A COST BENEFIT ASSESSMENT OF IMPLEMENTING MARINE RESERVES IN THE NORTHERN SHELF BIOREGION OF BRITISH COLUMBIA

by

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Abstract

Marine reserves are one type of Marine Protected Areas (MPAs) that are no-take used as instruments for achieving ecosystem-based conservation globally. Currently, over 6 percent of the global oceans are protected under MPAs, with about 2,7 percent highly protected through marine reserves. A recent study estimates that protecting at least 30 percent of the global oceans by 2030 could generate additional economic benefits of between US$170 and $534 billion annually by 2050. Canada surpassed its 10 percent target protection of ocean and land for 2019, with the country's current targets being to protect 25 percent by 2025 and 30 percent by 2030. To that end, this thesis estimates the net benefits of creating and implementing marine reserves in the Northern Shelf Bioregion (NSB). To do so, I first conducted a literature review on the valuation of MPAs in general, highlighting the past and current studies on the valuation of marine reserves. Secondly, I carried out a Cost-Benefit Analysis (CBA) of implementing marine reserves in the NSB and conducted the CBA under three scenarios of reserve sizes, i.e., 10, 30 and 50 percent, respectively. These scenarios were ultimately compared with the status quo, where no marine reserves were implemented. The economic indicator used for this comparison is discounted profit of both market and non-market values generated by marine reserves in the NSB. I calculated net benefits for the (i) short term (eight years); and (ii) long term (50 years). The results suggest that the highest net benefits of $67 million/year are achieved over the long term when a marine reserve of 30 percent is implemented. Finally, comparing results from the three scenarios points to the need to strike a balance between the level of MPA protection and the resulting net benefits associated with implementing marine reserves as protecting half of the NSB could result in a decline in net benefits of 30 percent protection to ~$47 million/year over the long term.

Lay Summary

The Northern Shelf Bioregion (NSB) is a strategically important region that supports diverse activities that have substantial economic implications for local communities through the generation of the market and non-market economic benefits emanating from marine ecosystem-based such as fishing. Using a mix of methods such as benefit transfer and econometrics, I estimate the net benefits of implementing marine reserves in the NSB. Results from study shows that in the long term, implementing marine reserves of 30 percent could generate highest net benefits of about $67 million/year while protecting half of the NSB could result in a fall in net benefits to about $47 million/year. Overall, I conclude that the establishment of marine reserves could be strategic and largely generate positive net benefits for adjacent communities through the income generation opportunities from both market and non-market activities if they do not cover more than half of the NSB marine area.

Preface

I am the main author in all the chapters. I took the principal duty for the research contained in all the thesis chapters, including the design, literature review, data collection, analysis, and writing. Dr U. Rashid Sumaila, Dr William Cheung and Dr Megan Bailey contributed their knowledge and advice with ideas, methods, and general layout of this thesis.

I drafted and conducted the literature review of this study. Dr. Sumaila guided me intellectually and on the general structure and flow of the draft. Dr Thomas W. Ross also gave me some feedback from time to time on the thesis outline and structure. Dr Sarah Harper and Dr Muhammed Oyinlola provided frequent comments on the thesis while Dr Issifu Ibrahim, Lazarus Muchabaiwa, Dr Lawrence Chidzambwa and Luckmore Chivandire also provided valuable insights.

Table of Contents

List of Tables

List of Figures

List of Abbreviations

BC	British Columbia
CBA	Cost Benefit Analysis
CVM	Contingent valuation method
DFO	Department of Fisheries and Oceans Canada
EBM	Ecosystem Based Management
ESF	Ecosystem Services Framework
ESI	Environmental Sustainability Index
GDP	Gross Domestic Product
GHG	Green House Gas
HK	Hong Kong
LMA	Large Ocean Management Area
MPA	Marine Protected Area
NEA	North East Atlantic
NPV	Net Present Value
NSB	Northern Shelf Bioregion
OPT	Optimal Control Theory
PNCIMA	Pacific North Coast Integrated Management Area
SIDS	Small Island Developing States
TEEB	The Economics of Ecosystems and Biodiversity
UBC	University of British Columbia
UN	United Nations
WTP	Willingness-to-Pay

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First, I thank Dr. U. Rashid Sumaila, my supervisor for his enduring support. Even when I felt like I was not making progress, he kept on providing valuable insights and guidance. My utmost thanks also go to my committee members, Dr Megan Bailey and Dr William Cheung for their insightful comments and feedback throughout this project.

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Additionally, I extend my sincere gratitude to the faculty, staff, and my fellow students at the University of British Columbia (UBC), who have inspired me to continue my work in this field. I am most especially indebted, in no order, to Dr. T. W. Ross, Dr. R. Barichello, Dr. M. A. Oyinlola, Dr. M. Khalfallah, Dr. Lydia Teh, Dr. Louise Teh and. T. R. Cashion for their specific feedback on my thesis parts.

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Dedication

To my parents,

Casnos Jonas Verengayi and Alice Musekiwa,

your infinite love and continuous support keep me aiming higher.

Chapter 1: The Economics of implementing Marine Reserves in the Northern Shelf Bioregion of British Columbia

1.1 Introduction

Marine reserves are especially highly protected areas of the oceans and other water bodies such as rivers in which extractive and harmful human activities are banned (Sumaila *et al*., 2007; Sala *et al*., 2021). Thus, marine reserves are a subset of Marine Protected Areas (MPAs) which are spatially designated areas in the ocean, including the high seas and inshore water bodies such as lakes, rivers and streams protected from human activities such as overfishing. To ensure effective governance structure, MPAs are protected and managed through legal instruments, mostly implemented through a management plan (Board & National Research Council, 2001; Kelleher, 1999).

Given the increasing momentum in developing the 30 by 30 campaign of the planet which aims to protect at least 30 percent of the planet's land and oceans by 2030 (Waldron *et al*., 2020), there is need for science based evidence to support the effectiveness and justification for using MPAs as a tool to assess the benefits and costs of such policies. Thus, the reasons for creating marine reserves may vary from safeguarding and restoring ocean biodiversity and associated services such as food provisioning to complimenting conventional fisheries management and addressing climate change by protecting marine carbon stocks (Cisneros-Montemayor *et al*., 2021; Sala *et al*., 2021). Marine reserves have been shown to offer an opportunity to support a sustainable blue ocean economy towards a socially equitable, environmentally sustainable, and economically viable ocean industries (Cisneros-Montemayor *et al.*, 2021). Blue ocean economy is a term in economics that relates to the use and preservation of the marine environment. A recent study Sala *et al.,* 2021, has shown that protecting 71 percent of the ocean could generate 91 percent maximum biodiversity benefits and also yield 48 percent carbon benefits without offsetting the current fisheries catches.

Hence, as a result of the increasing evidence of MPAs success as effective conservation-based instrument, they have become a widely applied ecosystem-based tool to address the effects of human activities such as overfishing (Sumaila, 1998; Sumaila *et al.*, 2000a; Sumaila *et al*., 2000b) and mitigate climate change impacts (Cheung *et al*., 2012; Lam *et al*., 2012; McLeod *et al*., 2009; Sumaila *et al*., 2011) and ensure biodiversity protection (ICUCN 2020).

Thus, MPAs are an important conservation-based management tool that has been extensively considered in the mainstream policy discourse to address climate change, increase the socio-economic well-being of fisheries-dependent coastal communities globally and biodiversity protection. However, because of the broad scope of the issues around their designation, optimal shape, and size for them to be more effective, it is important to first provide a contextual background of the generally agreed definitions and examples of the various types of MPAs available in the literature. In addition, this thesis focus on estimating the net benefits of creating and implementing marine reserves which are defined in the first paragraph. In the following paragraphs, I introduce the thesis structure that I will follow to achieve the research goals and objectives summarized at the end of this chapter.

1.2 Marine Protected Areas (MPAs): Definitions, objectives, and concepts

Generally, MPAs are recognized as defined geographic areas in the ocean and inland water bodies, dedicated and managed, through a legal or other effective means, to achieve the long-term conservation goals of nature and their associated ecosystem services, including, education and cultural services (IUCN, 1995; Kelleher, 1999). Since MPAs vary in size and degree of protection globally because of different geographic and marine organism composition: their effectiveness has been of differing scales (Sala *et al*. 2018). These differences have been identified mostly at a global level resulting in the formation of bodies that recommend and support the management of MPAs globally through providing platforms where relevant stakeholders such as governments meet and share ideas. These bodies include the United Nations under the Sustainable Development Goal (SDG) 14 and the International Union for Conservation of Nature (IUCN).

Besides, in response to the call for countries around the world to act on conserving the declining ocean ecosystems, various international forums have been held defining the goals and objectives of MPAs. The United Nations Convention of Biological Diversity (CBD) was such a notable conference that brought together countries around the world in 2010 to develop a strategic framework via the Aichi Biodiversity Targets for the 2011–2020 period. Specifically, the Aichi target 11 challenged countries globally to set goals that ensure that they protect at least 17 percent of territorial and inland water, and 10 percent of the coastal and marine areas (CBD, 2010). Protecting both terrestrial and oceans ecosystems are of special importance for biodiversity and ecosystem services conservation as they help conserve and equitably manage and support effective management of ecologically sensitive ecosystems (CBD, 2010).

In addition, the marine and land conservation objectives were reaffirmed by the United Nations General Assembly (UN) in 2015 as part of its 2030 Agenda for Sustainable Development (SDG) goal 14. The UN Sustainable Development goal 14 aims to conserve and sustainably use the oceans, seas, and marine ecosystems for sustainable development. To date, only about 7.7 percent of the world's oceans are protected by MPAs[1]. Thus, to ensure the effectiveness of MPA conservation goals and objectives, integrated plans were stipulated for the specific MPA-wide restrictions on human activities such as fishing, tourism and oil and gas extraction that were required in the protected areas (CBD, 2010).

Consequently, due to the many different types of MPAs and various coordination efforts to conserve the marine ecosystems, there is a need to define the various MPAs that are available. In this regard, the various types of MPAs include marine reserves are of particular focus in this thesis. As noted earlier, marine reserves have mainly the primary goal of protecting specific categories of fisheries and/or ecological ecosystems, hence the terms fisheries and ecological reserves (Sumaila, 2002). These two types of marine reserves comprise "no-take" and "take" zones. As the name suggests, "no-take" zones are characterized by a complete ban on extractive activities such as fishing and mining. On the other hand, "take" zones allow selective human activities within the protected area. Studies have shown that marine ecosystems require a minimum of 30 percent "no-take" coverage of the total marine area to be effective in sustaining marine ecosystem restoration

[1]UNEP-WCMC and IUCN (2020), Protected Planet: The World Database on Protected Areas (WDPA) [Online], September 2020, Cambridge, UK: UNEP-WCMC and IUCN. Available at: www.protectedplanet.net.

(Sala & Giakoumi, 2018; Waldron *et al*., 2020). Thus, marine reserves can be further split into fishery reserves and ecological reserves.

1.2.1 a) Fishery reserve

A fishery reserve is a delimited zone where some or all fishing activities on some or all species are regulated to protect critical habitat and fish species (Board & National Research Council, 2001; Kelleher, 1999). Thus, the main goal in a fisheries reserve is to temporarily restrict some or all fishing activities to reduce the threat of overfishing and to allow the fish and invertebrate stocks to rebuild and support the long-term flow of economic benefits (Board & National Research Council, 2001; Ye *et al*., 2013). Also, fisheries reserves protect critical fish and invertebrate habitat and provide an insurance mechanism against overfishing and potentially improve the fishery yield over time term (Board & National Research Council, 2001; Ye *et al*., 2013). There are varying degrees of protection with some parts of the reserve being "no-take' areas while other parts might be "take" areas and these may change over time, e.g., seasonally. Notable examples of marine reserves include the Saguenay Fjord-St Lawrence Marine Park established to protect beluga whales in Canada[2] and the Gorges Closed Area I and II in the United States designed to safeguard groundfish.

The Saguenay Fjord-St Lawrence Marine Park, Quebec is a popular whale-watching location, with several tour operators in the region. Similarly, the Gorges Closed Area I and II is a large, elevated

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[2] https://www.pc.gc.ca/en/amnc-nmca/qc/saguenay.

area of the sea between Cape Cod, Massachusetts, United States and Cape Sable Island Nova Scotia (Canada). Although the marine area is not as productive in terms of fisheries potential, compared to other parts of the world, it does form the most geographically accessible fishing banks in the North Atlantic. In a "no-take" reserve, some or all-human activities are banned. For instance, the Gully Marine Protected Area in Nova Scotia, Canada is a "no-take" marine reserve. The Gully marine reserve is the largest underwater canyon in North America established in 2004 and covering 2,363[3] km^2, with 20 percent of the total marine area under a total ban on all human activities. In contrast, the remaining 80 percent of the Gully Marine Protected area is open for licensed human activities such as fishing, tourism, mining, and gas extraction. Thus the "no-take" marine reserve area of the Gully marine area acts as a 'fish bank' to supports the rich, diverse deep-sea coral species and endangered Northern bottlenose whales from depletion.

1.2.2 b) Ecological reserve

An ecological reserve provides safeguards to all living resources through the prohibition of human activities such as fishing and the removal or disturbances of any living or non-living marine resource from the designated area, aside from monitoring or research to assess reserve effectiveness (Board & National Research Council, 2001). Ecological reserves can also have "no-take" zones or fully protected areas (Board & National Research Council, 2001). Examples are the Checleset Bay Ecological reserve and the Baccalieu Island ecological reserve in Newfoundland and Labrador, Canada, and the Cano Island National Park in Costa Rica. The Checleset Bay

[3] https://www.dfo-mpo.gc.ca/oceans/mpa-zpm/gully/index-eng.html.

ecological reserve was created in 1981, mainly to protect sea otters and their habitat. The Checleset Bay ecological reserve is on the west coast of Vancouver Island between the Brooks Peninsula and Kyuqot[4]. Similarly, the Cano Island National Park in Costa Rica was created in 1976, became a biological reserve in 1978, and primarily established to preserve the natural and indigenous history of Costa Rica. The Cano Island National Park is popular with tourists as a snorkelling destination. Tourists also enjoy watching the sea turtles and humpback whales and pilot whales.

1.3 Background of Study Area: The Northern Shelf Bioregion of British Columbia

While several recent studies have documented the benefits of marine reserves at the global level such as improving habitat quality and biodiversity (Nicholos *et al*., 2020), supporting food provision services in communities worldwide (Cabral *et al*., 2020) and enabling the rebuilding of fisheries in the long term (Teh & Sumaila, 2020). Also, increasing evidence on MPAs shows that marine reserves play an important role in supporting the recovery of fisheries species that have been declining globally (Teh & Sumaila, 2020; Pauly & Palomares, 2005). This is achieved because marine reserves help support fisheries rebuilding by limiting unsustainable human activities in certain areas of the designated marine areas which is crucial to allow marine ecosystems to rejuvenate and increase future fish catches to meet the increasing global demand for seafood products (Nicholos *et al*., 2020).

[4] http://bcparks.ca/eco_reserve/checleset_er.html.

To date, most studies on MPAs have mainly focused on their effectiveness related to environmental conservation, and cost-benefit analysis of their implementation have primarily been done at a macro scale (Brander, Luke *et al*., 2015; Brander *et al*., 2020a; Cullis-Suzuki & Pauly, 2010; Pitcher *et al*., 2000; Rojas Nazar, 2013). In addition, there is a general debate in the literature on the contributions of MPAs to poverty alleviation and sustainable development (Mascia, Claus, & Naidoo, 2010), as some studies argue that MPAs place the welfare of fishes at the expense of communities who rely on fisheries for their livelihood (Paddock, 2006; West, Igoe, & Brockington, 2006).

