streams: implications for sustained invasions. *Biological Invasions*, 1-10.

Fisheries and Oceans Canada (DFO; 2014a). Aquaculture in British Columbia. *Fisheries and Oceans Canada Website*. Retrieved from http://www.pac.dfo-mpo.gc.ca/aquaculture/index-eng.html

Fisheries and Oceans Canada (DFO; 2014b). Public Reporting on Aquaculture – Marine Mammals. *Fisheries and Oceans Canada Website.* Retrieved from < http://www.pac.dfo-mpo.gc.ca/aquaculture/reporting-rapports/mar_mamm-eng.html>

Fisheries and Oceans Canada (DFO; 2014c). Canada's Sustainable Aquaculture Program. *Fisheries and Oceans Canada Website*. Retrieved from < http://www.dfo-mpo.gc.ca/aquaculture/programs-programmes/sustainable-durable/index-eng.htm>

Fisheries and Oceans Canada (DFO; 2013a). Farming the Seas – A Timeline. *Fisheries and Oceans Canada Website.* Retrieved from < http://www.dfo-mpo.gc.ca/aquaculture/sector-secteur/frm-tml-eng.htm>

Fisheries and Oceans Canada (DFO; 2013b). Fish Health Management. *Fisheries and Oceans Canada Website*. Retrieved from < http://www.pac.dfo-mpo.gc.ca/aquaculture/reporting-rapports/health-sante-eng.html>

Fisheries and Oceans Canada (DFO; 2013c). Scientific Research on Integrated Multi-Trophic Aquaculture. *Fisheries and Oceans Canada Website*. Retrieved from: < http://www.dfo-mpo.gc.ca/aquaculture/sci-res/imta-amti/res-eng.htm>

Fisheries and Oceans Canada (DFO; 2011). Aquaculture in British Columbia. *Fisheries and Oceans Canada Website*. Retrieved from < http://www.pac.dfo-mpo.gc.ca/publications/pdfs/aqua_mgmt-gest_aqua-eng.pdf.>

Fisheries and Oceans Canada (DFO; 2012). Assessment of the Fate of Emamectin Benzoate, the Active Ingredient in SLICE®, near Aquaculture Facilities in British Columbia and its Effect on Spot Prawns (Pandalus platyceros). Canadian Science Advisory Secretariat Science Advisory Report 2011/082.

Fisheries and Oceans Canada. (2010). Economic study of closed-containment options for the Canadian aquaculture industry. Quebec: Fisheries and Oceans Canada

Font, A. R. (2000). Mass tourism and the demand for protected natural areas: a travel cost approach. *Journal of Environmental Economics and Management*,*39*(1), 97-116.

Foster, V., & Mourato, S. (2003). Elicitation format and sensitivity to scope. *Environmental and Resource Economics*, *24*(2), 141-160.

Furnham, A., & Boo, H. C. (2011). A literature review of the anchoring effect. *The Journal of Socio-Economics*, *40*(1), 35-42.

Gates, Jodie (2007). Public Support for Climate Justice: A Survey of British Columbian Residents. Master's Thesis. Retrieved from < https://circle.ubc.ca/handle/2429/35919>

Giles, H. (2008). Using Bayesian networks to examine consistent trends in fish farm benthic impact studies. *Aquaculture*, *274*(2), 181-195.

Glenk, K., Lago, M., & Moran, D. (2011). Public preferences for water quality improvements: implications for the implementation of the EC Water Framework Directive in Scotland. *Water Policy*, *13*(5), 645-662.

Gough, Joseph (2010). The Environmental Impacts of Salmon Aquaculture in Passamaquoddy Bay, New Brunswick. Petition to the Auditor General of Canada: Environment and Sustainable Development. Retrieved from < http://www.oag-bvg.gc.ca/internet/english/pet_300_e_34331 .html>

Greene, W. H., & Hensher, D. A. (2003). A latent class model for discrete choice analysis: contrasts with mixed logit. *Transportation Research Part B: Methodological*, *37*(8), 681-698.

Hanley, N. (1988). Using contingent valuation to value environmental improvements. *Applied Economics*, *20*(4), 541-549.

Hanley, Nick, Robert E. Wright and Vic Adamowicz (1998). Using Choice Experiments to Value the Environment: Design Issues, Current Experience and Future Prospects. *Environmental and Resource Economics* 11(3-4), 413-428.

Hanley, N., Mourato, S., & Wright, R. E. (2001). Choice Modelling Approaches: A Superior Alternative for Environmental Valuation? *Journal of economic surveys*, *15*(3), 435-462.

Hanley, N., & Barbier, E. (2009). *Pricing nature: cost-benefit analysis and environmental policy*. UK: Edward Elgar Publishing.

Hanemann, W. M. (1994). Valuing the environment through contingent valuation. *The Journal of Economic Perspectives*, 19-43.

Hargrave, B.T. (2003). Far-field Environmental Effects of Marine Finfish Aquaculture. In A Scientific Review of the Potential Environmental Effects of Aquaculture in Aquatic Ecosystems – Volume 1. *Fisheries and Oceans Canada Website.* Retrieved from <http://www.dfo-mpo.gc.ca/science/enviro/aquaculture/sok-edc/volume1/hargrave-eng.htm>

Haya, K., Burridge, L. E., and Chang, B. D. (2001). Environmental impact of chemical wastes produced by the salmon aquaculture industry. *ICES Journal of Marine Science*, 58: 492–496.

Hensher, D. A., Rose, J. M., & Greene, W. H. (2005). *Applied Choice Analysis.* New York: Cambridge University Press.

Hishamunda, N., Ridler, N., Bueno, P., Satia, B., Kuemlangan, B., Percy, D., Gooley, G., Brugere, C. & Sen, S. 2012. Improving aquaculture governance: what is the status and options? *In* R.P. Subasinghe,

Arthur, J.R. , D.M. Bartley, S.S. De Silva, M. Halwart, N. Hishamunda, C.V. Mohan & P. Sorgeloos, eds. *Farming the Waters for People and Food.* Proceedings of the Global Conference on Aquaculture 2010, Phuket,Thailand. 22–25 September 2010.. 233–264.

Hoyos, D. (2010). The state of the art of environmental valuation with discrete choice experiments. *Ecological economics*, *69*(8), 1595-1603.

Jolliffe, I. (2002). *Principal component analysis*. New York: John Wiley & Sons, Ltd.

Kahneman, D., & Knetsch, J. L. (1992). Valuing public goods: the purchase of moral satisfaction. *Journal of environmental economics and management*, *22*(1), 57-70.

Kaoru, Y., Smith, V. K., & Liu, J. L. (1995). Using random utility models to estimate the recreational value of estuarine resources. *American Journal of Agricultural Economics*, *77*(1), 141-151.

Kataria, M., Bateman, I., Christensen, T., Dubgaard, A., Hasler, B., Hime, S., & Nissen, C. (2012). Scenario realism and welfare estimates in choice experiments–A non-market valuation study on the European water framework directive. *Journal of environmental management*, *94*(1), 25-33.

Koundouri, P., Kountouris, Y., & Remoundou, K. (2009). Valuing a wind farm construction: a contingent valuation study in Greece. *Energy Policy*, *37*(5), 1939-1944.

Krkosek, M., Lewis, M. a, & Volpe, J. P. (2005). Transmission dynamics of parasitic sea lice from farm to wild salmon. *Proceedings. Biological sciences / The Royal Society*, *272*(1564), 689-696

Krutilla, J. V. (1967). Conservation reconsidered. *The American Economic Review*, 777-786.

Kuhfeld, Warren (2010). Experimental Design: Efficiency, Coding, and Choice Design. Technical Note. SAS Business Analytics Inc. Retrieved from <https://support.sas.com/techsup/technote/mr2010c.pdf>

Lancaster, K. J. (1966). A new approach to consumer theory. *The journal of political economy*, 132-157.

Lanz, B., & Provins, A. (2012). Do status quo choices reflect preferences? Evidence from a discrete choice experiment in the context of water utilities' investment planning (No. 12-87). *CEPE Center for Energy Policy and Economics, ETH Zurich.*

Legislative Assembly of British Columbia (2007). Special Committee on Sustainable Aquaculture: Final Report. Retrieved from < http://www.leg.bc.ca/CMT/38thparl/session-3/aquaculture/reports/Rpt-AQUACULTURE-38-3-2007-MAY-16.htm>

LiveSmart BC (2014). Incentive and Rebate Programs. LiveSmart BC Website. Retrieved from <http://www.livesmartbc.ca/incentives/index.html>

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*(1), 103-117.

Louviere, J., Hensher, D., & Swait, J. (2000). *Stated Choice Methods: Analysis and Applications.* New York: Cambridge University Press.

Luce, R. D. Individual choice behavior. New York: Wiley, 1959.

MacDonald, B. A., Robinson, S., & Barrington, K. A. (2011). Feeding activity of mussels (< i> Mytilus edulis</i>) held in the field at an integrated multi-trophic aquaculture (IMTA) site and exposed to fish food in the laboratory. *Aquaculture*, *314*(1), 244-251.

