COASTAL GREEN INFRASTRUCTURE AS A SEA LEVEL RISE ADAPTATION MEASURE: ASSESSING ENVIRONMENTAL, LOCAL AND INSTITUTIONAL CONTEXTS

by

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A THESIS SUBMITTED IN PARTIAL FULFILMENT OF

THE REQUIREMENTS FOR THE DEGREE OF

DOCTOR OF PHILOSOPHY

in

The Faculty of Graduate and Postdoctoral Studies

(Resource Management and Environmental Studies)

The University of British Columbia

(Vancouver)

December 2018

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Coastal green infrastructure as a sea level rise adaptation measure: Assessing environmental local and institutional contexts

submitted by Tugce Conger in partial fulfillment of the requirements for

the degree of Doctor of Philosophy

in Resource Management and Environmental Studies

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Abstract

With the acceleration of climate change impacts, adaptation is no longer a matter of choice for most communities. There has been a growing interest in coastal green infrastructure (CGI), natural and nature-based adaptation measures, due to its role in flood and erosion protection, and provision of multiple environmental, social and economic benefits. However, there remains a gap in understanding the context-dependency of CGI as an adaptation measure. In this dissertation, I empirically investigate the environmental, local and institutional contexts in which CGI can be used as a sea level rise adaptation measure through three distinct studies, focusing on the coastal regions of British Columbia (BC) and Washington State (WA).

First, I conduct a regional study. Using climatic and environment indicators, I investigate where CGI has the highest coastal protection potential while taking into account its vulnerability. I conclude that CGI in the large population centers in BC and most of the communities in WA may not provide high coastal protection benefits, where CGI in the smaller communities have a higher potential. Second, I undertake a local study in BC, investigating community trade-offs between CGI and other adaptation strategies. I incorporate local perspectives to develop adaptation scenarios and create an evaluation framework using the literature and expert inputs. Applying the framework to the scenarios, I conclude that there are important trade-offs between the local implications of different strategies. I find that the CGI scenario had the highest positive impacts, but displayed institutional drawbacks compared to others. Third, I undertake an institutional study comparing the barriers to and facilitators of CGI implementation in BC and WA. I conclude that besides barriers and facilitators common to adaptation, factors specific to CGI, such as coastal jurisdiction and ownership; financial variation and flexibility; vision; organization efficiency and access to resources; partnerships and collaborations; NGOs; and community advocacy are also influential.

Ultimately, this dissertation concludes that CGI's context dependency influence its potential benefits, its applicability as a local adaptation measure, and implementation within the existing

institutional arrangements. Considering contextual factors can support more successful implementation of CGI, and therefore can increase adaptation to sea level rise.

Lay Summary

Acceleration of climate change necessitates communities to adapt to sea level rise (SLR). Coastal green infrastructure (CGI) has the potential to help communities adapt to SLR and to increase overall community resilience. However, little is known about in which conditions CGI can be used as a meaningful adaptation action. Therefore, I investigated the environmental, local, and institutional contexts of CGI to provide insights to support the wider implementation of CGI and to increase adaptation to sea level rise. Using three distinct studies in the coastal regions of British Columbia (BC) and Washington State (WA), I concluded that CGI (1) has different coastal protection benefits in different environments, (2) has positive trade-offs compared to other adaptation actions but it not well established in the current regulatory frameworks, and (3) is influenced by different institutional barriers and facilitators in BC than in WA.

Preface

This dissertation is my original and independent work. I identified the research questions, developed the research design, defined the methodologies, collected and analyzed the data, and wrote the manuscripts for each chapter. My supervisor and advisory committee (Drs. Stephanie Chang, Maged Senbel, Mark Johnson) provided guidance and feedback at each step. My supervisor also provided edits on the manuscripts.

All empirical chapters of this dissertation are stand alone papers, intended for journal publication, which results in some repetition of the content, particularly the literature review/background sections, across the chapters.

Chapter 2 was conducted with support from the Pacific Institute for Climate Solutions (PICS) and the Marine Environmental Observation, Prediction and Response Network (MEOPAR). A version of Chapter 2 has been submitted for publication with Stephanie Chang as co-author. I collected and analyzed the data and wrote the manuscript. Dr. Chang provided guidance, comments and edits.