Though, some studies argue that a healthy marine ecosystem acts as a form of nature's investment bank that would generate future dividends via the provision of more fish and higher incomes through marine-related jobs to the fisheries-dependent communities (Leisher, Carlton, Van Beukering, & Scherl, 2007). In addition, MPAs have been cited to increase the general health of the marine ecosystem through mitigating harmful activities in the oceans such as mining, overfishing (O'Hara *et al*., 2020a), thus enabling healthy oceans which produce more oxygen for humans to breath (Bijma, Pörtner, Yesson, & Rogers, 2013; Boonzaier & Pauly, 2016; Cullis-Suzuki & Pauly, 2010).

Even so, few of these studies on marine reserves have focused on estimating their benefits and costs in small coastal communities in the province of British Columbia (BC) (Alder *et al*., 2002; Burt *et al*., 2018; O'Hara *et al*., 2020a) such as the Northern Shelf Bioregion. The majority of the studies on MPAs in BC have concentrated on ecosystem valuation of market-based benefits

(Mitchell, 1989; Sumaila *et al*., 2000; Sumaila *et al.* 2001), with only a few both market and non-market (Philcox 2007, Molnar 2015). Furthermore, few studies on ecosystem valuation have been done at local levels such as in the NSB of British Columbia. British Columbia is one of the ten provinces and three territories of the Canadian federation. The BC province has an approximate human population of just over 5 million which mostly enjoy activities such as hiking in mountains and biking in trails. In addition, BC province is located in the Western part of Canada and is mainly surrounded by the Pacific Coastline and mountain ranges.

The first attempt to include ecosystem services in BC combining market and non-market benefits is by Philcox (2007), who provides a framework for non-market ecosystem services valuation. Examples of market-based ecosystem services include capture fisheries, tourism, and recreation while habitat protection, nutrient recycling fall under non-market-based benefits. Also, several studies (Cabral *et al.*, 2020; Costanza *et al.*, 2014), and technical reports on the estimation of economic benefits of ecosystem services have been produced (Levy, 2014; Molnar, 2015). These benefits include habitat protection, tourism, and recreation services. The David Suzuki Foundation has produced some notable reports for BC on the valuation of the Marine and Coastal Ecosystem Services in the Pacific North Coast Integrated Management Area (PNCIMA) and the Howe Sound area (Molnar, 2015a). In particular, the major findings of the David Suzuki Foundation report of 2015 on the Howe Sound Ecosystem valuation comprised demonstrated the unrecognized potential natural wealth in the Howe region and that are yet to be factored in for major decision making at local, provincial, and federal levels. This study further estimates that the Howe Sound watershed has the potential to generate between $800 million and $4.9 billion in ecological services annually (Molnar, 2015).

A closely related study to my current study on the Cost-Benefit Analysis (CBA) of creating and implementing marine reserves in the NSB was conducted by Department of Fisheries and Oceans Canada (DFO) in 2019 for the proposed MPAs in the Tavaijuittuq, North West Coast of Ellesmere Island in Nunavut, Canada[5]. This CBA report demonstrates the potential socio-economic impacts of the proposed MPAs in the Tavaijuittuq to human welfare measures such as scientific research, safety, security, and emergency activities that would be allowed in the protected area (DFO, 2019). Thus, the CBA on the Tavaijuittuq MPA showed the potential socio-economic benefits that could be generated from the vital direct and indirect services to the community on the Arctic marine and ice-associated ecosystem and biodiversity by comparing the impact of the activities to be potentially affected by the MPA; before and after MPAs are implemented (DFO, 2019).

Thus, the establishment of MPAs across the different Canadian provinces and territories contribute to the success of the country in protecting marine ecosystems compared to other countries. As a result of the concerted conservation efforts at different levels of governance across Canada, the country has surpassed its 10 percent MPA target protection for 2019 (DFO, 2021). Canada's current targets being to protect 25 percent by 2025 and 30 percent by 2030 (DFO, 2021). In 2016

[5]https://www.dfo-mpo.gc.ca/ea-ae/economic-analysis/CBA-MPA-Tuvaijuittuq-ACA-ZPM-eng.html.

alone, the federal government of Canada invested $1.5 billion through the Ocean Protection Plan to implement partnerships with Indigenous and coastal communities to develop marine safety systems that meet the country's needs (DFO, 2021).

In addition, detailed blueprints such as the Canadian Blue Economy Strategy have been created which estimate the economic contribution of the blue economic sectors such as fisheries, tourism, and recreation to approximately $31.7 billion annually in Gross Product and employ over 300 000 jobs (DFO, 2021). Thus, given these huge socio-economic contributions of protecting the marine ecosystems in Canada, the study on the net benefits in the Northern Shelf Bioregion would be hugely important especially to local communities whose livelihood rely on the ocean for food provisions and jobs.

However, to my knowledge, there are no known studies at the local level such as the NSB that provide an estimation of the net benefits of implementing marine reserves. This study, therefore, provides the first attempt to estimate the net benefits of implementing marine reserves in the NSB. To estimate the impact of the changes in marine reserve size in the NSB, I simulate how the net benefits could change under three scenarios of coverage i.e., 10, 30 and 50 percent of the NSB marine area compared to the status quo approach, where no marine reserves are implemented at all. To conduct the CBA for the NSB, I first provide a background of this study area below.

1.4 Demographic and Geographic Profile of the Northern Shelf Bioregion of British Columbia

The Northern Shelf Bioregion is located in the North Coast of BC encompassing a marine area that stretches over a total area size of about 101000km^2 covering two-thirds of BC's North Coast[6]. The NSB has four sub-regions that include Haida Gwaii, Northern Vancouver Island, the Central Coast, and the North Coast (See Figure 2.1).

The Haida Gwaii sub-region is an archipelago consisting of about 150 islands located 100 km west of the north coast of British Columbia. It has a diverse marine life that extends both onshore and offshore. Thick kelp forests and lush eelgrass meadows, coral and sponge reefs provide a lifeline to invertebrates and fish communities. Common fish species in this sub-region include Pacific halibut (*Hippoglossus stenolepis*), Pacific herring (*Harengus pallasii*) and all five species of Pacific salmon. This archipelago has about 4,400 people of Haida ancestry[7].

The North Vancouver Island region is in the interior BC area covering numerous islands, inlets, and fjords[8]. This area supports about 40000[9] people who live in main port areas such as Port Hardy, Port McNeil, and Campbell River. The main water bodies that support the vast biodiversity-ecosystem such as salmon, halibut, whales, and seals include Smith Inlet, Bute Inlet, Johnstone Strait and Queen Charlotte. More so, this region supports shellfish and finfish aquaculture,

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[6]https://www.dfo-mpo.gc.ca/index-eng.htm.

[7] https://www.dfo-mpo.gc.ca/index-eng.htm.

[8] https://mpanetwork.ca/bcnorthernshelf/the-region/.

[9] https://mpanetwork.ca/bcnorthernshelf/the-region/.

commercial fishing, seafood processing, transportation, and tourism activities such as Kayaking and sport-fishing charters.

The North Coast region is physically complex with a variety of diverse ecosystems, including important estuaries and fish species[10]. The North Coast estuaries provide important spawning habitat for salmon and herring, which are cultural keystone species for many of the coastal First Nations communities living along the North Pacific coast. There are also sea birds and important marine mammals such as humpback whales in this region. Overall, this region supports about 42000[11] people through tourism, commercial fisheries, processing facilities and logging. There are ports centered on Prince Rupert, Kitimat and Stewart communities serving other communities in BC and beyond. More so, the First Nations communities of the Gitga'at, Gitxaala, Haisla, Kitselas, Kitsumkalum, Metlakatla and Lax Kw'alaams have an intricate spiritual connection with this area.

The Central Coast region is characterized by a beautiful and ecologically diverse ecosystem that has rich culture across hundreds of its many islands[12]. The most common marine life that thrives in this sub-region includes Pacific halibut (*Hippoglossus stenolepis*), salmon, crab, prawn, and many rockfish species. There are also killer whales and sea otters that have helped restore kelp

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[10] http://mpanetwork.ca/bcnorthernshelf/.

[11] https://www.dfo-mpo.gc.ca/index-eng.htm.

[12] http://mpanetwork.ca/bcnorthernshelf/.

forest ecosystem dynamics. The Central Coast region has about 3500 people who live in the islands with ancestry from Heiltsuk, Kitasoo and Nuxalk Peoples[13].

In addition, the NSB is an ecologically diverse, robust, and representative group of marine reserves that help protect the biological and health of this marine ecosystem, for the present and future generations[14]. The NSB is one of the 13 ecological bioregions that were identified for protection across Canada through the Ocean Act.

According to DFO, the following six goals that underpin the establishment of MPAs in the NSB:

(i) To protect and maintain marine biodiversity, ecological representation, and special natural features;
(ii) To contribute to the conservation and protection of fishery resources and their habitats;
(iii) To maintain and facilitate opportunities for tourism and recreation;
(iv) To contribute to social, community, and economic certainty and stability;
(v) To conserve and protect traditional use, cultural heritage, and archaeological resources;
(vi) To provide opportunities for scientific research, education, and awareness.

In addition, the Northern Shelf Bioregion has four main subregions as shown on the Figure 1.1 on next page.

[13] http://mpanetwork.ca/bcnorthernshelf/.
[14] www.coastalnations.ca

Below, Figure 1.1 shows the map for the NSB showing the various sub-regions.

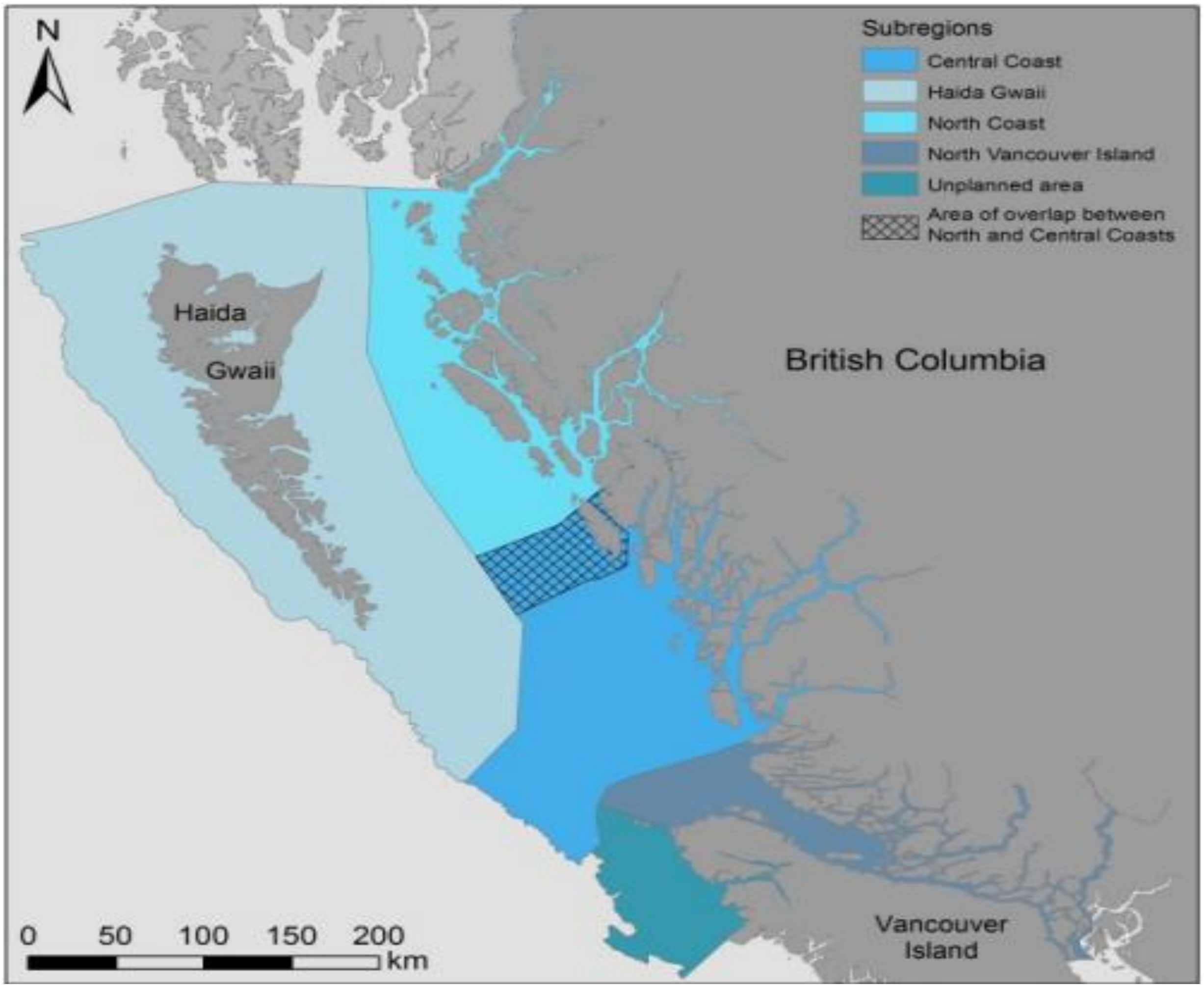

Figure. 1.1 Map of the Northern Shelf Bioregion

Source: https://waves-vagues.dfo-mpo.gc.ca/Library/40817787.pdf

Table 1.1: Summary of main community geography and demographics in the NSB

	Haida Gwaii	**North Vancouver Island**	**The North Coast region**	**The Central Coast region**
Human Population	4400	40000	42000	3500
Main First Nations communities living in the area	Xaadaa, Xaaydaga Gwaay yaay	Mamalilikulla, Tlowitsis, Da’nakda’xw-Awaetlatla, Wei Wai Kum and K’ómoks First Nations	Gitga’at. Gitxaala, Haisla, Kitselas, Kitsumkalum, Metlakatla and Lax Kw’alaams First Nations	Heiltsuk, Kitasoo, Nuxalk, and Wuikinuxv
Geographic areas	Old Masset, Port Clements, Tlell, Skidegate, Queen Charlotte and Sandspit	Mount Waddington, Strathcona between Vancouver, and Mainland, Port Hardy, Port McNeill, Alert Bay, Sayward and Campbell river	Prince Rupert, Terrace and Kitimat	Bella Coola, Bell Bella, Ocean Falls, Wuikinuxv and Klemtu
Main types of ecological life and human activities in the area	Humpback and killer whales, Dungeness crabs and Pacific Halibut	Shellfish and finfish, commercial fishing, seafood processing, tourism (e.g., Sport Fishing)	Salmon. Eulachon, herring, killer whales, and killer whales	Bears, and Grey humpback whales

Source: https://mpanetwork.ca/bcnorthernshelf/the-region/.

1.4.1 Relevant stakeholders in the Northern Shelf Bioregion

The main stakeholders involved in the NSB include the various businesses that employ people in various sectors such as recreation centers, federal and provincial agencies and the 17 First Nation communities and their governments as rightsholders[15]. First Nations communities are the Gitga'at, Gitxaala, Kitsumkalum, Kitselas, Haisla, Metlakatla, Kitasoo/Xai'Xais, Heiltsuk, Nuxalk and Wuikinuxv First Nations, Old Massett Village Council and Skidegate Band Council, Mamalilikulla-Qwe'Qwa'Sot'Em, Tlowitsis, Da'nakda'xw-Awaetlatla, Wei Wai Kum, Kwiakah and the K'ómoks First Nations. These First Nations communities primarily rely on the NSB marine ecosystem for fishing and cultural and spiritual connection. Recognizing the importance of the NSB, the Canadian Federal government introduced the 2005 Canada Oceans Action Plan that created the Pacific North Coast Integrated Management Area (PNCIMA) framework to develop and implement conservation goals in this area[16]. Thus, the NSB as part of the PNCIMA region was identified for key ecosystem conservation measures. The main conservation goals in the NSB include protecting biodiversity and supporting the health and resiliency of the NSB ecosystems through building thriving coastal communities with strong cultural and economic ties to coastal and marine areas (Vandermoor, 2017).