Magidson, Jay and Jeroen Vermunt (2003). A Nontechnical Introduction to Latent Class Models. *Statistical Innovations.* Retrieved from: <http://www.statisticalinnovations.com /articles/ lcmodels2.pdf>

Marsh, D., Mkwara, L., & Scarpa, R. (2011). Do Respondents' Perceptions of the Status Quo Matter in Non-Market Valuation with Choice Experiments? An Application to New Zealand Freshwater Streams. *Sustainability*, *3*(9), 1593-1615.

Martínez-Espiñeira, R., Chopin T., Robinson, S., Noce, A.Yip, W. and Knowler, D. (2012). Estimation of the biomitigation benefits of Integrated Multitrophic Aquaculture in Canada. Unpublished. St. John's, NL: Memorial University of Newfoundland.

Martínez-Espiñeira, R., Chopin, T., Robinson, S., Noce, A., Knowler, D., & Yip, W. (2015). Estimating the biomitigation benefits of Integrated Multi-Trophic Aquaculture: A contingent behavior analysis. *Aquaculture*, *437*, 182-194.

McFadden, D. (1986). The choice theory approach to market research.*Marketing science*, *5*(4), 275-297.

Meuser, Emily Margaret (2011). Conservation priorities, policy and public opinion in British Columbia. Master's Thesis. Retrieved from < http://summit.sfu.ca/item/12198>

Morton A, Routledge RD, Peet C, and Ladwig A. (2004) Sea lice (*Lepeophtheirus salmonis*) infection rates on juvenile pink (*Oncorhynchus gorbuscha*) and chum (*Oncorhynchus keta*) salmon in the nearshore marine environment of British Columbia, Canada. Canadian Journal of Fisheries and Aquatic Sciences 61, 147-157

Muir, J.F., Brugère, C., Young, J.A. & Stewart, J.A. 1999. The solution to pollution? The value and limitations of environmental economics in guiding aquaculture development. *Aquaculture Economics and Management*, 3(1), 42-57

'Nagmis First Nation. KUTERRA Land-Based Closed Containment Salmon Farm. 'Nagmis First Nation Website. Retrieved from: <http://www.namgis.bc.ca/CCP/Pages/default.aspx>

Nash, C. E., Iwamoto, R. N., & Mahnken, C. V. (2000). Aquaculture risk management and marine mammal interactions in the Pacific Northwest.*Aquaculture*, *183*(3), 307-323.

Naylor, Rosamond, Rebecca J. Goldburg, Jurgenne H. Primavera, Nils Kautsky, Malcolm C. M. Beveridge, Jason Clay, Carl Folke, Jane Lubchenco, Harold Mooney & Max Troell (2000). Effect of aquaculture on world fish supplies. *Nature* 405, 1017-1024.

Nguyen, Thai and Tim Williams (2013). Aquaculture in Canada. Library of Parliament Background Paper (Publication no. 2013-12-E) Retrieved from <http://www.parl.gc.ca/Content/LOP/ResearchPublications/ 2013-12-e.htm>

Noakes, D.J. (2011). Impacts of salmon farms on Fraser River sockeye salmon: results of the Noakes investigation. Cohen Commission Tech. Rept. 5C. Retrieved from <http://www.watershed-watch.org/wordpress/wp-content/uploads/2012/07/Exh-1536-NonRT.pdf>

Noakes, D.J., R.J. Beamish and R. Gregory (2002). British Columbia's Commercial Salmon Industry. North Pacific Anadromous Fish Commission (NPAFC Doc. No. 642). Retrieved from http://www.richardbeamish.com/uploads/1/6/0/0/16007202/npafc642canada.pdf

Nobre, A. M., Robertson-Andersson, D., Neori, A., & Sankar, K. (2010). Ecological–economic assessment of aquaculture options: comparison between abalone monoculture and integrated multi-trophic aquaculture of abalone and seaweeds. *Aquaculture*, *306*(1), 116-126.

Ocean Coordinating Committee (2007). BC's Ocean Economy: Link to our Past, Bridge to our Future. Retrieved from <http://www.env.gov.bc.ca/omfd/reports/BCs-Ocean-Economy.pdf>

Othman, J., Bennett, J., & Blamey, R. (2004). Environmental values and resource management options: a choice modelling experience in Malaysia.*Environment and Development Economics*, *9*(06), 803-824.

Price, M. H. H., Morton, a., & Reynolds, J. D. (2010). Evidence of farm-induced parasite infestations on wild juvenile salmon in multiple regions of coastal British Columbia, Canada. *Canadian Journal of Fisheries and Aquatic Sciences*, *67*(12), 1925-1932.

PriceWaterhouseCoopers LLC. (2009). Profile of the BC Farmed Salmon Industry in 2008. Prepared for the BC Salmon Farmers Association. Retrieved from< http://www.salmonfarmers .org/sites/default/files/research-resources/ 2008_ industryprofile _pwc.pdf>

Research Now (2015). About Us. *Research Now Website.* Retrieved from <http://www.researchnow.com/en-CA/AboutUs.aspx>

Ridler, N., Wowchuk, M., Robinson, B., Barrington, K., Chopin, T., Robinson, S., *et al.* (2007). Integrated multi-trophic aquaculture (IMTA): a potential strategic choice for farmers. Aquaculture Economics & Management , 11 (1), 99-110.

Rosenberger, R. S., Peterson, G. L., Clarke, A., & Brown, T. C. (2003). Measuring dispositions for lexicographic preferences of environmental goods: integrating economics, psychology and ethics. *Ecological Economics*, *44*(1), 63-76.

Sælensminde, K. (2006). Causes and consequences of lexicographic choices in stated choice studies. *Ecological Economics*, *59*(3), 331-340.

Saksida, S. M., Greba, L., Morrison, D., & Revie, C. W. (2011). Sea lice on wild juvenile Pacific salmon and farmed Atlantic salmon in the northernmost salmon farming region of British Columbia. *Aquaculture*, *320*(3), 193-198.

Savage, Scott and Donald Waldman (2008). Learning and fatigue during choice experiments: a comparison of online and mail survey modes. *Journal of Applied Econometrics* 23(3), 351-371.

SeaVision Group (2015). About Us. *Cascadia Seafoods Website.* Retrieved from: <http://www.seavisiongroup.ca/cascadia/about-us>

Semeniuk, C. A., Haider, W., Beardmore, B., & Rothley, K. D. (2009). A multi-attribute trade-off approach for advancing the management of marine wildlife tourism: a quantitative assessment of heterogeneous visitor preferences.*Aquatic Conservation: Marine and Freshwater Ecosystems*, *19*(2), 194-208.

Shen, J. (2009). Latent class model or mixed logit model? A comparison by transport mode choice data. *Applied Economics*, *41*(22), 2915-2924.

Spash, C. L. (2000). Ecosystems, contingent valuation and ethics: the case of wetland re-creation. *Ecological economics*, *34*(2), 195-215.

Stroomer, Chad, Miriam Wilson (2012). British Columbia's Fisheries and Aquaculture Sector, 2012 Edition. Prepared for Fisheries and Oceans Canada by BC Stats. Retrieved from <http://www.bcstats.gov.bc.ca/aboutus/news/13-01 29/British_Columbia_s_Fisheries_and_Aquaculture_ Sector.aspx>

Swait, J., & Adamowicz, W. (2001). The influence of task complexity on consumer choice: a latent class model of decision strategy switching. *Journal of Consumer Research*, *28*(1), 135-148.

Tacon, Albert G.J. and Marc Metian (2008). Global overview on the use of fish meal and fish oil in industrially compounded aquafeeds: Trends and future prospects. *Aquaculture* 285(1-4), 146-158.

Taylor, Mike (2011). The existence value of Hawaiian coral reefs under conditions of climate changes. Masters thesis. Simon Fraser University. Retrieved from: < file:///C:/Users/HP%20USER/Downloads /etd6454_MTaylor.pdf>

Tyrväinen, L. (1997). The amenity value of the urban forest: an application of the hedonic pricing method. *Landscape and Urban planning*, *37*(3), 211-222.

Vermunt, J. K., & Magidson, J. (2002). Latent class cluster analysis. *Applied latent class analysis*, *11*, 89-106.

Vermunt, J.K. (2005). Technical Guide for Latent Gold 4.0: Basic and Advanced. Retrieved from <www.statisticalinnovations.com/products/LGtechnical.pdf>

Volpe, E Taylor, D Rimmer, B Glickman (2000). Evidence of natural reproduction of aquaculture-escaped Atlantic salmon in a coastal British Columbia River. *Conservation Biology* 14, 899-903.

Waknitz, RN Iwamoto, MS Strom (2003). Interactions of Atlantic salmon in the Pacific Northwest IV: Impacts on local ecosystems. *Fisheries Research* 62, 307-328.

Wang, X., Olsen, L. M., Reitan, K. I., & Olsen, Y. (2012). Discharge of nutrient wastes from salmon farms: environmental effects, and potential for integrated multi-trophic aquaculture. *Aquaculture Environment Interactions*, *2*(3), 267-283.

Watson, Tom (2011). Questions and Answers on Salmon Aquaculture in British Columbia. Retrieved from < http://www.salmonfarmers.org/sites/default/files/research-resources/t_watson_questions__ answers_version_2_16_aug_2011.pdf>

Whitmarsh, D. J., Cook, E. J., & Black, K. D. (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.