Chapter 3 was conducted with support from the Pacific Institute for Climate Solutions (PICS) and the UBC Public Scholar's Initiative (PSI). A version of Chapter 3 has been submitted for publication with Stephanie Chang as co-author. The research conducted in Chapter 3 was approved by the Behavioral Research Ethics Board (ethics certificate number H16-01408). I collected and analyzed the data and wrote the manuscript. Dr. Chang provided guidance, comments and edits.

Chapter 4 was conducted with support from the University of British Columbia (UBC) Public Scholar's Initiative. A version of Chapter 4 will be submitted for publication with Stephanie Chang as co-author. The research conducted in Chapter 4 was approved by the Behavioral Research Ethics Board (ethics certificate number H17-03556). I collected and analyzed the data and wrote the manuscript. Dr. Chang provided guidance, comments and edits.

Table of Contents

List of Tables

List of Figures

List of Abbreviations and Acronyms

BC	British Columbia
BEACH	The Beaches Environmental Assessment and Coastal Health
CGI	Coastal Green Infrastructure
CSD	Canadian Census Subdivision
CZM	Coastal Zone Management
DFL	Designated flood levels
DFO	Fisheries and Oceans Canada
DoE	Washington State Department of Ecology
ECC	Environment and Climate Change Canada
EEZ	The Exclusive Economic Zone
EPA	The Environmental Protection Agency
FCL	Flood Construction Levels
FLNRRD	The Ministry of Forests, Lands, Natural Resource Operations and Rural Development
FWS	The U.S. Fish and Wildlife Service
GIS	Geographic Information Systems
IPCC	Intergovernmental Panel on Climate Change
LWM	The low water mark
MEOPAR	Marine Environment and Marine Environmental Observation Prediction and Response Network
MLLWL	The mean lower low water line
MoECCS	The Ministry of Environment and Climate Change Strategy
NGOs	Non-governmental organizations
NOAA	The National Oceanic and Atmospheric Administration
OCPs	Official Community Plans
PICS	Pacific Institute for Climate Solutions
PSI	Public Scholars Initiative
SMA	Shoreline Management Area
TC	Transport Canada
THSs	Traditional hard structures
UBC	University of British Columbia

UGA	American Census City/Urban Growth Areas (UGA)
USACE	The U.S. Army Corps of Engineers
USGS	United States Geological Survey
WA	Washington State
WDFW	Washington State Department of Fish and Wildlife

Acknowledgements

The dissertation process can be all-consuming. Here, I would like to thank a number of persons and organizations who in tangible and intangible ways contributed to this dissertation.

To begin, I want to thank my supervisor Prof. Stephanie Chang for supporting me in more ways than I can count. She has been a patient, forbearing, and compassionate mentor while providing constructive criticisms and guidance over the past years. She helped me navigate many twists and turns during my research, and supported me when I faced obstacles. Besides her academic excellence, she has been a role model through her mentorship style and professionalism. I consider it to be my absolute privilege to have had her as my Ph.D. supervisor. I am also extremely grateful to my committee members, Prof. Maged Senbel and Prof. Mark Johnson for their mentorship and guidance, and sharing their expertise to support my research.

I would like to thank my funders the Marine Environmental Observation, Prediction, and Response (MEOPAR) Networks Center for Excellence, Pacific Institute for Climate Solutions (PICS), and UBC's Public Scholars Initiative for their scholarship and other financial support that made this research happen.

The research in this dissertation had greatly benefited from time, support and expert knowledge provided by the British Columbia Ministry of Environment and Climate Change's Climate Action Secretariat and Fraser Basin Council. While I cannot mention them by name, I am also grateful to all of the experts in British Columbia and Washington State who participated in my research, sharing their time and expertise with me in Chapter 4. I have learned so much from them. I also would like to thank the District of North Saanich for the in-kind support and their cooperation, and all the workshop participants in Chapter 3.