Moreover, the PNCIMA was further developed in 2017 via a collaborative process led through an Ocean Governance Agreement between the Federal, Provincial and First Nations Governments

[15] http://mpanetwork.ca/bcnorthernshelf/

[16] https://www.dfo-mpo.gc.ca/oceans/management-gestion/pncima-zgicnp-eng.html

(Vandermoor, 2017). A diverse group of organizations, stakeholder's government groups and rightsholders constitute the membership of PNCIMA (Vandermoor, 2017). The PNCIMA plan summarizes the background for ecosystem-based management (EBM) for the region, including, the assumptions, principles, goals, objectives, and strategies (Vandermoor, 2017). Some of PNCIMA's goals include ensuring the integrity of marine ecosystems in the NSB and supporting the well-being and spiritual connectedness of First Nations to marine ecosystems in the region (Vandermoor, 2017).

The EBM framework, upon which PNCIMA's work is based, is a reference point for managers, decision-makers, regulators, community members and resource users, as well as the Federal, Provincial and First Nations Governments, along with stakeholders, develop the integrated approach to ocean use in the planning area (Vandermoor, 2017). Furthermore, the PNCIMA plan provides a matrix of the information base and management tools used by other parties to facilitate the application of EBM at a variety of scales within the NSB. The five priorities identified for short-term implementation of the plan include governance arrangements for implementation, marine protected area network planning, monitoring and adaptive management, integrated economic opportunities, and tools to support implementation (Vandermoor, 2017).

Hence, this thesis will develop an empirical model to estimate the economic benefits of implementing marine reserves in the NSB and subsequently draw some proposed policy changes from the results. The NSB is home to 17 First Nations communities whose livelihoods, identity and wellbeing are intricately connected to the marine ecosystem. Hence the findings of this study will present some scientific evidence on the benefits of marine reserves in the NSB. Also, various federal agencies such as Fisheries and Oceans Canada, Natural Resources Canada and provincial agencies like the Ministry of Agriculture and Ministry of Environment and Climate Change Strategy play a key role in the governance of the NSB. Hence quantifying the net benefits of creating marine reserves will help paint a picture of the impact of creating marine reserves and increasing them in the NSB.

Also, this study has the potential to serve as a model case study that demonstrates the net benefits of implementing marine reserves in British Columbia. Additionally, it could be replicated across other provinces in Canada that already have or are considering establishing marine reserves. Moreover, estimating the economic benefits of creating and maintaining marine reserves in the NSB will provide scientific evidence that is important for policymaking at multiple levels such as provincial and federal policymakers and the 17 First Nation's communities across who rely on this region for their well-being.

There are few studies and reports focused on the economic valuation of marine ecosystems in Canada (White, 2001). In addition, other notable studies on MPAs have assessed their socio-economic benefits and contribution towards supporting human well-being, ecosystem health and aiding the meeting of the global conservation targets and promoting sustainable used of resources (Ban *et al*., 2017; O'Leary *et al*., 2018). However, in BC, most of the studies on MPAs have focused on either the whole province of BC (Knowler *et al*., 2003; MacConnachie *et al.*, 2007; Philcox, 2007; Sumaila *et al*., 2000a; Sumaila *et al*., 2001) or a few other areas such as the Howe Sound (Molnar, 2015). Thus, this study on the NSB will be the first of its kind.

In addition, most findings from the past studies support the hypothesis that established MPAs increase fish catches in the surrounding waters when the effort is kept constant (Alban *et al*., 2006a; Dwyer *et al*., 2020; Schmidt, 1997), due to the creation of a buffer zone where the fish can grow without being overfished (Schmidt, 1997). Related to this, the NSB case study will investigate how the different marine reserves scenarios (i.e., 10 , 30 and 50 percent), will affect different marine-based activities that generate economic benefits such as tourism, habitat protection, capture fisheries and fish processing sectors.

1.5 Research Goals and Objectives

The main objective of this master's thesis is to provide a Cost-Benefits Analysis of the potential economic impacts associated with the establishment and maintenance of marine reserves in the Northern Shelf Bioregion of British Columbia. Thus, through this study, I will: (i) provide a baseline scenario of economic activities currently happening in the NSB; and (ii) analyze the net benefits generated by the implementation of marine reserves using qualitative and quantitative methods.

To achieve this objective, the thesis is organized in the following manner:

Chapter 1: In this introductory chapter, the study goals, objectives, and motivations are presented, and marine reserves are defined, and the study area is described;

Chapter 2: Presents the results of a literature review which was conducted to assess the benefits of creating marine reserves according to previous work;

Chapter 3: A Cost-Benefit Analysis of marine reserves establishment in the NSB was developed and executed, and is described herein;

Chapter 4: Study findings are summarized, and policy implications discussed.

In the next chapter, I provide a summary of the key literature on the origins and progress in the field of MPAs to date. I describe the main objectives and motivations behind the establishment marine reserves as one type of marine protected areas and introduce the NSB of British Columbia as the case study of this thesis. I then develop a method to estimate the economic benefits of establishing the marine reserves in the NSB.

Chapter 2: Review of Marine Reserves benefits as a type of Marine Protected Areas

Globally, there is a growing body of literature that demonstrate the benefits of Marine Protected Areas (MPAs) in combating climate change and improving human well-being (Sala *et al*., 2018; Ban *et al*., 2019; Rasheed, 2020a). Also, MPAs have been publicized globally to conserve marine resources with 71 percent of reports on their impact showing positively increasing the fish populations and helping in improving relationships between policymakers and marine resources managers, and fisheries dependent communities globally through the creation of a shared discussion mechanism via the development of MPA management plans (Gill *et al*., 2017; Mascia, Claus, & Naidoo, 2010). The benefits of implementing MPAs are greater than the costs of such a conservation tool if stakeholders such as government policymakers and communities focus primarily on the role and impact in MPA effectiveness (Gill *et al*., 2017).

This brings into perspective the role of a clear and actionable management plan for establishing and maintaining marine reserves. A management plan is a blueprint document that essentially spells out the specific actions that are supposed to be taken and how the whole marine reserves would be implemented over time as well as their proposed phase plan including the objectives for protection. In addition to the extent of the marine area to be protected, the marine reserves' management plans also stipulate how the regulation of the protected marine area would be enforced for example, if specific fishes are prohibited from being fished or if sport fishing is to be allowed in the entire protected marine area. As noted earlier, the creation of marine reserves is to provide an area where there are no or strictly regulated human activities thus enabling marine organisms such as fish and marine living organisms to reproduce and grow with no human disturbance. In addition, marine reserves provide a ‘fish bank’ where fish and other living marine organisms can go and hibernate from human activities that can potentially impact their life.

Also, evidence from reviewed areas under marine reserves that have adequate staff capacity had improved ecological impacts of about 2.9 times more than those that were not well administered (Gill *et al*., 2017). In addition, marine reserves have been shown to increase the benefits from ecological functions and services, conserve ecosystems, and provide a buffer against ecological impacts of climate change; alleviate poverty in coastal communities (Fox *et al.*, 2012).

In addition, MPAs have been shown to increase equitable and inclusive decision-making methods that are more likely to achieve social and ecological outcomes (Edgar *et al*., 2014; Gill *et al*., 2019). The process of establishing MPAs involves consulting all relevant stakeholders and hearing their views including how the implementation of protected areas would affect their livelihood. Thus, bringing the stakeholders together and discussing the potential tradeoffs can help bring diversity and inclusivity which more likely influence all partners to collaborate and support the success of MPAs when they are implemented.

Furthermore, the extend of the benefits of protecting marine ecosystems worldwide is influenced by the size and degree of MPAs connectedness in achieving the conservation goals (Jonsson *et al*., 2020; Walters *et al*., 1999; Watson *et al*., 2000). Besides, several studies on MPA benefits suggest they generate higher streams of economic benefits such as quick replenishment of fisheries if they are created as networks rather than just individual protected area (Dinerstein *et al*., 2019; Lauck *et al*., 1998; Ye *et al*., 2013). An MPA network is a collection of single MPAs designed to operate collaboratively and in such an effective manner that a single MPA will not achieve e.g., in the NSB marine area, of the total marine area, MPAs could be designed in clusters throughout the whole area.

MPA networks have been shown to support the faster rejuvenation of trophic levels (McClure *et al*., 2020), and genetic diversity (Yan *et al*., 2020) which are critical to ecosystem health worldwide. Increasing evidence from studies also confirms the huge socio-economic benefits of MPA networks in the oceans (O'Leary *et al*., 2012; Sumaila *et al*., 2007b) and inshore coastal areas (Edgar, 2011; Gleason *et al*., 2013; Jonsson *et al*., 2020; Rees *et al*., 2014). The bioeconomic benefits are maximized when the network of MPA is strategically designed particularly if they are located in areas that were more overfished (Cabral *et al*., 2020).

Given the extent of Canadian ocean-based economic benefits such as jobs and ocean ecosystem health which contribute about 1.6 percent of total Gross Domestic Product (GDP), it has committed to implementing the Aichi Target 11 and UN Sustainable Development (SDG) goal 14 (DFO, 2021). The SDG will accelerate the conservation of marine ecosystems across the 10 provinces and the three territories. Thus, in line with the SDG 14, Canada has crafted a marine conservation strategy that aims to protect designated National Marine Conservation Areas, and marine portions of National Wildlife Areas, Migratory Birds Sanctuaries, National Parks, and provincial protected areas (DFO, 2021). In addition, the major step that Canada undertook in 2007 includes the establishment of the Ocean Act in 1996, which is a flagship marine protection law that mandates the minister of Fisheries, Oceans, and the Canadian Coast Guard to develop a national strategy and national system of MPAs (DFO, 2020).

In line with the Aichi Target 11, the government of Canada has invested over $1.5 billion since 2018 for five years to support achieving the 10 percent marine conservation target (DFO, 2021). Consequently, as of 2019, Canada has surpassed the 10 percent target of marine and coastal areas protection by over 3 percent (DFO, 2021). Subsequently, Canada is now working towards protecting 25 percent of the marine and coastal ecosystems by 2025 and achieving 30 percent by 2030 (DFO, 2021). In the paragraphs that follow, I describe the benefits of MPAs including marine reserves under the following headings: (i) biodiversity and habitat protection, (ii) Marine reserves and the restoration of threatened and degraded ecosystems, (iii) impacts of marine reserves on resource conservation for sustainable fishing, (iv) scientific benefits, (v) ecosystem benefits and (vi) socio-economic benefits of marine reserves. Benefits of marine reserves as a type of Marine Protected Areas

2.1 Biodiversity and habitat protection

The establishment of marine reserves helps achieve biodiversity and habitat protection by restricting harmful human activities such as overfishing (Costello, 2014a). Strategically situated marine reserves have been shown to support the healthy marine ecosystem including preventing the collapse of fisheries. In addition, healthier ecosystems supported by well-managed MPAs such as marine reserves have been shown to generate more socio-economic benefits such as more profits from abundant fish stocks in the oceans and more profit from businesses in the tourism and recreation sector which support livelihoods for millions of people globally (Sumaila & Teh, 2019). Implementing marine reserves enable business owners to realize higher profits compared to those located in marine ecosystems that do not have marine reserves often associated with the collapse of fisheries and damaged marine ecosystems which do not attract more tourists.

Generally, MPAs can mitigate the decline in marine ecosystems, which has been increasing over the past several years (Pauly, Christensen, Dalsgaard, Froese, & Torres, 1998), resulting in accelerated loss of populations and species globally (Gregr *et al*., 2020; Worm *et al*., 2006). Studies have shown that MPAs such as marine reserves reduce fish mortality (Leenhardt, Low, Pascal, Micheli, & Claudet, 2015). Over the short term, the increase in fish and invertebrate densities and sizes can support reproductive output and recruitment in ecosystems (Leenhardt *et al*., 2015b). The decline in ocean health has been attributed partly to human activities such as rapid industrialization and an increasing human population that has put more pressure on marine ecosystems and exacerbated climate change (Dinerstein *et al*., 2019; Du Pontavice *et al*., 2020; Sumaila *et al*., 2019), resulting in a poleward shift of marine species and community culture (Cheung *et al*., 2009).

Since implementing marine reserves helps conserve marine ecosystems by closing off selected designated areas that are at risk of damage, regulating human activities such as agriculture near oceans and fossil fuels combustion can help mitigate potential marine damage. Studies have demonstrated that human activities such as agriculture, construction, fossil fuel burning and solid waste generation accelerate climate change which is harmful to both humans and the natural environment because of the impact these activities exert on the environment (Aluko, Opoku, & Ibrahim, 2021; Zheng, Wang, Mak, Hsu, & Tsang, 2021). The growing global population have increased the demand for more construction sites for housing and more carbon emissions from industries and automobile vehicles. Human activities have been justified as both necessary and inevitable conditions to achieve economic growth which has been achieved in most developed countries globally (Alagidede, Adu, & Frimpong, 2016).

Furthermore, the increased economic and population growth have come with some drawbacks especially to the environment. Several of the human activities highlighted above when unchecked, can cause unprecedented damage to the environment. Studies have shown that as the industrial revolution has picked pace globally, anthropogenic Green House Gas (GHG) emissions have increased considerably principally as a consequence of economic and population growth (Alagidede *et al*., 2016; Wang, He, & Dong, 2019).

Thus, to their credit, well-managed and well-located MPAs such as marine reserves have been shown to generate more marine ecosystem benefits due to the reduced extractive pressure in biodiversity and provision of habitat protection as well as ecosystem resilience (Bates *et al*., 2014; Costello, 2014; Davis *et al*., 2019). Ecosystem benefits are the ‘rents’ to owners of capital or the natural environment that flow to humans through the use of those ecosystem services. Examples of ecosystem benefits from activities linked to the environment such as fishing, recreation, and tourism include profits to business owners in the tourism and recreational fishing sector. In this study, net benefits will be estimated using a topline number of net profits from specific private and public related sectors minus the costs of creating and implementing marine reserves in the NSB.

Furthermore, strategically implementing marine reserves supports long term biodiversity conservation of oceans and marine ecosystems which are important for providing food through fish to coastal communities (Cabral *et al*., 2020). Intricately connected to this, the establishment of MPAs such as marine reserves have enabled people to enjoy the beauty of nature and the health benefits that come from marine ecosystems (Ban *et al*., 2019; Kelleher, 1999). Health benefits include the mental well-being of humans derived from a well-managed marine ecosystem. Moreover, MPAs promote positive human well-being outcomes generated from the aesthetic beauty of well-managed marine ecosystems (Ban *et al*., 2019).

There is also encouraging evidence that implementing MPAs, in general, encourage communities to be good stewards of the ocean through stricter land use and policies by allowing them to be part of a larger conservation story of nature (Kelleher,1999). The process of establishing marine reserves involves stakeholder engagement which typically includes the local communities and governments agencies who are stewards of the marine ecosystems. This stakeholder engagement process can create increased awareness of the communities regarding the benefits of using marine reserves as a tool to manage resources such as fisheries in the ocean. Thus, marine reserves can increase the ecosystem benefits by bringing relevant stakeholders at the interface of each other to collaborate on discussions that include habitat protection, existence values of marine resources which are important for communities.

2.2 Marine reserves and the restoration of threatened and degraded ecosystems

With over 6 percent of the global marine ecosystem covered with MPAs of different sizes and degrees of protection[17], there is increasing evidence from studies showing improved food services benefits (Cabral *et al.*, 2020), and improved long-term health of the ocean ecosystem (Sala & Giakoumi, 2018; Teh & Sumaila, 2020b) in areas that have MPA networks. The marine ecosystem benefits can be in different shapes and forms such as restoration of fisheries that were near collapse and the restoration of threatened and degraded ecosystems such as vegetation that thrive in the oceans (Cheung *et al*., 2019; O'Connor *et al*., 2020). Thus, implementing marine reserves and other forms of MPAs can help support ecosystem biodiversity by restoring critical environment functions such as predation, thus strengthening energy flows and community assembly within natural ecosystems (Cheung *et al*., 2019).