Whitmarsh, D., & Wattage, P. (2006). Public attitudes towards the environmental impact of salmon aquaculture in Scotland. *European Environment*, *16*(2), 108-121.

Wright, A. S., & Arianpoo, N. (2010). Technologies for viable salmon aquaculture: an examination of land-based closed containment aquaculture. Retrieved from < http://www.watershed-watch.org/wordpress/wp-content/uploads/2012/07/Exh-1845-NonRT.pdf>

Yip, Winnie (2012). Assessing the willingness to pay in the Pacific Northwest for salmon produced by integrated Multi-Trophic Aquaculture. Master's thesis. Simon Fraser University. Retrieved from < http://rem-main.rem.sfu.ca/theses/YipWinnie_2012_MRM530.pdf>

Appendix 1: Final Survey

BC Salmon Aquaculture Survey

Hello and thank you for taking the time to participate in our survey!

We are conducting this survey to better understand the opinions and perceptions of British Columbians about salmon farming and the coastal marine environment. Your feedback will contribute to the management of our coastal ecosystems for present and future generations of British Columbians.

The survey will take about 15 minutes to complete. Please answer the questions in sequence. The survey's intent is to capture your initial response in the order given. **Please DO NOT press the "back button" on your browser to revisit or change your answer.**

To view the privacy policy please click the button below. By clicking 'Begin', you acknowledge that you have read and agree to the privacy policy.

To begin the survey, please click here → **Begin**

To exit the survey, please click here → **Exit**

Privacy Policy

This project has received ethics approval by the Research Ethics Board at Simon Fraser University.

This survey is administered by the School of Resource and Environmental Management at Simon Fraser University, and is funded by the National Sciences and Engineering Research Council of Canada. This survey is not connected to any proposed initiative of any government program, or commercial enterprise.

By filling out this questionnaire, you are consenting to participate. Your participation in this survey is voluntary. The risks you could face resulting from your participation are not greater than what might be encountered in normal day-to-day activity. If at any point you are faced with a question you do not want to answer, you are free to leave items blank or exit the survey completely, without penalty.

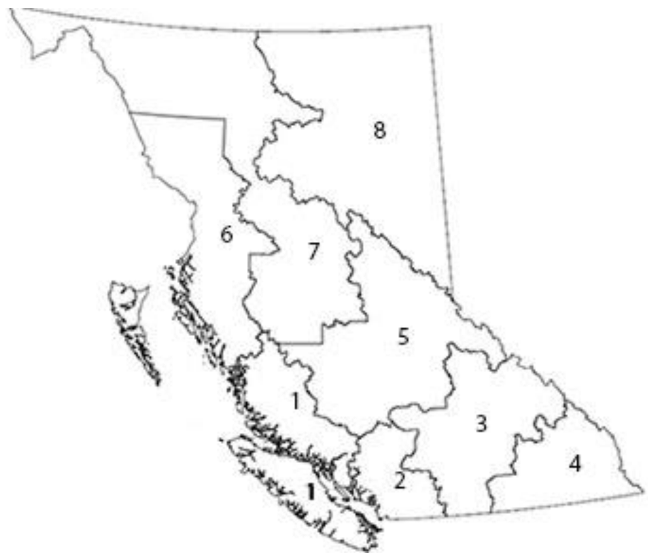
All information that you provide in this survey will be kept strictly confidential. Your response will be stored in a secure password-controlled cache. Individual records will be identified using a code for data analysis and all records will be destroyed after a period of ten years. Your responses will be analyzed in aggregate and will not be identifiable in any publications.

Your may address any concerns or complaints about this research to Dr. Dina Shafey, Associate Director, Office of Research Ethics at: dshafey@sfu.ca or 778-782-9631 with reference to File #: 2013s0064.

Section A: Relationship to the Marine Environment

1) Where in British Columbia is your primary residence? ***[Please specify one region]***

- ○ Vancouver Island/Central Coast
- ○ Lower Mainland Southwest
- ○ Thompson-Okanagan
- ○ Kootenay
- ○ Cariboo-Prince George
- ○ North Coast
- ○ Nechako
- ○ Northeast
- ○ I don't live in BC[*screen out*]
- ○ I'm not sure [*screen out*]



1a) Do you consider yourself to be a resident of the coastal region of British Columbia? ***[Please select one]***

- ○ Yes
- ○ No
- ○ I don't know

2) In the past 12 months, how many days (or portions of days) have you spent on the Pacific Coast of British Columbia, either on the water or within 100 metres of the shoreline? ***[Please select one]***

- ○ None
- ○ 1 to 4 days
- ○ 5 to 9 days
- ○ 10 to 29 days
- ○ 30 to 49 days
- ○ 50 to 100 days
- ○ More than 100 days

- I don’t know

3) In The past 12 months, which of the following coastal recreational activities have you engaged in at least once on the Pacific Coast of British Columbia? ***[Please choose all that apply]***

- Swimming/bathing
- Kayaking/canoeing/sailing
- Power boating/jet skiing
- Surfing/paddle boarding
- Recreational marine fishing
- Sightseeing/whale watching
- Land-based coastal recreation (e.g. sunbathing, coastal hiking, picnicking)
- I haven’t participated in any recreational activities on the Pacific Coast
- Other recreation activity, please specify [ ]

4) In the last 5 years, have you been employed seasonally, part-time or full-time, in any of the following marine-related activities? ***[Please choose all that apply]***

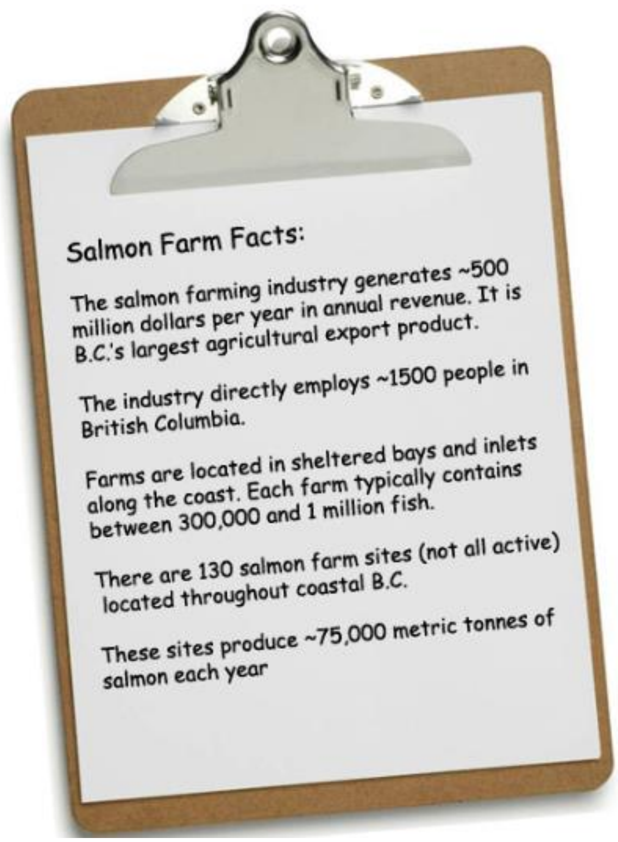
- Commercial marine fishing
- Aquaculture (e.g. fish/shellfish farming)
- First Nations fishing (e.g. subsistence, social or ceremonial)
- Marine tourism (e.g. whale watching, recreational fishing, boat rentals)
- Marine transport (BC Ferries, marine shipping, float plane service)
- Port, dock and harbour-related industries (e.g. longshoremen, coastal infrastructure construction, dock workers)
- Marine-related position within the federal/provincial government (e.g. Coast Guard, Fisheries and Oceans Canada etc.)
- None of the above
- Other, please specify [ ]

5) How familiar are you with the practice of salmon farming? *[Please choose all that apply]*

Not Familiar at All		Somewhat Familiar		Very Familiar
1	2	3	4	5
○	○	○	○	○

Salmon Farming in British Columbia

Salmon farming involves raising salmon in controlled environments for commercial production. Salmon are born in hatcheries, and transferred to marine-based net-cages as juveniles, where they remain until they reach market size. While a few farms produce salmon species native to the Pacific Ocean, the vast majority of farms in British Columbia produce Atlantic salmon.