Several studies have also shown that MPAs help improves conditions of marine environments such as enhancing biological parameters, survival rates of juvenile fish, species diversity (Brander *et al*., 2020), fish biomass by about 600 percent (Sala & Giakoumi, 2018), density and species richness by 20 percent (Lester *et al*., 2009; Sala & Giakoumi, 2018) especially marine reserves which increase the degree of protection of human activities in designated marine ecosystems. Likewise, these changes to the environmental situation generate more socioeconomic benefits of ecosystem services provision, such as increased profits to owners of capital, increasing job

[17]UNEP-WCMC and IUCN (2020), Protected Planet: The World Database on Protected Areas (WDPA) [Online], September 2020, Cambridge, UK: UNEP-WCMC and IUCN. Available at: www.protectedplanet.net.

opportunities in sectors that benefit from the protection of marine ecosystems such as tourism and recreation (Badalamenti *et al*., 2000; Brander *et al*., 2015; Potts *et al*., 2014; Russi *et al*., 2016a).

2.3 Scientific benefits of marine reserves

The establishment of marine reserves provides value to policymakers such as government officers by allowing for more insights into the functions of marine organisms and the marine ecosystem in general. As noted earlier on, the research and scientific evidence that is purposefully allowed in the monitoring of "no-take" fisheries reserves enhance the management of the marine resources as a result of the provision of valuable data in these protected areas (Kelleher, 1999). Several scientific methods have helped improve the understanding of MPAs effectiveness in marine ecosystems and adaptive management mechanisms (Pauly *et al.*, 2000; Rosales, 2018; Watson, 2020). Besides, techniques such as remote sensing have helped in providing rapid and highly detailed views of marine ecosystems (Allen *et al*., 2020; Sainsbury & Sumaila, 2003; Todd *et al*., 1999).

2.4 Ecosystem benefits of implementing marine reserves

MPAs come in different types and with different levels of protection. Thus, marine reserves a type of MPAs can mitigate climate change, restore depleted populations of target species (Sørdalen *et al.*, 2020; Walters, 2000), and repair damaged habitats (Jones *et al*., 2017; Sumaila *et al*., 2011). For instance, recent studies show that marine reserves rescue a sexually selected trait in European lobster by closing off the marine areas where these fish species are situated (Walters, 2000; Watson *et al*., 2000). In addition, marine reserves limit exploitation rates in marine fisheries to sustainable levels (Beattie *et al*., 2002). These ecosystems can be valued monetarily by estimating their current and or future value of earnings from these fisheries. Moreover, MPAs such as marine reserves help address climate change impacts by lessening pressure on the oceans and designated land-based protected areas through regulating harmful human activities to the environment (Bates *et al*., 2014; Davis *et al*., 2019; Mora *et al*., 2011; Roberts *et al*., 2017). More so, climate impacts have caused economic damage globally through the destruction of infrastructure and at times human lives.

MPAs contribute towards regulating human use of the oceans thus minimizing the impact on the environment (Alban, Appéré, & Boncoeur, 2006b; Costanza *et al*., 1998; Costanza *et al*., 2014). The intentional closure of certain marine areas as part of the MPA networks also diffuse potential conflicts in resources use, particularly in the multi-purpose parks, coastal areas, and highly contested parts of the oceans such as high seas (Kelleher, 1999).

Thus, the establishment of MPAs such as marine reserves help sustain life on earth through the preservation of marine life (Kelleher, 1999; Sumaila *et al*., 2019). Likewise, oceans are an important mechanism that provides coastal protection and marine biodiversity and carbon sequestration functions to the earth (OECD, 2017). A case in point, mangroves and coral reefs mitigate extreme weather actions such as storms and floods, by absorbing one-third of the carbon dioxide generated from human activities (Bijma *et al*., 2013; OECD, 2017). Therefore, establishing marine reserves worldwide enhances this crucial regulatory function and thus generates non-market benefits which can be quantified monetarily.

While the health of today's ocean ecosystems continues to decline due to increasing pressure from human activities such as overfishing and extractive actions like mining (Dinerstein *et al*., 2019; Pauly & Palomares, 2005a; Pauly & Palomares, 2005b), marine reserves present an opportunity to reverse this trend through carbon sequestration and nutrient cycling. Marine reserves create a buffer zone for ensuring fisheries habitat to be preserved (MacConnachie, 2007). In addition, marine reserves lessen ecosystem decline by creating a safeguard within for marine organisms such as fish to thrive and spawn (MacConnachie *et al*., 2007; Sumaila *et al*., 2000; Walters, 2000), while also saving public funds in the future that would otherwise be used to restore the species populations and long-term protection of critical habitat (Teh & Sumaila, 2020; Sumaila, 1998). Also, when fisheries are saved from collapse via the establishment of marine reserves, they increase future fish catches which are a revenue source for coastal communities.

2.5 Socio-economic benefits if marine reserves

Several studies show that marine reserves established on the oceans including the high seas and inshore support global fisheries (Cabral *et al*., 2020; Sala *et al*., 2002; Sala *et al*., 2018) and are vital for many coastal communities worldwide as the source of livelihood (Teh & Sumaila, 2013). Various international organizations such as the United Nations have been instrumental in stressing the need for conservation and sustainable use of high seas as indicated by the rise in summits on ocean science and management (Sumaila *et al*., 2007). In addition, human life on earth depends on the ocean with billions worth of food coming from the ocean (Kelleher, 1999; Sala *et al*., 2018). Furthermore, marine ecosystems cover 70 percent of the earth's surface and promote a diversity of other services that are critical for human wellbeing (OECD, 2017; Sumaila *et al*., 2015). For example, fisheries provide food and jobs to millions of people around the world (Teh & Sumaila , 2020; Russi *et al*., 2016b). In the marine ecosystems where marine reserves have been strategically implemented, studies have reported increased food provision from fisheries (Cabral *et al*., 2020).

Global estimates show that about 40 percent of fish stocks in the North-East Atlantic and 87 percent in the Mediterranean and Black Seas, for instance, are currently under unsustainable fishing practices (Somero, 2012; Sumaila & Tai, 2020), increasing significant stress on ocean life (Somero, 2012). All the noted benefits above generate monetary benefits to owners of the capital in the oceans and direct income from employment income. Without MPAs these incomes could face the threat of collapse as the employment sector will not be there anymore. A case in point in Canada is that of the Atlantic Cod (*Gadus morhua*) fishery that abruptly collapsed in 1993 owing to overfishing in the late mid-1950s resulting in over 35, 000 jobs being lost[18].

The implementation of marine reserves creates revenue-generating opportunities such as business and branding opportunities around the thriving protected marine areas (Beaumont *et al*., 2007; Böhnke-Henrichs *et al*, 2013; Russi *et al*., 2016). In the European Union Natura, for example, the establishment of marine reserves have created financial opportunities for companies through quality certification of MPA brand labelling. The European Union Natura branding initiative enables anglers and aquaculture producers to charge a premium price for their MPA produce (Russi

[18] https://www.dfo-mpo.gc.ca/fisheries-peches/ifmp-gmp/cod-morue/2020/cod-atl-morue-2020-eng.html

et al., 2016). In Canada, the Seafood product preparation and packaging revenues contributed about $6 billion in economic impact 2018 (Statistics Canada, 2019).

Furthermore, marine reserves support other blue economy sectors such as tourism and recreation (Bari, 2017; Dwyer, 2018; Garza-Gil *et al*, 2019). As noted earlier, Canadian ocean-based economy generates about $31.7 billion annually from jobs and tourism sectors. In addition, several case studies globally such as the European Union Natura MPA initiative and MPAs established across North America have shown increased long-term capture fisheries benefits (Sala *et al*., 2002; Sala & Giakoumi, 2018; Sala *et al*., 2018; Sumaila *et al*., 2000).

In this chapter, I described the definitions and the various local and international conventions that have been connected and that underpinned the implementation of MPAs and their various types such as marine reserves as a notable tool for the conservation of marine ecosystems. I also described the major sources of benefits from the implementation of MPAs specifically focusing on marine reserves globally. In the next chapter, I provide a framework that I employed in the Cost-Benefit Analysis methodologies for this study. I also provide a brief background of the main economic sectors that can be impacted by the implementation of marine reserves in the NSB, thus creating room for potential economic benefits. I show that the efforts taken to establish marine reserves in the NSB will generate net benefits by subtracting the costs of establishing and maintaining the marine reserves from the aggregate economic benefits from the relevant revenue-generating sectors of the NSB economy (Market benefits and non-market benefits).

Chapter 3: Cost-Benefit Analysis of Implementing Marine Reserves in the Northern Shelf Bioregion

3.1 Introduction

The goal of this analysis is to estimate the benefits and costs of implementing marine reserves in the NSB. Thus, I assess the potential changes in the net revenues generated from a selected source of benefits that have a socio-economic impact on the NSB community and subtract the costs of creating and implementing marine reserves over time. The creation of marine reserves will affect the NSB community through the potential change in the trajectory of the future revenue streams from certain economic sectors described below and as some costs such as establishment and maintenance costs throughout the life of their life cycle.

In addition, investing in the implementation of marine reserves in the NSB will involve the use of public funds that have some potential alternative costs (opportunity costs), as such there are potentially winners and losers when MPAs are implemented (Sumaila *et al*., 2015). Opportunity costs are the value of the alternative public policy tool that could have been employed to conserve the NSB marine resources, for example, closing off the marine area from commercial fishing could result in a drop in revenue in this category. Hence Cost-benefit analysis (CBA) is the public sector's profit and loss analysis tool for helping society make economically sound decisions. It particularly helps in deciding what policies or programs should be implemented from the standpoint of society. Thus, CBA incorporates the social valuation of all inputs and outputs related to a given project or policy – whether or not they are transacted in private markets or not.

In this chapter, I conduct a CBA to estimate the potential net benefits of implementing marine reserves using benefit transfer and econometric modelling methodologies. In addition, the analysis uses net revenue from the variables that fall under market and non-market benefits categories as the topline number.

The CBA process follows three different procedures. Firstly, to capture the potential economic benefits of implementing marine reserves in the NSB, I identified 4 sources of market benefits that relate to the human well-being of the NSB communities over time. In addition, the net benefits of implementing marine reserves from these sectors were chosen because; (i) as noted earlier on, because they affect human well-being and the general health of the marine ecosystem, (ii) these selected sectors of the market and non-market benefits have been shown in the literature to be affected by the implementation of MPAs in general. Hence, establishing marine reserves in the NSB will affect the potential net profit in these selected sectors either positively or negatively (Sala *et al.*, 2016, Sala *et al*., 2018, Molnar, 2015).

In this study, the CBA assumes that the implementation of marine reserves in the NSB marine ecosystem is connected to both market and non-market benefits. Examples of non-market benefits in this study will include habitat protection, existence, and carbon sequestration. The net benefits of non-market benefits in this study estimated using the Willingness-to-Pay method. I use a flow diagram to show the various benefits and courses employed in this study below.

Flow diagram of calculation for the net benefits of implementing marine reserves in NSB using the CBA approach

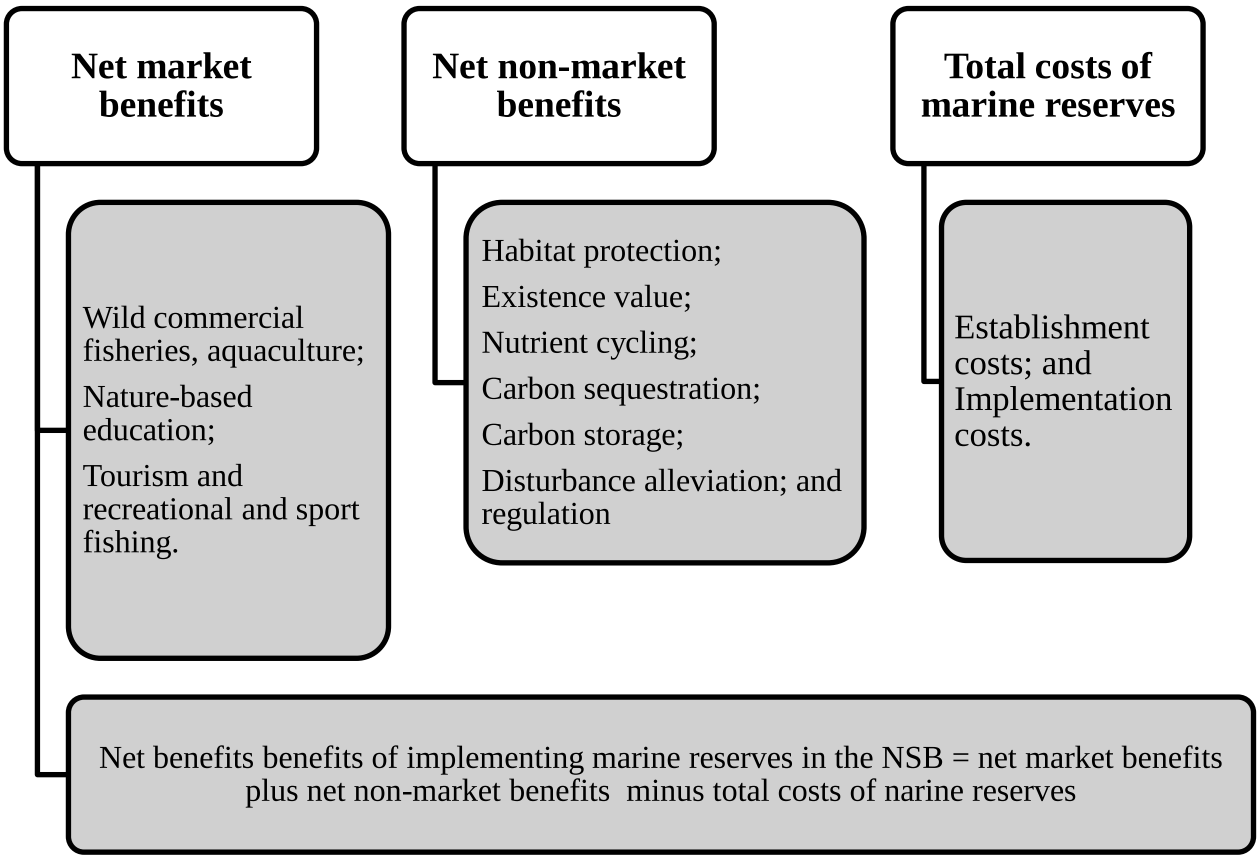

Figure 3.1. The methodological process that was followed to estimate the net benefits of implementing marine reserves in the NSB.

The data for the gross market benefits of variables listed above were obtained from literature, and where not available, I used guesstimates based on theoretical foundations from literature. In addition, the data were divided into three sections, market and non-market benefits using the following order; (i) market benefits, (ii) non-market benefits and (iii) the costs of creating and implementing marine reserves in the NSB. Where the values were obtained in the gross terms, they were subsequently adjusted to net benefits by multiplying them with the average profit margins in their respective categories as obtained from Statistics Canada (See Table 3.1. for specific profit margins that were used in the CBA of the NSB).

The choice of the 4 sources of market benefits was informed by the literature, which suggests that establishing MPAs such as marine reserves in an ecosystem would affect the capture fisheries, tourism, and recreation (Sala *et al*., 2002; Sala *et al.*, 2016; Sala & Giakoumi, 2018). Moreover, nature-based education has been highlighted as a key source of ecosystem benefits in literature, as such, marine reserves will have an impact on this benefit too (Molnar, 2015). The following sectors representing market benefits in the NSB are included in the study;

(i) wild commercial fisheries;
(ii) aquaculture;
(iii) nature-based education; and
(iv) tourism and recreational and sport fishing.

(i) Commercial wild capture fisheries

Many business activities depend on the marine ecosystem to succeed (Dyck and Sumaila, 2010; GsGislason *et al*., 2007; Teh & Sumaila, 2020). These include resources extraction, processing, and distribution services. Commercial wild fisheries fall in the extractive services sector as it generates profit from the sales of fish landing and sale of tradeable fishing quotas. In addition, social and economic benefits such as job creation (Sumaila *et al*., 2012), seafood provision services

(Cabral *et al*., 2020) and food processing sectors that employ millions of people in BC and globally. Hence the relevant questions here are;

a) What are the current commercial fisheries revenues derived from the NSB? and,

b) How will the implementation of additional marine reserves affect these?

(ii) Aquaculture

As noted in the main community geography and demographics section in Chapter 1, aquaculture is a common practice in the NSB area. Aquaculture is the farming, rearing, and harvesting of fish, shellfish, and other creatures in all types of marine environments (NOAA, 2020). Aquaculture can be divided into two categories: (i) marine aquaculture which denote the breeding of fish species that live in the ocean, and (ii) freshwater aquaculture.

In addition, aquaculture and marine reserves implementation have synergies that can be explored to allow for regulated multi-purpose use that includes aquaculture activities within marine reserve zones example e.g., under the IUCN classification (See Appendix Table A2) of MPAs (Day *et al.,* 2012; Le Gouvello *et al*., 2017b). As such, implementing marine reserves can generate opportunities for increased revenues through enhanced aquacultural activities within MPAs, e.g., in Italian MPAs, there was evidence of increased productivity of the pellet-reared dusky grouper *Epinephelus marginatus* juvenile fish (Day *et al*., 2012). Moreover, rebuilding fisheries using aquaculture in the NSB marine reserves could reduce the pressure from the fish stocks in the ocean. Aquaculture has been noted to support the rebuilding of the fish population where it has been implemented (Le Gouvello *et al*., 2017).

(iii) Nature-based education

As noted in the main community geography and demographics, the NSB is endowed with whales and spectacular scenery. As such, the data from nature-based education were obtained from the ecosystem valuation report by the David Suzuki Foundation (Molnar, 2015). Similarly, the goal here included addressing the following two questions;

a) What are the current nature-based revenues derived from the NSB?
b) How will the implementation of additional marine reserves affect these?

(iv) Tourism, recreational and sport fishing

Tourism, recreation, and sport fishing generate revenues from tourists who are willing to pay for these services. Equally, as noted above, I focus on answering the following two questions;

a) What are the current revenues in the NSB that come from tourism, recreational and sportfishing sectors?
b) How will the implementation of additional marine reserves affect these?

Thus, I use the proportion of net revenues from tourism, recreation, and sport fishing in BC to estimate the potential revenues from this sector in the NSB. In my calculations, I divided the proportion of the BC revenues from the tourism, recreational and sport fishing to that of the NSB by multiplying the ratio of the BC marine area to that of the NSB. For example, I obtained the proportion of BC's revenues from tourism and recreation and sport fishing for the year 2016 and adjusted this value to 2020 values to capture the effects of inflation using the Central Bank of Canada Consumer Price Index calculator. I then multiplied the resulting value by the proportion of NSB marine area and divided it by the total BC[19] marine area, which is a factor of 0.2[20]. The resulting market benefit estimate of the tourism and recreation and sport fishing was then multiplied by the profit margin of 73 percent (Statistics Canada, 2020).

Secondly, I examined 5 sources of non-market benefits, referred to as non-market benefits thereafter. These were selected based on the literature review I conducted and reported above (Figueroa & Pasten, 2011; Molnar, 2015b; O'Connor *et al*., 2020). Based on the literature review, there is increasing evidence that MPAs including marine reserves increase the potential benefits from the following sectors when implemented. The selected non-market benefits consist of;

(i) habitat protection;
(ii) nutrient recycling;
(iii) carbon sequestration;
(iv) carbon storage; and
(v) disturbance alleviation and regulation.

Finally, I estimated the establishment and maintenance costs associated with the creation of marine reserves, in the NSB using a model from McCrea-Strub *et al*. (2011).

[19] Canada-British Columbia Marine Protected Area Network Strategy (dfo-mpo.gc.ca).

[20] 101000/450000 which is the proportion of NSB marine area / BC marine area.

3.2 Methodology

The CBA was conducted for two-time horizons: (i) short term (eight years) and (ii) long term (50 years). The choice of the short term time horizon was informed from literature (Sala *et al*., 2016), and the 50 years were considered to be long enough to capture the long term benefits of implementing marine reserves in the NSB (Sumaila and Walters 2004; Dasgupta, 2021). The baseline year for calculating the economic benefits was 2020. The prices of values for the market and non-market benefits that were obtained before the baseline year were converted to 2020 prices using the Central Bank of Canada Consumer Price Index calculator. To investigate the impacts of implementing marine reserves versus not implementing at all, I compared the status quo (no marine reserve) scenario to potential future scenarios of new marine reserve sizes of 10 , 30 and 50 percent of the area of the NSB established, respectively.

Mathematically, the net benefits of creating and implementing over time were estimated by using the following;

$V_1, V_2, V_3 \ldots\ldots V_t$ …………………………………………………………………………… (1)

$C_1, C_2, C_3 \ldots\ldots C_t$ …………………………………………………………………………… (2)

$V_1 - C_1, V_2 - C_2, V_3 - C_3 \ldots\ldots V_t - C_t$ ………………………………………………………… (3)

The Net Present Value (NPV) was estimated using the following formula;

NPV = NFTt/(1+r)^t ……………………………………………………………………………(4)

Where NPV is the net present value/current value, NFTt the net future value in year t, and r is the discount rate, in this study 3 percent per year. Thus, V1 captures the NPV values for year 1, in this case, 2021 derived for the respective market and non-market benefits. For example, the NPV of benefits in the commercial wild capture fisheries, aquaculture, nature-based education and tourism, recreational and sport fishing. The NPV values for the non-market benefits were estimated using meta-analysis and regression analysis and forecasted yearly from 2020 through to 2070. Their values were captured and added to estimate the total annual NPVs. The final NPV values for NSB were then calculated by subtracting the total annual costs of establishing and maintaining marine reserves total annual NPV values e.g., results from Equation (4).

Thus, V_1 for example would capture the market and non-market benefits at period 1 (e.g., the year 2021) and C_1 captures the establishment and maintenance costs for the same period (e.g., the year 2021). Due to the concept of discounting, $1 received today is not equal to $1 to be received in the future. To account for this, I used a discount rate (r) of 3 percent per year to calculate future values of net benefits of implementing marine reserves in the NSB, and therefore in summing up net present values. I selected the discount rate of 3 percent per year because of the recommendation in the literature (Sumaila, 2004; Sumaila & Walters, 2005; Dasgupta, 2021).

Note that while the issue of the appropriate discount rate to use in estimating present values of project benefits in different services sectors including climate change mitigation, a recent review by Dasgupta, 2021, provides a more extensive literature review on this matter that has been brewing for many years. The study by Dasgupta, 2021 found that the use of a discount rate between 1-3 percent annually is acceptable for climate mitigation projects. While the mathematics behind the derivation of these appropriate discount rates is beyond the scope of this thesis, I acknowledge that this is a topical issue for debate that has gone on for many years.

The survey by Drupp *et al*., (2018) found that out of 90 percent of the economists consulted on the appropriate discount rate for investment projects recommended 1-3 percent per year as acceptable for long run public project (Dasgupta, 2021). Hence based on this evidence from literature, I used the 3 percent per year discounting rate to calculate the present values of the economic benefits of implementing marine reserves in the NSB.

Future values of benefits from marine reserves were determined using average historical growth rates from the grey literature published by the Department of Fisheries and Oceans in 2018[21], Oceana report of 2020[22] and Waldron *et al*., (2020).

$$NPV = \sum_{t=0}^{T} d^t (V_t - C_t) \qquad (5)$$

Where $t = 0,1,2,..,T$; and the discount factor, $d = \frac{1}{(1+\delta)}$, $\delta = d$iscount rate

[21]https://www2.gov.bc.ca/assets/gov/farming-natural-resources-and-industry/agriculture-and-seafood/statistics/industry-and-sector-profiles/sector-snapshots/sector_snapshot_2018_-agriculture_seafood_and_food__beverage.pdf.

[22]https://fisheryaudit.ca/appendix/Fisheries%20rebuilding%20success%20indicators%202020_FINAL.pdf.

3.3 Measuring market benefits of marine reserves in the NSB

For each of the four sources of market benefits that were identified above, market benefits were estimated, including for commercial fisheries (both wild and aquaculture), nature-based education, fish processing (both wild and aquaculture), tourism, recreation, and sport fishing, and wages and salaries from both wild and aquaculture sectors.

First, I considered that each management scenario (i.e., 10 percent, 30 percent, and 50 percent marine reserve protection), would be similar to not increasing the impact of human activities beyond the current activities in the NSB marine area. This approach was taken by DFO, 2019 in estimating the socio-economic impacts of the proposed Tavaijuittuq MPA. Also, because I could not find an alternative way to isolate the impacts of implementing marine reserves in the NSB, and other influences from other factors in the area such as climate change or unexpected changes in tourism and recreation revenues due to a pandemic such as COVID-19, I assumed that they would not have an impact on my estimations.

I then obtained the data for all the listed activities that could generate future benefits if marine reserves were to be implemented in the NSB. I assumed that the gradual implementation of marine reserves in the NSB from 10 , 30 and 50 percent would provide a stop-gap measure for the fisheries to grow, and higher catches would be realized in the long term square kilometer of the NSB marine area. Based on my data, I considered the year 2020 to be the baseline for all my calculations and projected the NPV for potential economic benefits in the following years up to 2070. I obtained the values of the sources of market benefits mentioned I paragraphs above using market prices in the latest in fisheries reports published by the Department of Fisheries and Oceans 2018[23] and adjusted for inflation using the Central Bank of Canada's Consumer Price Index[24]. Landed values for wild capture fisheries were obtained from the Statistics Canada and BC Statistics databases (Table 3.1).

Also, the baseline landed values from 2016 were used to forecast values for fisheries for the study period. Furthermore, the fish processing values were calculated as the difference between wholesale values and landed value to reflect value addition. Wages and salaries, and tourism, recreation, and sport fishing values were obtained from Statistics Canada and BC Statistics.

As noted earlier on, the gross revenues from selected sources of market benefits were adjusted to net profit and calculated using a profit margin of 4 percent and 7 percent (Edwards & Pinkerton, 2020). The profit from the market-based sectors in the NSB were assumed to be between 4 and 7 percent (Edwards & Pinkerton, 2020) as shown on Table 3.1.

Table 3.1. Profit margins used in calculating net profits of creating marine reserves in NSB

Low scenario (%)	**High scenario (%)**
0.04	0.07

Source; (Edwards & Pinkerton, 2020)

[23]https://www2.gov.bc.ca/assets/gov/farming-natural-resources-and-industry/agriculture-and-seafood/statistics/industry-and-sector-profiles/sector-snapshots/sector_snapshot_2018_-agriculture_seafood_and_food__beverage.pdf.

[24]https://www.bankofcanada.ca/rates/related/inflation-calculator/.

Since there were challenges in obtaining some data, such as obtaining absolute numbers of people employed in the NSB, I estimated the wages and salaries values as the proportion of people working in BC relative to the total population in BC in the same ratio as the proportion of NSB area compared to the total BC marine area. Thus, to address the potential challenge of using imported data from another policy site, in this case from BC to the NSB marine area, I adjusted the wages and salaries data from the British Columbia proportionally by multiplying the BC numbers with the ratio of NSB marine area to BC total marine area. The adjustments to the data were done to capture the differences in area size between where the data were taken and the study area (Figueroa & Pasten, 2011; Newbold *et al*., 2018). Also, NSB's carrying capacity was estimated based on (Oceana, 2019)[25]. Table 3.2 on next page provides a summary of the data sources used in the calculations of net benefits.

[25]https://fisheryaudit.ca/appendix/Fisheries%20rebuilding%20success%20indicators%202020_FINAL.pdf

Table 3.2. Growth rates of model parameters used in calculating net benefits of implementing marine reserves in the NSB

Growth rates of model parameters	Parameter values (%)	Sources for parameter values
Wild commercial fisheries	3	BC Statistics and Statistics Canada
Aquaculture revenue	7	BC Statistics and Statistics Canada
Nature-based education	9	BC Statistics and Statistics Canada
Tourism and Recreation and Sportfishing	4	BC Statistics and Statistics Canada

Note that as on Table 3.2, the landed wild commercial capture fisheries in BC are forecast to grow by 3 percent annually into the future (DFO, 2018). Also, total contributions to BC's Gross Domestic Product from the aquacultural sector in BC; nature-based education; tourism and recreational fishing are estimated to grow by 7, 9, 4 percent, respectively (DFO, 2018).

3.4 Measuring non-market benefits of marine reserves in the NSB

Non-market benefits are derived from most environmental goods and services such as clean air, habitat protection and existence values (Bateman & Kling, 2020; Haab & McConnell, 2002). As such, these goods and services are not traded in the market. In this study, non-market benefits were captured mainly using benefits transfer and econometrics methods.

Benefit transfer is a non-market valuation tool that is employed in varying decision contexts, especially, when there is limited existing data other than from another 'policy site' (Rosenberger

& Loomis, 2017; Randall & Loomis, 2017a). Benefit transfer method that involves using data from one 'study area' to estimate the values for the same variable in another[26] (policy area) where there are no data for measuring that particular variable in question (Richardson, Loomis, Kroeger, & Casey, 2015). Hence, the benefits transfer method was applied as it uses prices from past studies to value goods and services in the analysis where such data are lacking (Johnston & Wainger, 2015; Rosenberger & Loomis, 2017).

When conducted carefully, the benefits transfer method provides reasonable estimates of the value of unstudied resources (Richardson *et al.*, 2015), such as those in the NSB. Moreover, the benefits transfer method offers a quick estimate of the value of resources under time constraints and resources to conduct primary data collection such as legislative deadlines due to short fiscal deadlines (Iovanna & Griffiths, 2006). Moreover, studies have also shown that even in cases where the precise valuation of welfare estimates are required, the results would not likely change the main conclusion of the analysis (Timmons, 2013), and such approximate values are enough to be the basis for sound policy recommendations (Dupras *et al.*, 2015; Johnston & Wainger, 2015; Richardson & Loomis, 2009).

[26] The NSB is the policy area in this case where there are no data to estimate the non-market benefits of establishing MPAs in this area. Hence the benefits transfer method was employed to provide an estimate for the net benefits of establishing MPAs in this area.

There are four ways to implement the benefit transfer methodology:

1) The easiest to implement is the *unit value transfer*, which does not require adjustment of unit values (Figueroa & Pasten, 2011);
2) The *adjusted unit value transfer* method, which allows for adjustment of differences in population characteristics such as incomes and demography as well as area attributes such as hectarage (Andreopoulos & Damigos, 2017; Figueroa & Pasten, 2011);
3) The *value function transfer* method, which relies on a regression analysis underpinned by a theoretical model of valuing the environment (Figueroa & Pasten, 2011).
4) The *econometric model*, with population and area characteristics as explanatory variables. This is implemented using data from past studies on the valuation of non-market benefits of the environment.

Also, note that the explanatory variables that are statistically significant factors for the *econometric model* are then used to predict the Willingness-To-Pay (WTP) for the identified "policy site' (Andreopoulos & Damigos, 2017), in this case, the NSB. The significant predictors at the study site of WTP typically from contingent valuation or choice experiment studies are identified at the policy site. The average value of predictors at the 'policy site' is then 'plugged into' the 'study site' Value Function to derive an adjusted WTP figure for the policy site.

However, the limitation of the value function is that it assumes that all values can be obtained from a single source (Andreopoulos & Damigos, 2017), yet data are usually gathered from more than one study. Hence, to address the challenges that may arise when values are imported from different sources, the meta-analytic function of the *econometric model* becomes more appropriate. This approach involves the meta-analysis of multiple studies. It also assumes that the utility of the marine areas is uniform across the different study sites.