A Net-Cage Salmon Farm in British Columbia

Photo Courtesy of B.C. Salmon Farmers Association

Section B: Familiarity with Salmon Farming

6) Please choose the statement that most closely resembles your situation with regards to salmon farms ***[Please choose one of the following options]***

- ○ I have seen, or spent time near, a salmon farm
- ○ I have never seen or spent time near a salmon farm
- ○ I don't know if I've ever seen or spent time near a salmon farm

7) How much have you seen, heard or read about salmon farming in the media in the past 12 months (e.g. TV, newspapers, magazines or websites)? ***[Please choose the option that best describes you]***

Nothing at All		**A Moderate Amount** One media piece per month		**A Large Amount** Several media pieces per month
1	2	3	4	5
○	○	○	○	○

8) What has been your main source of information on salmon farming in the last 12 months? ***[Please choose one of the following options]***

- ○ Friends/family
- ○ News stories/journalism
- ○ Scientific journals/studies
- ○ Non-profit organizations (e.g. David Suzuki Foundation, Greenpeace)
- ○ Salmon farming industry public relations/advertising
- ○ Other, please specify ______
- ○ I haven't heard or seen anything about salmon farming in the last twelve months

9) In the last 12 months, how often did you eat salmon at home or in restaurants? ***[Please choose the option that best describes you]***

- ○ Never
- ○ 1-2 times in the last 12 months
- ○ 3-4 times in the last 12 months
- ○ 7-11 times in the last 12 months
- ○ Once or twice in a month
- ○ 3 times a month
- ○ At least once a week

10) In general, do you prefer to eat farmed or wild salmon ***[Please choose the option that best describes you]***

Strongly Prefer Wild	I Prefer Both Equally		Strongly Prefer Farmed		I don't know what type of salmon I eat
1	2	3	4	5	
○	○	○	○	○	○

10) Why do you choose not to eat salmon? ***[Select all that apply]***

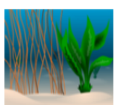
- I don't like fish
- I don't like salmon
- I'm a vegetarian
- Salmon is too expensive
- I don't know how to cook salmon
- Salmon is unsafe
- Salmon is unhealthy
- Salmon is not environmentally friendly
- Salmon is unavailable where I live
- Salmon smells bad in the house
- Other reason, please specify ______

11) How familiar are you with the potential impacts of salmon farming on the marine environment? ***[Please select the option that best describes your familiarity]***

Not Familiar at All		**Somewhat Familiar**		**Very Familiar**
1	2	3	4	5
○	○	○	○	○

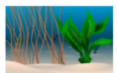
Section C: Salmon Farming and the Environment

The boxes below outline some of the potential impacts of salmon farming. However, the extent and severity of these impacts in British Columbia remains highly controversial. Furthermore, impacts will vary considerably between farm sites based on environmental conditions, operating procedures and production methods.

Marine Habitat Quality	**Parasite and Disease Transfer**	**Coastal Aesthetic Quality**
		
Salmon farms release uneaten feed, feces and agro-chemicals (e.g. antibiotics) into the marine environment. Under certain conditions, this can damage the quality of surrounding marine habitat.	Farmed and wild species can transfer diseases and parasites (e.g. sea lice) to one another. Under certain conditions, this may harm marine wildlife populations.	Salmon farms can obstruct coastal views and increase noise, unpleasant smells and marine debris. In certain coastal areas, farms may interfere with marine-based recreation and reduce the overall amenity value.

12) In your opinion, what is the overall condition of the marine environment around salmon farms in BC? ***[Please select the option that best describes your opinion based on the categories provided]***

Marine Habitat Quality



Very Good	Good	Fair	Poor	I don't know
1	2	3	4	
○	○	○	○	○

Parasite and Disease Transfer

No Risk	Low Risk	Moderate Risk	High Risk	I don't know
1	2	3	4	
○	○	○	○	○

Coastal Aesthetic Quality

Very Good	Good	Fair	Poor	I don't know
1	2	3	4	
○	○	○	○	○

<u>Section D: Choice Experiment</u>

The potential environmental impacts of salmon farming could be reduced if the B.C. government implemented a program that provided financial incentives for salmon farmers to develop and adopt environmentally friendly technologies. The eventual impact of such a program would depend on the number of companies that participate in the program and the types of technologies they adopt. However, without such a program environmental conditions may deteriorate.

In the following exercise, you will be presented with potential outcomes of such a program in terms of employment, marine habitat quality, likelihood of disease/parasite transfer, and coastal aesthetic quality **in 10 years**. *The program would be funded by additional annual taxes paid by each household in B.C.*

Please select the program that you would be most likely to support.

An example of the exercise is provided below. On the following pages, you can click on the question marks to learn more about specific features of the program.

	Program Outcomes	Program 1	Program 2	No Program
?	*Employment in Salmon Farming*	2000	1500	1500
?	*Disease and Parasite Transfer*	Low Risk	Low Risk	Moderate Risk
?	*Marine Habitat Quality*	Good Quality	Very Good Quality	Fair Quality
?	*Coastal Aesthetic Quality*	Fair Quality	Good Quality	Fair Quality
?	*Additional* ***ANNUAL*** *Taxes per Household for the Next Ten Years*	$10	$60	$0

SAMPLE

Please consider each of the six tasks on the next pages independently of each other. When making your choice imagine that you would actually be facing these outcomes and have to dig into your household budget to pay the additional taxes.

Sample 1 ('Medium-case Scenario' status quo)

Program Outcomes	Program 1	Program 2	No Program
Employment in Salmon Farming	1000	0	1500
Disease and Parasite Transfer	No Risk	No Risk	Moderate Risk
Marine Habitat Quality	Fair Quality	Very Good Quality	Fair Quality
Coastal Aesthetic Quality	Very Good Quality	Very Good Quality	Fair Quality
Additional **ANNUAL** *Taxes per Household for the Next Ten Years*	$10	$80	$0
Choose One	○	○	○

Sample 2 ('Worst-case Scenario' status quo)

Program Outcomes	Program 1	Program 2	No Program
Employment in Salmon Farming	500	1500	1500
Disease and Parasite Transfer	Low Risk	Low Risk	High Risk
Marine Habitat Quality	Fair Quality	Fair Quality	Poor Quality
Coastal Aesthetic Quality	Very Good Quality	Good Quality	Poor Quality
Additional **ANNUAL** *Taxes per Household for the Next Ten Years*	$60	$10	$0
Choose One	○	○	○

13) Why did you choose the 'No Program' option? ***[Please choose the ONE option that best describes the reason for your response]***

- The reduction in jobs was too great
- I don't think the proposed environmental changes are realistic
- I don't think the proposed environmental changes are good enough given the tax increase
- I don't think environmental issues are important
- I don't think salmon farming should be allowed to take place in BC at all
- I disagree with an increase in annual taxes for my household for any reason
- I think those tax dollars could be better spent on more pressing issues
- I don't trust the government to implement these changes
- There was not enough information provided to make this decision
- Other (please specify) ____________

14) In your opinion, who should be primarily responsible for ensuring that the marine environment surrounding salmon farms is in good condition? ***[Choose one of the following options]***

○ Salmon farming companies
○ Federal/provincial/municipal government
○ Non-governmental organizations (e.g. environmental groups, industry associations etc.) ____________
○ Other (please specify)
○ I'm not sure/I don't know

15) To what extent would you support or oppose the following government policies? **Note that more than one policy could be implemented at the same time.** ***[Please indicate your level of support for each policy below]***

	Strongly Support	Support	Undecided	Oppose	Strongly Oppose	I don't know
Create stricter mandatory environmental regulations for the salmon farming industry	○	○	○	○	○	○
Allow the salmon farming industry to develop its own voluntary environmental guidelines	○	○	○	○	○	○
Hold salmon farming companies financially responsible for their environmental impacts using 'green taxes' or similar measures	○	○	○	○	○	○
Fund research to develop greener technologies that improve salmon farming's environmental performance	○	○	○	○	○	○
Provide financial incentives (e.g. tax credits) to salmon farming companies to adopt greener technologies that improve their environmental performance	○	○	○	○	○	○

There are two main types of alternative, 'greener' aquaculture systems that have been developed in recent years. While these new systems reduce some of the environmental impacts of salmon farming, neither fully eliminates all impacts. These two alternatives to conventional net-cage aquaculture are:

- **Integrated multi-trophic aquaculture (IMTA)**
- **Closed-containment aquaculture (CCA)**

Closed Containment Aquaculture (CCA) separates salmon farming operations from the natural environment by using closed water tanks on land or in water to raise salmon. Sea water is continuously cycled through the tanks and waste is disposed of on land, rather than being dispersed into the sea. CCA eliminates the impacts from conventional aquaculture on the marine environment, such as the release of any uneaten feed and waste and the interaction between farmed & wild salmon.

CCA requires a significant amount of energy and could face issues related to land use and waste disposal.

The diagram below illustrates a CCA system:

16) Have you heard of Closed Containment Aquaculture (CCA) prior to this survey?
[Please choose one of the following options]

- Yes, I have heard of it
- No, I have not heard of it
- I'm not sure

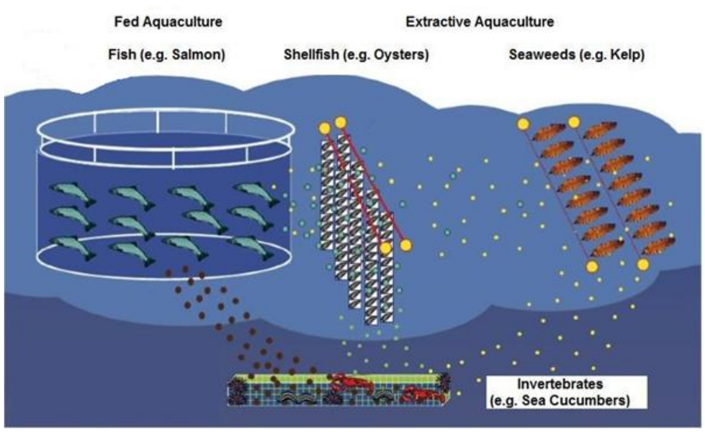
17) What is your opinion of CCA? ***[Please choose one of the following options]***

- Very positive
- Somewhat positive
- Indifferent
- Somewhat negative
- Very negative
- I don't know

Integrated Multi-Trophic Aquaculture (IMTA) seeks to replicate aspects of a natural ecosystem by combining the culture of fed species (i.e. salmon), with the culturing of other species that extract their food from seawater (i.e. shellfish, seaweeds and invertebrates). Uneaten feed and waste from the fed species are recaptured and used by the extractive species, rather than remaining in the marine environment (as is the case with conventional aquaculture). Later, the extractive species can be harvested and marketed as well.