The assumption that utilities are similar across different studies is too restrictive. However, it can be relaxed and resolved by adopting a meta-analytic function that allows for different utilities. Figueroa & Pasten (2011), suggested the use of a WTP adjustment factor in transferring values from other studies. The adjustment factor is derived from an empirical estimation of the responsiveness of WTP to changes in Gross Domestic Product (GDP). Equation 1 shows that WTP of the current study relative to that of the foreign study site can be adjusted by incomes of the respective countries:

$$\frac{WTP_{NSB}}{WTP_{import}} = GDP_{NSB}/GDP_{import} \qquad (6)$$

WTP values are expected to change in response to changes in income (Figueroa & Pasten, 2011; Horowitz & McConnell, 2003; Lindsay, Halstead, Tupper, & Vaske, 1992). Thus, WTP values change in response to changes in income by a factor ϵ, for elasticity. The elasticity in the model will capture the changes in the income from the NSB as related to that of the income level from the data source.

$$\frac{WTP_{NSB}}{WTP_{import}} = \left(\frac{GDP_{NSB}}{GDP_{import}}\right)^{\epsilon} \qquad (7)$$

$$WTP_{NSB} = WTP_{import} * \left(\frac{GDP_{NSB}}{GDP_{import}}\right)^{\epsilon} \qquad (8)$$

To mathematically obtain the ϵ function, I take logs on both sides. Thus, taking logs of both sides yields:

$$logWTP_{NSB} = log\left[WTP_{import} * \left(\frac{GDP_{NSB}}{GDP_{import}}\right)^{\epsilon}\right] \ldots\ldots(9)$$

$$logWTP_{NSB} = logWTP_{import} + \epsilon\left[logGDP_{NSB} - logGDP_{import}\right] \ldots\ldots (10)$$

Thus, $logWTP_{NSB}$ is an unknown constant that can be A for simplicity. Additionally, whilst $\epsilon(logGDP_{NSB})$ is a known constant that can be denoted by B. Equation (10) becomes:

$$A = logWTP_{import} + B - \epsilon logGDP_{import} \ldots\ldots (11)$$

$$logWTP_{import} = (A - B) + \epsilon logGDP_{import} \ldots\ldots (12)$$

Letting $C = (A - B)$ results in the following function.

$$logWTP_{import} = C + \epsilon logGDP_{import} \ldots\ldots (13)$$

Thus, ϵ can be estimated empirically using regression analysis. The empirical regression model can control for other factors, which affect WTP beyond GDP and their coefficients can jointly determine elasticity ϵ. The empirical model estimated in this study was;

$$WTP = C + GDP + \text{area} + \text{population} + \text{country} \ldots\ldots (14)$$

where C is a constant, area refers to the marine area of the study, population refers to provincial or national population depending on the scope of the study. In this study, the marine area is the NSB. Country refers to the country of the study. Population and study area both capture the concept of differences in utilities in the study sample. Theoretically, a larger population is likely to increase demand for natural resources which suggests increasing WTP upwards to an optimal point beyond which environmental degradation will begin to occur (Cropper & Griffiths, 1994; Ehrlich & Holdren, 1971; Khan *et al.*,2018; Uniyal *et al.*, 2020).

On the other hand, a larger area is likely to reduce WTP due to diminishing marginal utility associated with large quantities of economic goods and environmental degradation (Cropper & Griffiths, 1994). The regression model in Equation 9 will produce a model for estimating WTP values for other settings such as NSB. Hence, the ratio of the estimated WTP_{NSB} to the WTP values from previous studies WTP_{import} was used to adjust the imported non-use[27] values. This approach, therefore, addresses the concerns raised in the literature over importing values between different places and adjusting for different utilities and diminishing utilities from the marine resources (Newbold *et al.*, 2018; Richardson *et al.*, 2015; Rosenberger *et al.*, 2017b). Furthermore, the meta-regression that produced the model from Equation (11) considered differences in the characteristics of previous studies due to the control variables.

The values from the literature used in this study span across decades, thus raising the need to adjust for temporal price changes. Subsequently, the prices used were adjusted to 2020 prices using Consumer Price Indices (CPI) obtained from the Bank of Canada website[28]. In addition, the meta-analysis approach in this model employed studies from different countries. Hence,

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[27]The value people allocate to ecosystem goods and services regardless of whether they are used or not. Use value on the other end, is generated from the direct benefits people derive from ecosystem goods.

[28] https://www.bankofcanada.ca/rates/price-indexes/.

income values were adjusted using the average exchange rate of the year of the original study to the Canadian dollar (CAD). These data are available on the OFX financial institute website[29].

3.5 Cost of creating marine reserves in the NSB

The final component needed to estimate the net benefits of implementing marine reserves in the NSB includes calculating the costs of establishing and maintaining the are under marine reserves. For simplicity of this study, I considered two sources of the costs;

a) Establishment costs, and;
b) Maintenance costs such as enforcement and paying wages and salaries for staff who ensure that marine reserves rules are adhered to.

a) Establishment costs of marine reserves in the NSB

The relevant model for estimating costs of establishing marine reserves in the NSB was taken from McCrea-Strub *et al*. (2011). I carried out a meta-regression analysis using the McCrea-Strub model to establish factors that determine variation in capital costs of creating the marine reserves in the NSB. The significant explanatory variables I determine is used to estimate establishment costs for setting up marine reserves for the NSB region under different coverage scenarios. The empirical model regressed establishment costs over marine reserve size and proportion of marine reserve to the total marine area using the following equation:

$$lnMPACost = C + lnMPA\text{area} + ln\text{PROPmpa} \qquad (15)$$

[29] https://www.ofx.net/.

Where MPA represents the marine reserve.

The regression estimates led to a model for estimating the NSB marine reserve maintenance cost. In addition, the costs of establishing a marine reserve were discounted through the years using a 3 percent discount rate (Sumaila & Walters, 2005) and as supported by the Canadian CBA Guidelines[30] which recommends less than 10 percent for big public projects.

b) Measuring maintenance cost of establishing marine reserve in the NSB

As noted earlier, the model for estimating maintenance costs for the NSB marine reserves was also obtained from McCrea-Strub *et al*. (2011), which is expressed as:

$MC = 10^{5.23} * \text{MPA}^{0.21}$ …………………………………………………………………….. (16)

where MC is recurrent costs, which are assumed to nonlinearly depends on MPA, which represents the marine reserve size. Hence to obtain the maintenance costs at the 0, 10 , 30 and 50 percent marine reserve coverages, the NSB marine area was entered into equation 12 and the results recorded in an excel spreadsheet. The time horizon covered for the short, medium, and long term were 2021 to 2070.

[30] https://www.tbs-sct.gc.ca/rtrap-parfa/analys/analys-eng.pdf.

3.5 Results

3.5.1 Short term market benefits for different marine reserve sizes created in the NSB

As noted earlier on, the results of estimating the net benefits of creating and implementing marine reserves in the NSB involved three steps; (i) estimating the net market benefits; (ii) estimating the non-market benefits and, (iii) simulating the costs of establishing and implementing the marine reserves. I then added up the discounted market and non-market benefits and subtracted the costs of creating and establishing the marine reserves. The analysis incorporated the short term (8 years) and long term (50 years) time horizons.

The results show that the net benefits for the short term are largely negative (See Figure. 3.1) assuming a profit level of 4 and 7 percent per year. Assuming closure of 10 percent of the NSB with marine reserve in the short term, the net benefits could be about negative $47 million/year if a profit margin of 4 percent is used. However, if a higher profit margin of 7 percent per year is used to estimate the net benefits, a value of ~$3 million/year could be generated in the short term. In addition, closing off 30 percent of the NSB with marine reserve in the short term could result in the net loss of about $53 million per year for a 4 percent profit margin while a 7 percent profit margin could generate a net loss of about $7 million per year. In addition, protecting half of the NSB with marine reserves could generate a higher net loss of about $58 million/year for a 3 percent profit margin while $13 million/year could be lost if a 7 percent profit margin is applied to the analysis.

Thus, in this analysis, I find that in the short term, the net market benefits under review were largely negative for the two profit margins except for the 10 percent marine protection at 7 percent profit margin. The net benefits (loss) are the region of about minus $58 million/year and $3 million/year over the short term. The decrease in net market benefits could be explained to be a consequence of the proportionately larger marine reserves that substantially reduce net profit on activities such as wild commercial fisheries, tourism and recreation and sport fishing, wages, and salaries from the commercial fisheries sector.

The results establish that having no marine reserve at all could generate about $42 million per year only in the short term. However, implementing 10, 30 and 50 percent marine reserves could generate an additional net non-market benefits to the tune of about $41 million annually over 8 years (See Table C.2 in the appendix). (Also, note that the net market benefits for long term are presented in Table C.4).

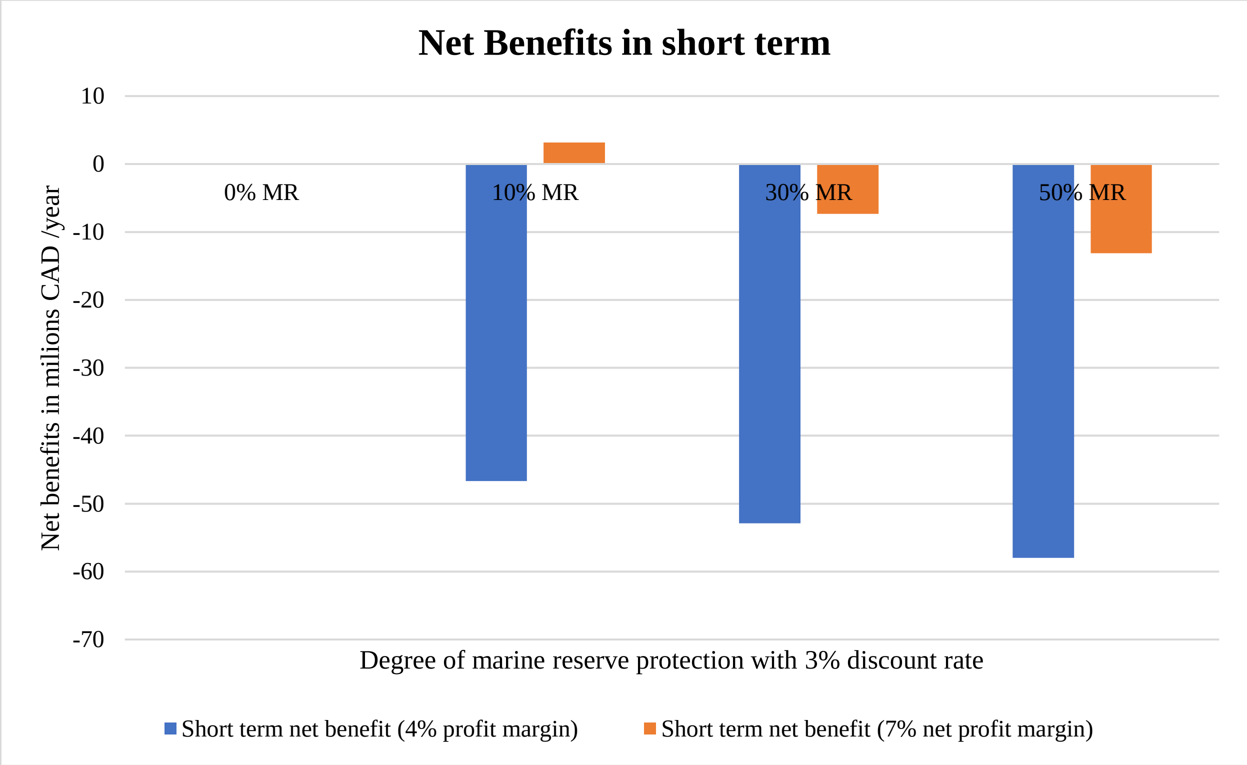

Figure 3.2. Short term market benefits of creating and implementing marine reserves in NSB using 3% discount rate.

Note that the figures for calculations were largely taken from the British Columbia's Fisheries and Aquaculture sector report, 2016 edition published in 2018. I adjusted the numbers from the 2016 values to 2020 price level using the Consumer Price Index for Canada from the Central Bank of Canada database.

3.5.2 Long term net market benefits of creating and implementing marine reserves in NSB

Using the same method as in the short term calculations, results from the study show that in the long term, the net market benefits of creating and implementing marine reserves in the long term are all positive for 4 and 7 percent profit margin. Closing the 10 percent of NSB with marine reserves could generate about $24 million/year for 4 percent profit over the long term. The 30 percent marine reserve scenario could yield the highest net benefits for at both 4 and 7 percent profit margin. At 30 percent marine reserve, about $67 million/year could be generated in net benefits in the long term. For the same timeframe, closing 30 percent of the NSB could generate et benefits of about $37 million/year if 4 percent profit margin is used in the calculations (See Figure.3.3). Further increasing marine reserves to cover 50 percent could result in a drop in net benefits to about $47 million/year over the long term factoring in 7 percent profit margin. Also, closing off half of the NSB marine area could generate net market benefits of about $26 million/year in net benefits if 4 percent profit margin used in the estimations for the long term.

In addition, the declining trend on the net market benefits as marine reserve sizes are increased could be a result of a disproportional drop in the net benefits as more sources of these benefits are regulated i.e., ban on fishing, could reduce wages and salaries in the tourism and sport fishing sectors. These results could have a substantial knock down effects on the market benefits in the NSB marine area. This suggests that while marine reserves may play a crucial role in enabling the recovery of fisheries, it is important to strategically place them in areas that could offset the potential costs of heavily restricted economic activities in the marine area in a bid to protect the marine ecosystem. Studies show that placing marine reserves in overfished marine zones could have higher impact on the marine ecosystem as they fish and other marine organisms could be allowed to replenish faster with no disturbances from human activities (Cabral *et al*., 2020). The Figure 3.3 below shows the outcomes from the calculations from the study.

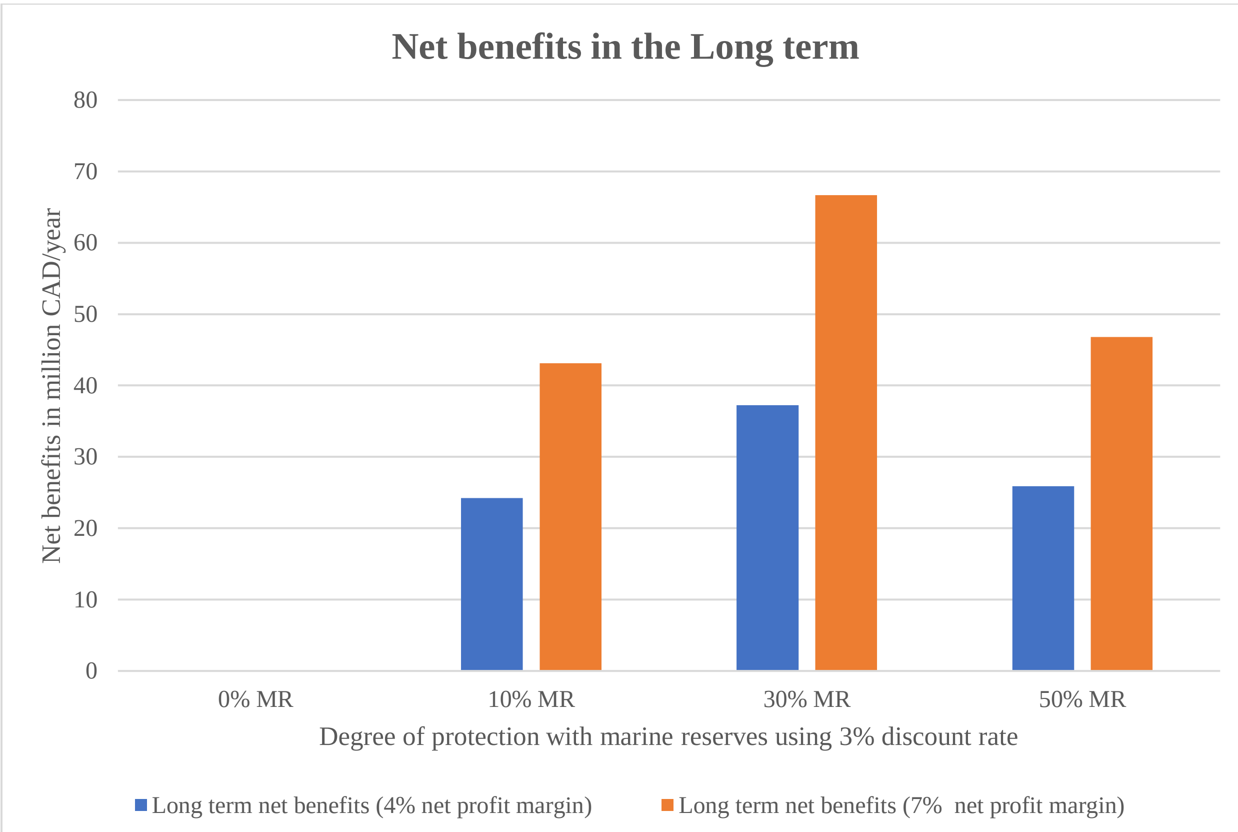

Figure.3.3. Long term net benefits with respect to creating marine reserves in the NSB.