IMTA does not address escapes by farmed salmon and may not significantly reduce the infestation of wild salmon by sea lice.

The diagram below illustrates an IMTA system:



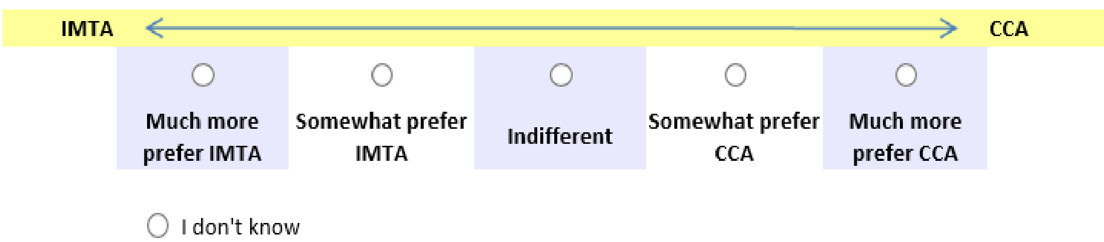
18) Have you heard of Closed Containment Aquaculture (CCA) prior to this survey? ***[Please choose one of the following options]***

- Yes, I have heard of it
- No, I have not heard of it
- I'm not sure

19) What is your opinion of CCA? ***[Please choose one of the following options]***

- Very positive
- Somewhat positive
- Indifferent
- Somewhat negative
- Very negative
- I don't know

20) If either IMTA or CCA was to be adopted for salmon farming, how str21)ong is your preference for one method over the other? ***[Please choose one of the following options]***



21) Why do you prefer IMTA over CCA? ***[Please choose one of the following options]***

- It seems more innovative
- It seems more efficient for producing seafood
- It seems more effective in addressing conventional salmon farming issues
- It seems to use less resources
- It seems more natural
- It seems more environmentally friendly
- It seems more sustainable
- It combines the culturing of multiple species
- Other, please specify ______
- I don't know

21) Why do you prefer CCA over IMTA? ***[Please choose one of the following options]***

- It seems more innovative

- It seems more efficient for producing seafood
- It seems more effective in addressing conventional salmon farming issues
- It seems to use less resources
- It seems more natural
- It seems more environmentally friendly
- It seems more sustainable
- It separates farmed salmon from the marine environment
- Other, please specify [ ]
- I don't know

22) Are you a member of or a donor to an environmental organization (Greenpeace, Sierra Foundation, local environmental organizations, etc.)? ***[Please select one]***

- ○ Yes
- ○ No
- ○ I don't know

23) In the last two years, have you attended an environment-related meeting, lecture or protest? ***[Please select one]***

- ○ Yes
- ○ No
- ○ I don't know

24) To what extent do you agree or disagree with each of the following statements? ***[Please select the responses that best describe you]***

	Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree	I don't know
I think the government should play an active role in protecting the environment	○	○	○	○	○	○
I believe that humans are having a serious and irreversible effect on the environment	○	○	○	○	○	○
Humans have the right to modify nature in order to suit their needs	○	○	○	○	○	○
The earth has plenty of natural resources if we just learn how to develop them responsibly.	○	○	○	○	○	○

This next section asks for some limited personal details to enable important statistical analysis. As a reminder, responses to these questions and all other questions will be treated anonymously and kept strictly confidential.

25) What is your gender? ***[Please select one]***

- ○ Male
- ○ Female
- ○ No Response

26) Please indicate the highest level of education you have completed. ***[Please select one]***

- ○ Elementary/Middle School Graduate (grades 1-8)
- ○ High School Graduate (grades 9-12)
- ○ Some Post-Secondary Education
- ○ College or Trade Certification
- ○ Bachelor's Degree
- ○ Graduate, Post-Doctoral or Professional Degree

27) How many years (in total) have you lived in British Columbia? ***[Please select one]***

- ○ Less than 2 years
- ○ 2-5 years
- ○ 6-10 years
- ○ More than 10 years

28) What are the **first three letters** of your postal code? ***[Please fill in the blank below]***

29) Which of the following categories best represents your annual household income before tax? ***[Please select one]***

- ○ Less than $24,999
- ○ $25,000 to $34,999
- ○ $35,000 to $49,999
- ○ $50,000 to $74,999
- ○ $75,000 to $99,999
- ○ $100,000 to $149,999
- ○ $150,000 to $199,999
- ○ $200,000 +
- ○ No response

30) How many individuals currently live in your household? ***[Please fill in the blank below. Household includes all family members that share expenses, including children]***

31) Please indicate your age. ***[Please select one]***

- ○ 19
- ○ 20-24
- ○ 25-34
- ○ 35-44
- ○ 45-54
- ○ 55-64
- ○ 65+

Comments

If you have any additional comments or concerns regarding this survey or salmon farming in British Columbia, we would appreciate hearing from you.

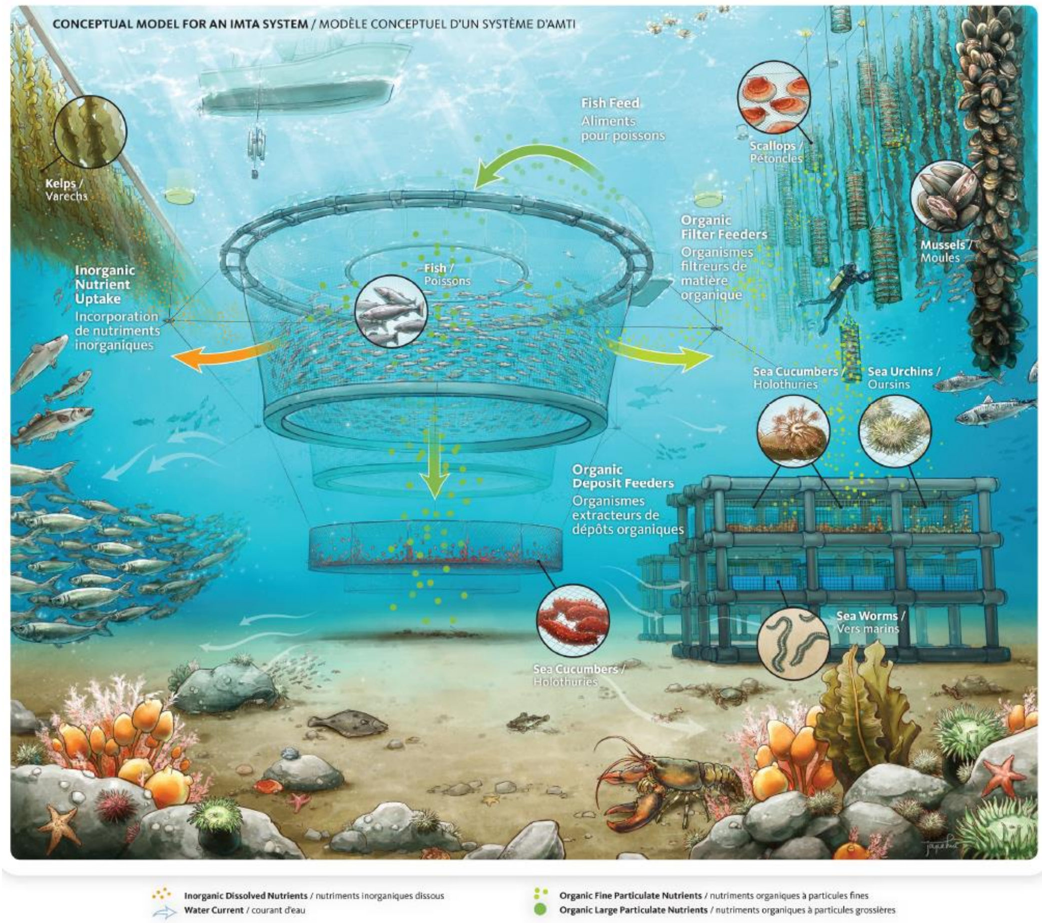
Thank you very much for filling out our survey!