As can be seen on the clustered column charts above, I also conducted a sensitivity analysis of the two net profit margins (4 and 7% per year) used in calculating the net benefits. I compared the results for net benefits obtained for short and long-term timeframes and in both cases, consistent with economic theory of the firm, a higher profit margin (7%) generated higher net benefits compared to a lower rate of 4%/year. As noted earlier, the results shown in the clustered column charts below demonstrate that both in the short and long term timeframes, using the 7% net profit margin in the calculation of net benefits results in higher outcomes in the NSB. The results are shown of Figure 3.4 below.

In addition, the clustered column chart below shows the results for the sensitivity analysis of using 4% profit margin in estimating net benefits of creating and implementing marine reserves. Long term net benefits are higher than those obtained in the short term.

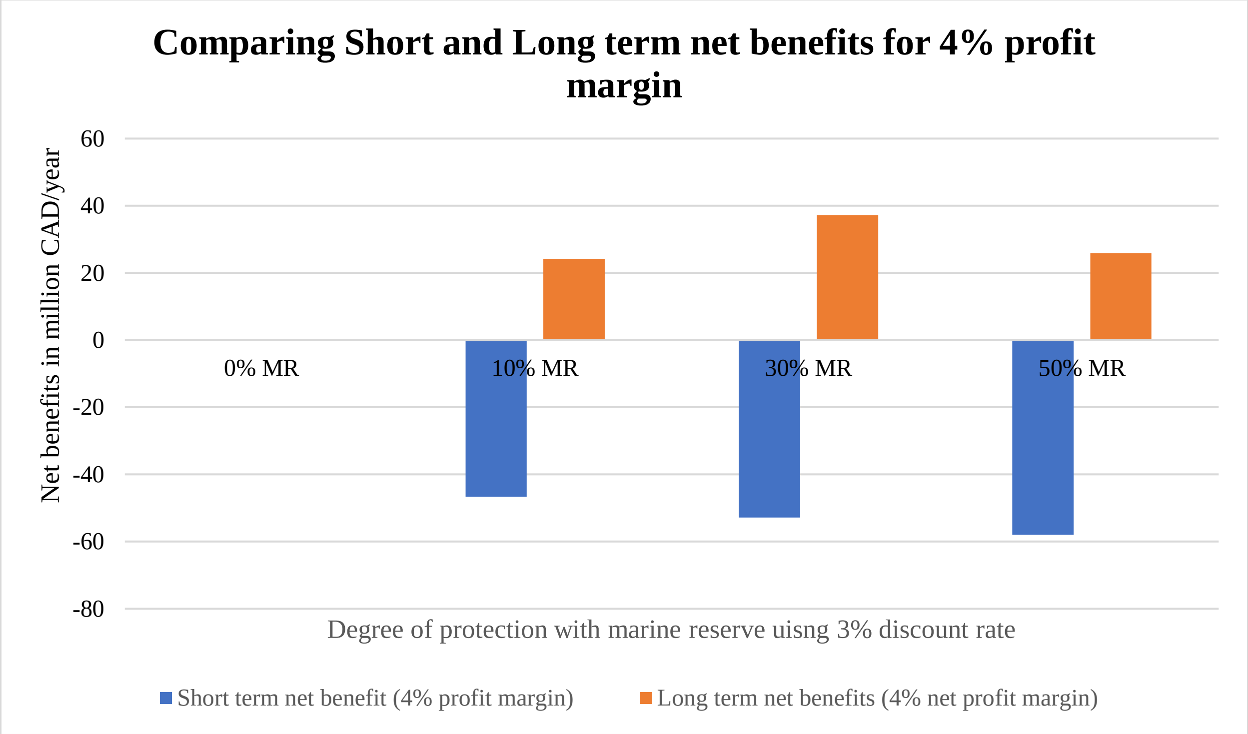

Figure 3.4. A comparison of short term and long term net benefits using 4% profit margin

The 30 percent marine reserve scenario could generate net benefits of about $37 million/year in the long term while protecting half of the NSB could reduce the net benefits to about $26 million per year if the profit margin of 4 percent is applied in the calculations.

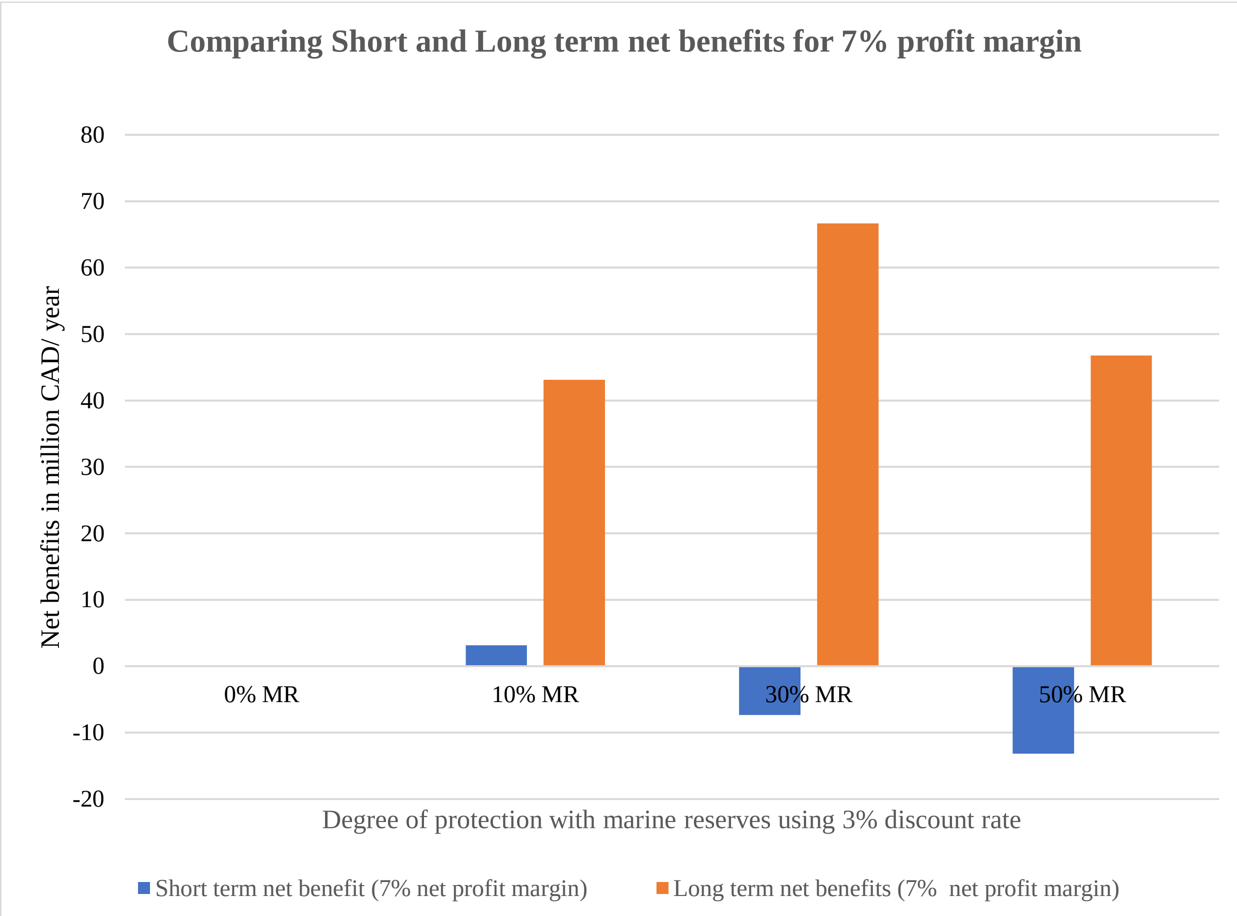

Figure 3.5. A comparison of short term and long term net benefits using 7% profit margin

Similarly, a higher profit margin of 7% per year generated greater benefits at all future scenarios compared with the same scenarios at 4 percent profit margin both in the short term and the long term time horizons.

In addition, I conducted a sensitivity analysis for using 3 and 5 percent discount rate in the estimation of the net benefits. The results from the sensitivity analysis are shown in appendix Tables C.4 and C.5. In summary, the 5 percent annual discount rate resulted in a lower gross benefits value compared to the 3 percent outcomes. This result is consistent with economic theory that states that a higher discount rate could result in a lower Net Present Value and vice versa since theoretically, there is an inverse relationship between discount factor and NPV.

3.6 Discussion of results

The study estimated the net benefits of implementing marine reserves in the NSB in three steps: (i) market benefits, (ii) non-market and (iii) costs of establishing and implementing marine reserves under 10, 30 and 5 percent scenarios. There are a number of assumptions made in this study that stood out in the results namely; (i) discount rate and, (ii) profit margin. Because of the uncertainties that could be created in this analysis because of the two factors noted above, I conducted a sensitivity analysis. To address the issues of different discount rates, my sensitivity analysis included 3 and 5 percent discount rates (Sumaila and Walters, 2004; Dasgupta *et al*., 2021). The sensitivity analysis for the profit margin captured 4 and 7 percent (Edwards & Pinkerton, 2020).

The findings from the study show that in the short term, net benefits are mostly negative owing to the decline in market benefits such as capture fisheries, and tourism as marine reserves are implemented. This is supported in literature as a short term shock from the reduced supply of fish as they rebuild in the marine reserves (Sumaila *et al.*, 2007). Consistent with literature, I found that protecting 30 percent of the NSB could generate the highest net benefits of $67 million per year using a 7 percent profit margin (Alban *et al.*, 2006; Cabral *et al*., 2020).

In addition, implementation of marine reserves is only part of the social priorities governments and communities can invest their resources in, even more substantial benefits can be generated from other benefits around the marine area and potentially spilling to adjacent areas. Hence it is important to consider the distributional effects of implementing marine reserves. In the NSB, there are 17 First Nations communities whose cultural and spiritual connection to the marine ecosystem is important. On the other hand, there are political consideration from the provincial and deferral policymakers that may need to be considered. As Canada joined the world in ratifying the United Nations Sustainable Development Goals that include protecting marine ecosystems, there is need to strike the balance between the potential conflicting objectives.

It is also important to ensure a transition mechanism for those who could be affected by the changes in marine area protection is crucial to the success of marine reserves as a conservation tool. In addition, as market benefits of implementing marine reserves can be easily measured by comparing the prices of those good and services across the relevant sources of market benefits, non-market benefits are often difficult to estimate. This study developed a method to estimate the non-market benefits in the NSB marine area and combined the outcomes with market benefits to arrive at the net benefits after subtracting costs of creating and implementing marine reserves in the NSB.

The benefits were estimated using 2020 as the baseline year for the estimation. The net benefits were captured as Net Present Values (NPV), representing the current estimates of the projected cash flows that are generated at different times (Teh & Sumaila, 2020b), in this case between 2021 to 2070. The cash flows that could be generated from the various market and non-market marine-related activities in the NSB. The market benefits accounted for in this study include wild commercial fisheries and aquaculture fisheries, wages and salaries from both wild commercial fisheries and aquaculture sectors, and fish processing sectors (wild commercial fisheries and aquaculture), tourism and recreation and sport fishing and nature-based education.

Similarly, the NPV values for non-market-based included habitat protection, existence value, nutrient recycling, carbon sequestration, carbon storage and disturbance alleviation and regulation. It should be noted that literature has highlighted that for the past 50 years, fisheries in Canada's oceans has been declining at an average of 1.04 percent annually (Oceana, 2019). As such, all status quo estimates in this study capture declining harvests to account for this decline.

My study results also suggest that increasing the area under marine reserves protection from 10 percent would result in an increase in net benefits in the long term. However, further increasing the marine reserves from 30 percent to 50 percent could reduce the net benefits from ~$67 million per year to about $47 million annually.

Finally, as highlighted in this study, protecting larger than optimal marine reserves in the NSB could result in substantial reductions in current net benefits. The literature demonstrates that while establishing MPAs can be beneficial especially when the net transfer rates for fisheries are high (Sumaila, 1998), the protected areas should be strategically situated in areas that can yield maximum impact to enable fisheries to recover (Cabral *et al*., 2020). Studies further show that optimally chosen marine reserve size also mitigate biological losses (Sumaila, 1998), in this case, 10 percent and 30 percent marine reserve would generate high net benefits compared to not implementing no marine reserves at all. These results should also be treated with caution because the model could not include the effects of transfer rate between the protected and unprotected area.

Furthermore, the study findings show that optimal marine reserve implementation sustains the growth of fisheries in the long term (i.e., 30 percent marine reserve with generated the highest net benefits). This would enable fisheries to rebuild and increase seafood provision which is an important part of the human diet (Cabral *et al*., 2020). In addition, sustainable fisheries harvesting can also support the continuous flow of revenues from fishing over time by avoiding their collapse to levels where complete or almost total closure will be required to enable the fish to recover.

3.7 Limitations of the study

1. The data used to estimate the market benefits of the NSB marine area were obtained from similar sectors in BC. The data for BC were readily available in government sources such as technical reports. To adjust for the differences in area size between BC and NSB, I adjusted the proportions of the marine area of the two areas by a factor.
2. To address potential problems of importing data from other studies in a different area for example in the estimation of non-market benefits of implementing marine reserves in the NSB, I used benefits transfer and employed relevant adjustment factors to capture differences in scale across countries for example for different income levels as measured by GDP.
3. The author also benefited from discussions from officials in the BC government ministries and non-profit sector who had some recent discussions on the changes in marine reserves in the NSB.

Chapter 4: Conclusion

This study is the first attempt at providing an estimate of the net benefits of implementing marine reserves in the NSB. The study combined market and non-market benefits from four sources of net benefits in the NSB (e.g., commercial wild and aquaculture fisheries, tourism and recreation and sport fishing, nature-based education, habitat protection and nutrient recycling). The highest net benefits, of implementing marine reserve could be obtained at 30 percent protection in the long term. These net benefits at 30 percent marine reserve coverage, could be north of $67 million annually. In addition, the second-best scenario could be protecting 50 percent of the NSB marine area which could generate ~$47 million/year in the long term using a 7 percent profit margin. However, its worth noting that even though the 50 percent marine reserve scenario could generate higher net benefits compared to protecting just 10 percent of the NSB, it shows a decreasing trend compared to the 30 percent scenario. This suggest that the net benefits could declines if further marine reserves are created beyond 50 percent.

As shown in the preceding sections and Figures in the results section, for the net benefits to be fully realized, it is important to emphasize the importance of extensively consulting with all the major stakeholders in the design and implementation of marine reserves. The relevant stakeholders include the federal and provincial government bureaucrats, the fishing industry and the 17 first nation communities in this region before such an action is undertaken. Strong cooperation with all relevant stakeholders in the NSB is required to bring maximum benefits from implementing marine reserves in this area.

Thus, the successful implementation of marine reserve scenarios in the NSB would require extensive user participation, carefully designing small scale marine protected areas and common pool resource management (Ban *et al*., 2017). The Pacific North Central Integrated Management Area is an important framework that has all the important stakeholders involved in this agreement. Through this framework, all the interested parties such as First Nations communities and the federal agencies can devise ways to ensure the parties who may lose in the short term maybe be supported through the transition process of increased marine reserve coverage within the NSB.

As highlighted in the thesis, worldwide, there is evidence of increasing net benefits in the long-term benefits of marine reserves, especially if the optimal marine reserve size is established (Cabral *et al*., 2020, Costello *et al*., 2021; Sala *et al*., 2021). Another dimension worth mention is the increasing net benefits generated from MPAs especially if they are structured as a network (Cabral *et al*., 2020). In the in the NSB case, 30 percent marine reserves generated highest net benefits than the status quo. As of February 2020, about 16 percent of the NSB was protected with MPAs of differing levels of protection (As per personal communication with Ross Jameson).

Besides, caution should be taken to estimate all the relevant sectors that would be affected by the creation of marine reserves in any given context. An appropriate discount rate should also be used that captures the intergenerational trade-offs between the present and the future generations (Sumaila, 2004, Sumaila & Walters 2005; Dasgupta, 2021).

Moreover, supporting those who may incur costs in the establishment of marine reserves is equally important. Thus, it is important to ensure that the sectors that are negatively affected are supported by relevant authorities such as local, provincial, and federal government agencies and their programmes. Such support could be in form of short-term subsidies for affected anglers to transition into other job sectors while the fisheries recover.

The net benefits estimate of marine reserves are important to many stakeholders, many of whom rely on the marine ecosystem for survival. The cost-benefit analysis is also important to spark a conversation between the relevant communities and policymakers such as the provincial and federal agencies on how to conserve the marine ecosystem and how marine reserves can be an effective tool that could be explored in the NSB.

The effectiveness of marine reserves as an ecosystem-based management tool is incomplete without scientific data to support the claims. Having models that can show the net benefits from marine reserves can also help the relevant stakeholders, as a starting point for developing complementary conservation policies such as Total Allowable Catch and determining marine reserve size and protection. Studies on the benefits and costs of marine reserves worldwide have shown that in general, they generate more overall positive benefits in the long-term. However, best policies by the government agencies in consultation with the fishing industry are limited by the lack of available information on the net benefits of establishing marine reserves in the Northern Shelf Bioregion.

Thus, (i) the estimation of the expected short-term losses from the establishment of the marine reserve might be helpful for social planners to achieve sustainable economic development of the communities in the NSB and (ii) long-term net benefits might be helpful for the fishing industry and government to identify the moral hazard of not enacting more marine reserves now.

Moreover, it is important to assess welfare implications across the board and make sure there is a consensus on the overall distribution of the net benefits of marine reserves. Studies have shown that most groups who resist the establishment of marine reserves perceive only the losses and hence see the establishment of marine reserves in general as a threat. Thus, communicating the findings of the net benefits of the establishment of marine reserves to all relevant stakeholders is encouraged. Too often, good policies fail because they are not communicated effectively to all stakeholders.

Finally, this study revealed that the net benefits of implementing marine reserves of more than 50 percent in the NSB marine area could result in declining trend. However, strategically implementing optimal marine reserve size of 30 percent of the NSB marine could be more beneficial than the status quo as a higher net benefits could be realized. These result support findings in the literature that marine reserves are an effective marine conservation tool (Alban *et al*. 2006; Cabral *et al*. 2020; Sala *et al.*, 2021). Also, care should be taken to implement the optimal size of the marine reserves to ensure the net benefits are maximized compared to the status quo (Di Lorenzo, Guidetti, Di Franco, Calò, & Claudet, 2020; Zhao *et al*., 2020). In addition, the distributional impacts of creating MPAs in general should be taken into consideration and make sure there are mechanisms to compensate the potential losers in the policy implementation.

Moreover, studies have shown that strategically situating the marine reserves in the NSB marine area could maximize the benefits such as food provision and accelerating fish recovery (Cabral *et al.*, 2020; Di Lorenzo *et al*., 2020). Also, other conservation instruments such as Total allowable catches could be implemented in conjunction with marine reserves in the NSB. Ideally, I would recommend the 10 and 30 percent marine reserve scenarios to be implemented gradually as a win-win situation amongst all the relevant stakeholders such as the fish industry and NSB community.

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Appendices

Appendix A : Regression steps followed to derive the Willingness to pay in Stata software

```
clear
import excel "C:\Users\user\Desktop\reg wta3_Oct14_Finaldata.xlsx", sheet("Sheet1") firstrow
rename Country country
label var country "country"
la bel define country 1 "scotland" 2 "Italy" 3 "New Zealand" 4 "United Kingdom" 5 "Northern Ireland" 6 "England" 7 "Wales" 8 "Canada" 9 "Australia" 10 "Malaysia" 11 "Norway"
label values country country
numlabel, add
reg WTP annualIncome Areasqkm Population country //model 1 wtp 229.81281 w2
outreg2 using wtp.doc
```

Appendix B : Regression steps followed to derive MPA costs in Stata software

```
use "C:\Users\user\Downloads\draft\mpa setup\marine setupcosts.dta", clear

gen lmpac=ln(mpaoveral)

gen lsize=ln(sizekm2)

gen lprop=ln(proportionoftotalmarinearea)

reg lmpac lsize lprop

outreg2 using mpasetup.doc

/*=e(10.94095+0.5584789lnsize)
```

Table B. 1 : Data used on calculating non-market benefits in Stata software

Author	Country with code used in Stata	WTP	Methodology	Population	Average annual Income ($)	Marine area (sqkm)	WTP NSB	WTP average ratio
Buhari, 2017	10. Malaysia	57	*DCE-CVM	31,110,000	10254	700	230	4.1
Jobstvogt *et al., 2014*	1. Scotland	118	DCE	4,184,000	25,000	107,773	230	1.5
Borger *et al.,2020*	4. United Kingdom	86	DCE	1,738,687	55,812	24,500	230	1.1
Borger *et al.,2020*	4. United Kingdom	116	DCE	1,738,687	55,812	34,300	230	1.1
McVittie & Moran, 2010	6. England	69	DCE	52,640,000	39,436	92,290	230	3.3
McVittie & Moran, 2010	1. Scotland	32	DCE	5,247,000	39,436	107,773	230	1.5
McVittie & Moran, 2010	7. Wales	204	DCE	3,044,000	39,436	1,400	230	1.1
McVittie & Moran, 2010	5. Northern Ireland	62	DCE	1,805,000	39,436	6,000	230	1.3
Gillespie and Bennett, 2011	9. Australia	107	DCE	22,340,000	65,518	130,000	230	2.1
Gillespie and Bennett, 2011	9. Australia	110	DCE	22,340,000	65,518	260,000	230	2.1
Gillespie and Bennett, 2011	9. Australia	110	DCE	22,340,000	65,518	390,000	230	2.1
Aanesen *et al.,2015*	11. Norway	266	DCE	5,199,836	30,242	2,445	230	0.7
Aanesen *et al.,2015*	11. Norway	323	DCE	5,199,836	30242	5,000	230	0.7
Aanesen *et al.,2015*	11. Norway	339	DCE	5,199,836	30,242	10,000	230	0.7
Tonnin, 2019	2. Italy	40	CVM	60,360,000	27,000	50,000	230	1.9
Tonnin, 2019	2. Italy	32	CVM	60,360,000	27,000	51	230	1.9
Ursula A. Rojas Nazar, 2013	3. New Zealand	75	CVM	6,861	100,000	9	230	4.1
Ursula A. Rojas Nazar, 2013	3. New Zealand	38	CVM	49,104	80,000	21	230	4.1
Brouwer,2016	5. Northern Ireland	114	CVM	17,280,000	27,192	58,000	230	1.3
O'Connor *et al., 2016*	2. Italy	47	CVM	60,360,000	30,242	50	230	1.9
Boxal, 2012	8. Canada	229	DCE	8,054,756	47,077	6,000	230	1.7
Rudd *et al. 2016*	8. Canada	145	DCE	13,505,900	42,527	158,000	230	1.7
Havens, 2008	8. Canada	43	CVM	33,250,000	46,595	350,000	230	1.7

Appendix C : Useful Tables with results in calculations of net benefits of implementing marine reserves in the NSB

Table C.1. Short term annual results of implementing marine reserves in the NSB

	0% marine reserve	**10% marine reserve**	**30% marine reserve**	**50% marine reserve**	**Net profit parameters (%)**
Market benefits					
Wild commercial fisheries revenue (‘000)	4,080	3,680	2,840	2,040	0.04
Aquaculture revenue (‘000)	9,160	10,920	10,920	10,920	
Nature-based education (‘000)	1,960	2,560	2,560	2,560	
Fish processing (wild fisheries) (‘000)	4,400	5,160	4,000	2,880	
Fish processing (aquaculture) (‘000)	8,520	11,080	11,080	11,080	
Tourism and Recreation and Sport fishing (‘000)	11,640	10,960	8,520	6,080	
Wages & salaries in Fisheries (‘000)	600	760	600	440	
Wages & salaries in aquaculture (‘000)	680	640	640	640	
Wages & salaries in Tourism and Recreation and Sport fishing (‘000)	2,480	2,320	1,800	1,280	
Wages & salaries in Fish processing (wild fisheries) (‘000)	400	360	280	200	
Wages & salaries in Fish processing (aquaculture) (‘000)	760	760	760	760	
Total market benefits (‘000)	93,880	49,200	44,000	38,880	
Add non-market values (‘000)	42,000	41,000	41,000	41,000	
Total benefits (‘000)	**135,880**	**90,200**	**85,000**	**79,880**	
Less establishment cost and maintenance costs (‘000)	0	1,000	2,000	2,000	
Net Present Value (‘000)	**135,880**	**89,200**	**83,000**	**77,880**	
Net benefit (4% profit margin) (‘000)	**0**	**-46,680**	**-52,880**	**-58,000**	

Table C. 2. Results of implementing marine reserves in NSB using 7% profit margin/year

	0% marine reserve	**10% marine reserve**	**30% marine reserve**	**50% marine reserve**	**Net profit parameters (%)**
Market benefits					
Wild commercial fisheries revenue (‘000’)	7,140	3,680	4,970	3,570	0.07
Aquaculture revenue (‘000’)	16,030	19,110	19,110	19,110	
Nature-based education (‘000’)	3,430	4,480	4,480	4,480	
Fish processing (wild fisheries) (‘000’)	7,700	9,030	7,000	5,040	
Fish processing (aquaculture) (‘000’)	14,910	19,390	19,390	19,390	
Tourism and Recreation and Sport fishing (‘000’)	20,370	19,180	14,910	10,640	
Wages & salaries in Fisheries (‘000’)	1,050	1,330	1,050	770	
Wages & salaries in aquaculture (‘000’)	1,190	1,120	1,120	1,120	
Wages & salaries in Tourism and Recreation and Sport fishing (‘000’)	4,340	4,060	3,150	2,240	
Wages & salaries in Fish processing (wild fisheries) (‘000’)	700	630	490	350	
Wages & salaries in Fish processing (aquaculture) (‘000’)	1,330	1,330	1,330	1,330	
Total market benefits (‘000’)	78,190	83,340	77,000	68,040	
Add non-market values (‘000’)	*42,000*	*41,000*	*41,000*	*41,000*	
Total benefits (‘000’)	**120,190**	**124,340**	**118,000**	**109,040**	
Less establishment cost and maintenance costs (‘000’)	0	1,000	2,000	2,000	
Net Present Value	120,190	123,340	116,000	107,040	
Net benefit (7% profit margin)	**0**	**3,150**	**-7,340**	**-13,150**	

Table C. 3. Results of implementing marine reserves in NSB using 4% profit margin/year

	0% marine reserve	**10% marine reserve**	**30% marine reserve**	**50% marine reserve**	**Net profit parameters (%)**
Market values					
Wild commercial fisheries revenue (‘000)	4,080	3,640	2,840	2,040	0.04
Aquaculture revenue (‘000)	9,160	25,200	1,960	14,000	
Nature-based education (‘000)	1,960	10,240	7,960	5,680	
Fish processing (wild fisheries) (‘000)	4,400	2,296	17,880	12,760	
Fish processing (aquaculture) (‘000)	8,520	4,440	34,520	24,680	
Tourism and recreation and sport fishing (‘000)	11,640	13,560	10,560	7,520	
Wages & salaries in fisheries (‘000)	600	6,120	4,760	3,400	
Wages & salaries in aquaculture (‘000)	680	480	360	280	
Tourism and recreation and sport fishing (‘000)	2,480	2,880	2,240	1,600	
Fish processing (wild fisheries) (‘000)	400	360	280	200	
Fish processing (aquaculture) (‘000)	760	680	560	400	
Total market values (‘000)	*44,680*	*69,896*	*83,920*	*72,560*	
Add non-market values (‘000)	*42,000*	*42,000*	*42,000*	*42,000*	
Total benefits (‘000)	*86,680*	*111,896*	*125,920*	*114,560*	
Less establishment cost and maintenance costs (‘000)	0	1,000	2,000	2,000	
Net Present Value (‘000)	86,680	110,896	123,920	112,560	
Net benefits (4% profit) (‘000)	**0**	**24,216**	**37,240**	**25,880**	

Table C.4. Short term net benefits of implementing marine reserves in NSB using 7% profit margin/year

	0% marine reserve	**10% marine reserve**	**30% marine reserve**	**50% marine reserve**	**Net profit parameters (%)**
Market values					
Wild commercial fisheries revenue (‘000)	7,140	6,370	4,970	3,570	0.07
Aquaculture revenue (‘000)	16,030	44,100	3,430	24,500	
Nature-based education (‘000)	3,430	17,920	13,930	9,940	
Fish processing (wild fisheries) (‘000)	7,700	4,018	31,290	22,330	
Fish processing (aquaculture) (‘000)	14,910	7,770	60,410	43,190	
Tourism and recreation and sport fishing (‘000)	20,370	23,730	18,480	13,160	
Wages & salaries in fisheries (’000)	1,050	10,710	8,330	5,950	
Wages & salaries in aquaculture (‘000)	1,190,	840	630	490	
Tourism and recreation and sport fishing (‘000)	4,340	5,040	3,920	2,800	
Fish processing (wild fisheries) (‘000)	700	630	490	350	
Fish processing (aquaculture) (‘000)	1,330	1,190	980	700	
Total market values (‘000)	*78,190*	*122,318*	*146,860*	*126,980*	
Add non-market values (‘000)	*42,000*	*42,000*	*42,000*	*42,000*	
Total benefits (‘000)	*120,190*	*164,318*	*188,860*	*168,980*	
Less establishment cost and maintenance costs (‘000)	0	1,000	2,000	2,000	
Net Present Value (000)	120,190	163,318	186,860	166,980	
Net benefits (7% profit) (‘000)	**0**	**43,128**	**66,670**	**46,790**	

Table C. 5. Sensitivity analysis for short term using gross benefits for 3 and 5 % discount rate/year

Degree of protection with marine reserves				
Type of benefit	**0% marine reserve**	**10% marine reserve**	**30% marine reserve**	**50% marine reserve**
Gross benefits at 3% discount rate (‘000)	0	110,000	-19,000	-149,000
Gross benefits at 5% discount rate (‘000)	0	2,000	-117,000	-235,000

Table C. 6. Sensitivity analysis for long term using gross benefits for 3 and 5 % discount rate/year

Long term benefits				
Type of benefit	**0% marine reserve**	**10% marine reserve**	**30% marine reserve**	**50% marine reserve**
Gross benefits at 3% discount rate (‘000)	0	2,146,000	1,415,000	695,000
Gross benefits at 5% discount rate (‘000)	0	622,000	232,000	-148,000