Your responses have been recorded. If you have any further comments or questions regarding this study, or to obtain the research results, please contact the principal researcher of this study at kirwin@sfu.ca

PLEASE CLICK HERE to register your response with Research Now

View Privacy

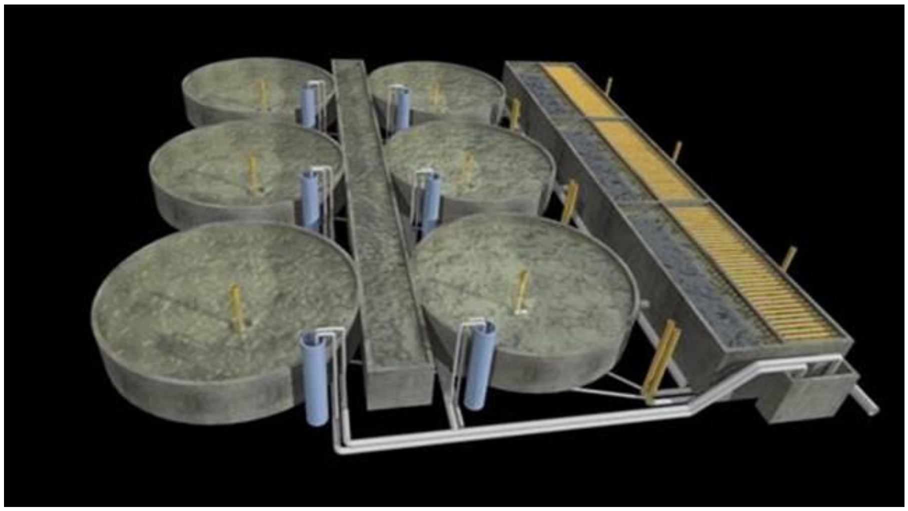
Appendix 2: Integrated Multi-Trophic Aquaculture Diagram



This reproduced image, entitled *Conceptual Model for an IMTA System*, was retrieved from <http://www.dfo-mpo.gc.ca/aquaculture/sci-res/imta-amti/imta-amti-eng.htm> courtesy of Fisheries and Oceans Canada

Appendix 3: Closed-Containment Aquaculture Diagrams

I) Land-based Closed-Containment Aquaculture System



This reproduced image, entitled *Schematic Drawing for One Fish Production Module* was retrieved from < http://www.dfo-mpo.gc.ca/aquaculture/programs-programmes/BC-aquaculture-CB-eng.htm> courtesy of Fisheries and Oceans Canada

II) Marine-based Closed-Containment Aquaculture System

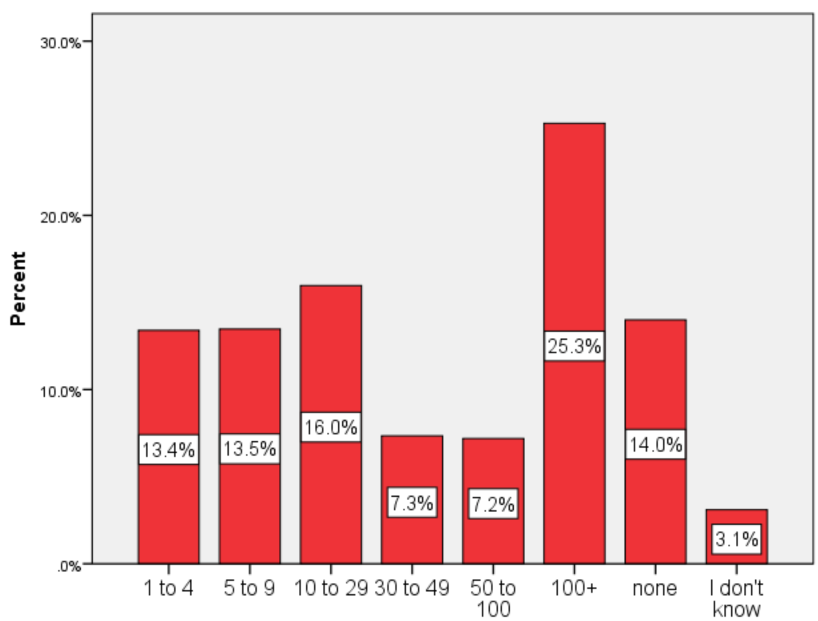
This reproduced image, entitled *Schematic Drawing of FutureSEA Technologies' SEA System* was retrieved from <http://www.dfo-mpo.gc.ca/aquaculture/programs-programmes/BC-aquaculture-CB-eng.htm> courtesy of Fisheries and Oceans Canada

Appendix 4: Survey Results – Connection to the BC Coast

The number of days (or potions of days) respondents spent on the Pacific Coast of British Columbia, either on the water or within 100 metres of the shoreline

Days Spent on the BC Coast	*Frequency*	*N*
1 to 4 days	13.4%	177
5 to 9 days	13.5%	178
10 to 29 days	16.0%	211
30 to 49 days	7.3%	97
50 to 100 days	7.2%	95
100+ days	25.3%	334
None	14.0%	185
I don't Know	3.1%	41
No Response	0.2%	3

The number of days (or potions of days) respondents spent on the Pacific Coast of British Columbia, either on the water or within 100 metres of the shoreline



Percentage of respondents who had engaged in different types of recreational activities in the last year on the Pacific Coast of British Columbia

Activity	***Level of Participation***	***N***
Swimming/bathing	31.6%	418
Kayaking/canoeing/sailing	16.3%	215
Power boating/jet skiing	10.1%	134
Surfing/paddle boarding	3.9%	52
Recreational marine fishing	12.2%	162
Sightseeing/whale watching	28.3%	374
Land-based coastal recreation	60.9%	805
Other recreation activity	5.5%	72
No recreational activities	23.4%	309

Percentage of respondents who have been employed seasonally, part-time or full-time in different marine-related activities in the last 5 years

Employment Type	***Level of Participation***	***N***
Commercial marine fishing	0.3%	4
Aquaculture	0.5%	7
First Nations fishing	0.1%	1
Marine tourism	1.5%	20
Marine transport	1.5%	20
Port, dock, harbor-related	0.8%	10
Government	0.7%	9
Other	1.5%	20
None	93.5%	1235

Appendix 5: Survey Results – Salmon Consumption Patterns

Respondent's Salmon Consumption Frequency in the Last 12 Months

Response	***Average Consumption per Year***	***Frequency***	***N***	***Mean/SD***
Never	0	9.1%	122	Mean = 15.01 SD = 15.52
1-2x/year	1.5	11.5%	155	
3-6x/year	4.5	19.4%	259	
7-11x/year	9	19.6%	256	
1-2x/month	18	20.8%	273	
3x/month	36	10.7%	140	
1x/week+	52	8.9%	116	
Total	NA	100.0%	1321	

Salmon Non-Consumers - Reasons for Not Consuming Salmon

Reason	***N***	***Frequency***
I don't like fish	53	43.44%
I don't like salmon	37	36.07%
I'm a vegetarian	18	14.75%
Salmon is too expensive	11	9.02%
I don't know how to cook salmon	3	2.46%
Salmon is unsafe	1	0.82%
Salmon is unhealthy	1	0.82%
Salmon is not environmentally friendly	2	1.64%
Salmon is not available where I live	0	0.00%
Salmon smells bad in the house	7	5.74%
Other[32]	13	10.66%

[32] Other reasons specified by respondents included food allergies and veganism

Respondent Preferences for Farmed vs. Wild Salmon

Reason	***N***	***Frequency***
Strongly Prefer Wild	547	45.7%
Somewhat Prefer Wild	214	17.9%
Neutral	274	22.9%
Somewhat Prefer Farmed	19	1.6%
Strongly Prefer Farmed	13	1.1%
I don't Know	129	10.8%

Appendix 6: Survey Results – Familiarity with Salmon Farming

Respondent's Prior Familiarity with Salmon Farming

Level of Familiarity	***Frequency***	***N***
1 (Not familiar at all)	14.91%	197
2	22.63%	299
3 (Somewhat familiar)	46.03%	608
4	12.49%	165
5 (Very familiar)	3.94%	52
Total	**100.00%**	**1321**
Mean	2.68	
Standard Deviation	1.00	
Mode	3	
Median	3	

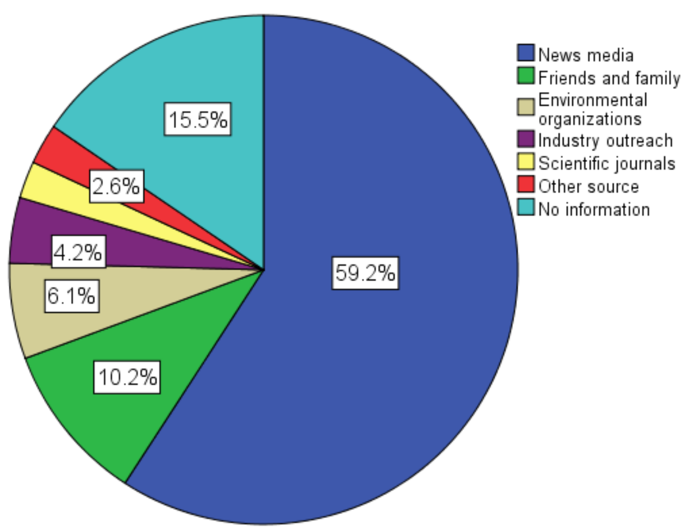
Respondent's First-Hand Experience with Salmon Farms

Answer	***Frequency***	***N***
I have seen, or spent time near, a salmon farm	27.6%	364
I have never seen or spent time near a salmon farm	60.1%	794
I don't know if I've ever seen or spent time near a salmon farm	11.7%	155
No response	0.6%	8
Total	100.0%	1321

Respondent's Main Source of Information on Salmon Farming in the Past Year

Info Source	***Frequency***	***N***
Friends	10.2%	134
Industry Outreach	4.2%	55
News stories/Journalism	59.2%	780
NGOs	6.1%	80
Scientific Journals/Studies	2.4%	31
Other[33]	2.6%	34
NA/Didn't Receive Info	15.4%	204
Total	100%	1318

Respondent's Main Source of Information on Salmon Farming in the Past Year



Appendix 7: Results – Salmon Farming and the Environment

Respondent Familiarity with the Potential Environmental Impacts of Salmon Farming

Scale	*N*	*Frequency*
1(Not Familiar at all)	258	19.7%
2	285	21.8%
3 (Somewhat Familiar)	524	40.1%
4	175	13.4%
5 (Very Familiar)	66	5.0%
Total	1308	100.0%

Respondent's own Opinion of the Status Quo

Disease and Parasite Transfer Risk

Response	*Frequency*	*N*
High Risk	32.1%	423
Moderate Risk	32.4%	427
Low Risk	9.8%	129
No Risk	0.4%	5
I don't know	24.8%	326
Total	100.0%	1317

Marine Habitat Quality

Response	Frequency	N
Poor	21.3%	281
Fair	34.1%	449
Good	15.2%	200
Very good	0.9%	12
I don't know	28.5%	375
Total	100.0%	1317

Aesthetic Quality

Response	Frequency	N
Poor	12.8%	168
Fair	34.7%	457
Good	19.3%	254
Very good	2.9%	38
I don't know	30.4%	400
Total	100.0%	1317

Appendix 8: Respondent Reasons for Choosing the Status Quo Option in DCE

Respondents reasons for choosing Option C (Status Quo)

Response	Frequency	N
I think tax dollars could be spent on other, more pressing issues	19.1%	69
I don't agree to a tax increase for any reason	16.3%	59
The Environmental Changes Presented are Not Acceptable	15.0%	54
The loss in jobs was too great	11.9%	43
I need more information to make an informed decision	11.1%	40
I don't trust the government to implement these changes	9.1%	33
I don't think there should be any salmon farms in British Columbia	7.2%	26
The proposed environmental changes were not realistic	3.9%	14
I don't care about the environment	0.6%	2
Other Reasons	5.8%	21

*361 people (27%) of respondents chose the 'No Program' Option at least once

Appendix 9: Results – Preference for IMTA vs. CCA Technology

Prior Knowledge of IMTA and CCA Technologies

	IMTA		CCA	
Response	***Frequency***	***N***	***Frequency***	***N***
Yes	14.2%	186	33.0%	435
No	76.4%	1003	57.9%	763
I'm not sure	9.4%	124	9.1%	120
Total	100.00%	1313	100.0%	1318

Opinion towards IMTA and CCA Technology

	IMTA		CCA	
Opinion/Attitude	***N***	***Frequency***	***N***	***Frequency***
Very Positive	74	5.6%	191	14.5%
Somewhat Positive	412	31.3%	493	37.4%
Neutral	188	14.3%	148	11.2%
Somewhat Negative	233	17.7%	176	13.3%
Very Negative	94	7.1%	45	3.4%
I Don't Know	317	24.1%	266	20.2%
Total	1318	100.0%	1319	100.0%

Respondent Preference for IMTA vs. CCA Technologies

Preference	***N***	***Frequency***
Strongly Prefer IMTA (2)	65	4.9%
Somewhat Prefer IMTA (1)	272	20.6%
Neutral (0)	280	21.2%
Somewhat Prefer CCA (-1)	276	20.9%
Strongly Prefer CCA (-2)	182	13.8%
I Don't Know (NA)	246	18.6%
Total	1321	100.0%

Correlations between familiarity and attitude of alternative aquaculture technologies

Correlations				
			Awareness of CCA	Attitude towards CCA
Spearman's rho	Awareness of CCA	Correlation Coefficient	1.000	.340**
		Sig. (1-tailed)	.	.000
		N	7188	5862
	Attitude towards CCA	Correlation Coefficient	.340**	1.000
		Sig. (1-tailed)	.000	.
		N	5862	6318

**. Correlation is significant at the 0.01 level (1-tailed).

Correlations				
			Attitude towards IMTA	Awareness of IMTA
Spearman's rho	Attitude towards IMTA	Correlation Coefficient	1.000	-.153**
		Sig. (1-tailed)	.	.000
		N	6000	5544
	Awareness of IMTA	Correlation Coefficient	-.153**	1.000
		Sig. (1-tailed)	.000	.
		N	5544	7134

**. Correlation is significant at the 0.01 level (1-tailed).

Appendix 10: Results - Attitudes towards Government Policy

Respondent's View on who is Responsible for the Marine Environment around Salmon Farms

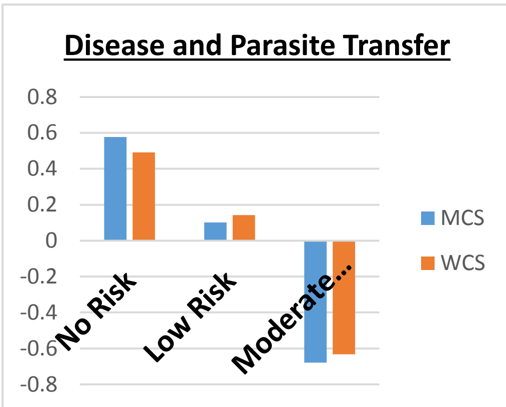
Response	*N*	*Frequency*
Government	603	46.2%
NGOs	154	11.8%
Salmon Farming Companies	409	31.3%
Other	38	2.9%
I Don't Know	101	7.7%
Total	1321	100.0%

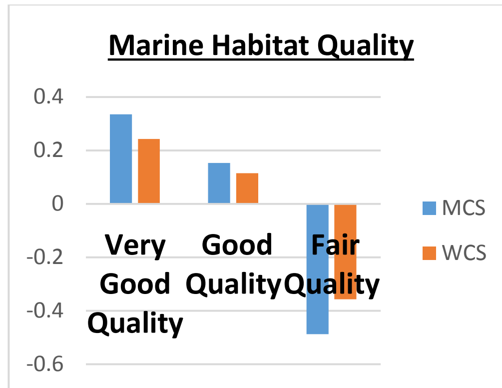
Respondent's View on who is Responsible for the Marine Environment around Salmon Farms

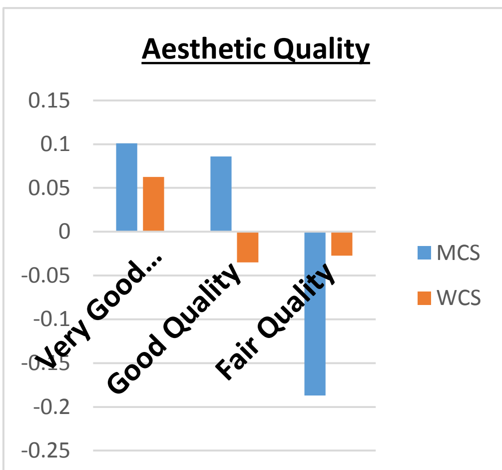
Policy Type	Strongly Support	Support	Undecided	Oppose	Strongly Oppose	I don't know
Stricter mandatory regulations	48.4%	39.1%	7.4%	0.6%	0.2%	3.9%
Industry-developed guidelines	2.4%	11.9%	19.8%	34.3%	26.9%	3.9%
Green taxes	43.8%	38.9%	10.4%	2.3%	0.7%	3.3%
Government funding of green technology R&D	24.8%	43.9%	20.1%	4.3%	2.1%	3.9%
Subsidies for green technology adoption	23.3%	42.6%	18.5%	7.3%	4.2%	3.5%

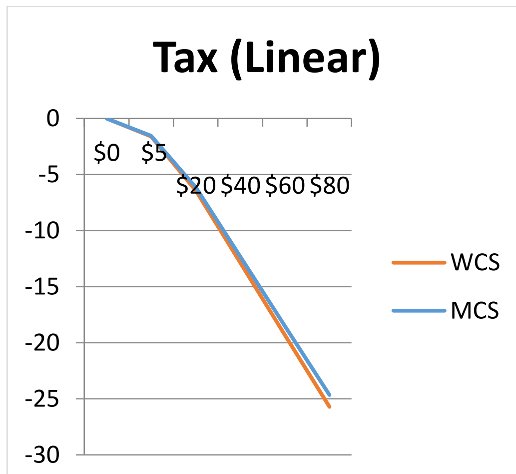
Appendix 11: Results - Part-Worth Utility for Attributes - Comparisons across Models

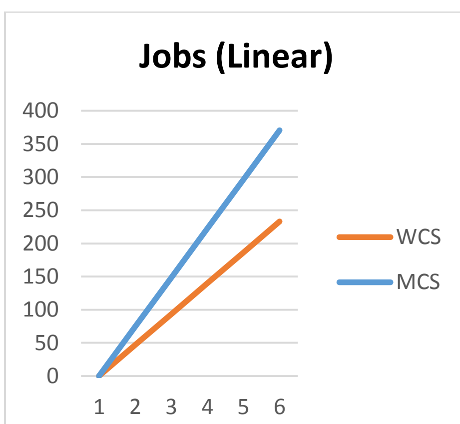
MNL – Comparison of MCS and WCS











Appendix 12: Latent Class Analysis – Fit Stats

MCS Fit Stats

	LL	BIC(LL)	AIC(LL)	AIC3(LL)	CAIC(LL)	$R^2(0)$	R^2
1-Class Choice	-3432.73	6930.13	6885.453	6895.453	6940.13	0.2089	0.1311
2-Class Choice	-3049.87	6235.558	6141.736	6162.736	6256.558	0.3787	0.3175
3-Class Choice	-2987.31	6181.584	6038.617	6070.617	6213.584	0.4541	0.4004
4-Class Choice	-2941.57	6161.251	5969.14	6012.14	6204.251	0.5026	0.4537
5-Class Choice	-2914.9	6179.056	5937.801	5991.801	6233.056	0.5336	0.4876
6-Class Choice	-2890.74	6201.884	5911.483	5976.483	6266.884	0.5568	0.5133

WCS Fit Stats

	LL	BIC(LL)	AIC(LL)	AIC3(LL)	CAIC(LL)	$R^2(0)$	R^2
1-Class Choice	-3130.39	6332.467	6282.773	6293.773	6343.467	0.2991	0.1484
2-Class Choice	-2800.22	5737.32	5642.448	5663.448	5758.32	0.4495	0.3308
3-Class Choice	-2701.17	5610.913	5466.347	5498.347	5642.913	0.5311	0.43
4-Class Choice	-2624.64	5529.532	5335.272	5378.272	5572.532	0.5758	0.4842
5-Class Choice	-2586.14	5524.24	5280.286	5334.286	5578.24	0.6171	0.5344
6-Class Choice	-2559.81	5543.276	5249.627	5314.627	5608.276	0.6516	0.5764

Appendix 13: Demographic Statistics by Latent Class Membership

<u>Demographic Statistics for the MCS 3-Class Model</u>

Demographic Categories	**% Frequency**		
	Serious Environmentalists	Sustainable Development Supporters	Tax-Conscious
Gender			
Male	31.3%	32.8%	48.3%
Female	67.6%	66.0%	49.3%
No Response	1.4%	1.2%	2.4%
Age			
19-24	1.4%	2.3%	0.5%
25-34	16.2%	18.9%	13.4%
35-44	20.9%	20.1%	24.4%
45-54	38.5%	34.4%	36.8%
55-64	12.8%	13.1%	14.4%
65+	8.8%	10.8%	10.5%
No Response	1.4%	0.0%	0.0%
Educational Attainment			
Elementary School	0.0%	0.4%	0.0%
High School	11.5%	15.8%	12.4%
Some Post-Secondary	20.3%	15.4%	16.3%
College Diploma	33.1%	25.1%	34.0%
Bachelor's Degree	24.3%	31.7%	23.9%
Graduate/Professional Degree	10.1%	10.8%	12.9%
No Response	0.7%	0.0%	0.5%
Region of Residence			
Lower Mainland/Southwest	49.3%	49.8%	51.2%
Vancouver Island/Central Coast	33.1%	31.3%	24.4%
North Coast	0.7%	2.3%	2.4%
	2.7%	2.3%	3.3%

Kootenay	8.8%	10.4%	13.9%
Thompson-Okanagan	4.1%	2.3%	4.3%
Caribou	1.4%	1.2%	0.5%
Northeast	0.0%	0.4%	0.0%
Nechako			
Income Level			
Less than $24,999	7.4%	5.0%	7.2%
$25,000-$34,999	6.8%	11.6%	5.7%
$35,000-$49,999	10.8%	10.4%	13.4%
$50,000-$74,999	17.6%	18.1%	23.4%
$75,000-$99,999	18.9%	18.9%	18.2%
$100,000-$149,999	21.6%	16.6%	13.9%
$150,000-$199,999	3.4%	3.5%	3.8%
$200,000 plus	2.0%	1.2%	2.9%
No Response	11.5%	14.7%	11.5%

Demographic Statistics for the WCS 3-Class Model

Demographic Categories	**% Frequency**		
	Serious Environmentalists	Sustainable Development Supporters	Tax-Conscious
Gender			
Male	34.4%	34.3%	45.0%
Female	64.7%	65.4%	55.0%
No Response	0.8%	0.4%	
Age			
19-24	1.6%	2.0%	1.7%
25-34	17.0%	20.1%	11.7%
35-44	11.6%	17.3%	10.0%
45-54	27.8%	26.4%	21.7%
55-64	20.3%	16.1%	20.0%
65+	21.2%	16.9%	33.3%
No Response	0.6%	1.2%	1.7%

Educational Attainment			
Elementary School	0.0%	0.8%	0.0%
High School	17.0%	15.0%	21.7%
Some Post-Secondary	14.9%	14.6%	15.0%
College Diploma	30.3%	28.0%	25.0%
Bachelor’s Degree	22.8%	27.2%	25.0%
Graduate/Professional Degree	14.9%	14.6%	13.3%
No Response	0.0%	0.0%	0.0%
Region of Residence			
Lower Mainland/Southwest	51.9%	48.0%	55.0%
Vancouver Island/Central Coast	28.2%	31.3%	21.7%
North Coast	2.1%	2.4%	0.0%
Kootenay	2.5%	2.4%	1.7%
Thompson-Okanagan	9.5%	11.8%	18.3%
Caribou	3.7%	3.1%	1.7%
Northeast	1.7%	1.2%	1.7%
Nechako	0.4%	0.0%	0.0%
Income Level			
Less than $24,999	6.6%	5.9%	5.0%
$25,000-$34,999	10.4%	6.3%	5.0%
$35,000-$49,999	10.8%	11.4$	5.0%
$50,000-$74,999	15.8%	19.3%	16.7%
$75,000-$99,999	16.2%	16.1%	25.0%
$100,000-$149,999	14.1%	16.1%	13.3%
$150,000-$199,999	5.0%	2.8%	3.3%
$200,000 plus	0.8%	2.0%	0.0%
No Response	20.3%	20.1%	26.7%

Appendix 14: Known Class Analysis for Status Quo

Known Class Analysis for Status Quo

Attributes and levels	MCS (Class 1)	Standard Error	WCS (Class 2)	Standard Error	Wald p-value	Wald(=) p-value
ASC	1.055***	0.049	2.092***	0.070	<0.001	<0.001
Tax (linear)	-0.308	0.028	0.025	0.028	<0.001	0.333
Disease and Parasite Transfer					<0.001	0.230
No risk	0.576***	0.036	0.491***	0.035		
Low risk	0.102***	0.036	0.142***	0.036		
Moderate risk	-0.678***	0.039	-0.633***	0.038		
Marine Habitat Quality					<0.001	0.043
Very good quality	0.576***	0.036	0.243***	0.038		
Good quality	0.102***	0.0036	0.115***	0.036		
Fair quality	-0.678***	0.039	-0.358***	0.036		
Aesthetic Quality					<0.001	0.006
Very good quality	0.101***	0.037	-0.035	0.037		
Good quality	0.086**	0.038	-0.035	0.037		
Fair quality	-0.187***	0.038	-0.027	0.035		
Employment (linear)	0.148	0.018	0.093	0.017	<0.001	0.027
Employment (quadratic)	-0.046***	0.012	-0.045	0.012	<0.001	0.990

***significant at 0.01 **significant at 0.05 *significant at 0.1

Appendix 15: Marginal WTP for Latent Classes

This appendix provides the breakdown of marginal WTP for a change in attribute level by latent class. Note that in certain cases, the parameter estimate (part-worth utility) was found to be not significant, and therefore the WTP is not valid. These invalid WTP estimates have an asterisk (*) next to them.

Sustainable Development Supporters

Attribute	Level Change	Model 1 – MCS	Model 2 - WCS
Disease & Parasite Transfer	Mod. Risk - Low Risk	$33.44	$25.50
	Low Risk to No Risk	$15.46	$14.32
Marine Habitat Quality	Fair - Good Quality	$41.20	$15.04
	Good – V. Good Quality	$17.49	$3.35*
Aesthetic Quality	Fair - Good Quality	$13.14	$9.67*
	Good – V. Good Quality	$5.74	-$4.37*
Employment in Salmon Farming	+500 jobs	$10.00	$10.00

Tax Conscious

Attribute	Level Change	Model 1 – MCS	Model 2 - WCS
Disease & Parasite Transfer	Mod. Risk - Low Risk	$38.18	$-13.74*
	Low Risk to No Risk	$13.72	$9.18*
Marine Habitat Quality	Fair - Good Quality	$29.65*	$-16.74*
	Good – V. Good Quality	$-7.78*	$0.66*
Aesthetic Quality	Fair - Good Quality	$23.49	$4.05*
	Good – V. Good Quality	$-7.64*	-$15.23*
Employment in Salmon Farming	+500 jobs	$10.00	$0.00*

Serious Environmentalists

Attribute	Level Change	Model 1 – MCS	Model 2 - WCS
Disease & Parasite Transfer	Mod. Risk - Low Risk	$138.45	$63.78
	Low Risk to No Risk	$77.22	$36.06
Marine Habitat Quality	Fair - Good Quality	$56.85	$57.79
	Good – V. Good Quality	$23.48	$17.91
Aesthetic Quality	Fair - Good Quality	$29.69	$9.67
	Good – V. Good Quality	$-18.24	$4.37
Employment in Salmon Farming	+500 jobs	$0.00	$5.00