Special thanks to my labmates Jackie Yip, Michelle Marteleira, Ryan Reynolds, Krista Cawley, Cher King-Scobie, David Righter, Alexa Tanner, Christopher J. Carter and Rebecca Chaster. It has been great to learn from and work with them. I am also grateful to the IRES department staff Lisa Johannesen, Bonnie Leung, Stefanie Ickert, Kyla Hicks, Gillian Harris, and Linda Steward for the administrative support and always being kind.

It may be unusual, but I also want to note my appreciation for this beautiful province, British Columbia, my home for the last six years. Exploring the fjords, rain forests, and majestic mountains of this magical place has been one of the most rewarding experiences of my life and has certainly improved my life quality during the challenging times of my PhD life.

Many friends had shared this journey with me, and have always been there when I needed them most. Ghazal Ebrahimi, Jackie Yip, Nancy Silva, Alejandra Echeverri, Lucy Rodina, Poushali Maji, and Elisabeth Wiliams have each touched my life in ways I will forever be grateful for. I thank you for all the endless hours of companionship, lifting me up when I was down, and making me laugh until I cry. Guillaume, Stephen, Golnoush, Natalia, Daniele, Flora, Alex, and Eric, Manuel as well as many other friends all around the world who are too numerous to name - thank you for your support and friendship.

I am deeply thankful for the love, understanding, support, and encouragement I have received from my family all around the world. Emel Aksu, Selcuk Conger, Onur Conger, Ezgi Karasozen, Aleida Reitberg, Ruud Peters, Nikki and Volkan Turan, Halime Conger, and Marijke, Jan-Jaap and Max van der Wal, thank you for always being there for me and reminding me the other important things in life.

Finally, I would like to express the depth of my love and gratitude to my husband Bas Peters for his continued love and support. There is nothing more precious than sharing your life with a joyful person, who loves to do the things you love, supports you to pursue your dreams, and keeps you happy and sane in the meantime. Thank you for sharing day and night, rain and sun, and oceans and mountains with me.

To my mother,
for your support, encouragement, and unswerving love.

Annem'e,
desteğin, cesaretlendirmen, ve tükenmeyen sevgin için.

Chapter 1

Introduction

1.1 Rationale

Over the years, science has left no space for dispute on the acceleration of climate change impacts throughout the 21st-century (IPCC, 2014). The last few decades have already witnessed an escalating number of extreme climate events linked to the changes in air and water temperatures; precipitation, storm, and circulation patterns; and mean sea levels (IPCC, 2014; Carson et al., 2016; Ekwurzel et al., 2017). Particularly, the rapid changes in sea levels have been one of the most pressing impacts of climate change (Azevedo de Almeida and Mostafavi, 2016), as the global mean sea levels are expected to rise around 1m by 2100 (IPCC, 2014). This rise is threatening the integrity of built and natural environments, as well as the social and economic well-being of coastal communities around the world (Nicholls, 2015; Devoy, 2015). This is because sea level rise affects coastal communities by expanding water's reach at coasts, bringing floodwaters and wave action closer to developed areas, and exacerbating erosion at the edge of critical assets and infrastructure (Glavovic, 2014; Bronen, 2015). These impacts of sea level rise amplify the existing risks and vulnerabilities of coastal communities to flooding and erosion (Hinkel et al., 2014; Felsenstein and Lichter, 2014; Neumann et al., 2015) due to the declining environmental conditions, and increasing number of people affected and economic losses associated with such events (Nicholls, 2011; Renaud et al., 2013). The magnitude of these impacts, however, is expected to vary greatly depending on regional and local characteristics of coastal communities, and their adaptation to sea level rise (Michener et al., 1997).

Until recently, the emphasis on adaptation to flood and erosion events has been on protecting coastal areas using hard structures such as dikes, seawalls, bulkheads, and other engineered measures. However, there has been a growing debate on the economic, environmental, and adaptability deficits associated with the use of the traditional[1] hard structures (THSs) for sea level rise adaptation (Tyler, 2016). The costs of building, maintaining, and eventually rebuilding THSs are very high (Temmerman et al., 2013). THSs have various unwanted effects on fish and wildlife habitat, and sedimentation patterns (Sutton-Grier et al., 2018). Moreover, THSs are not flexible enough to respond to changing environmental and climatic conditions as well as new engineering and planning regulations (Borsje et al., 2011). The increased understanding of THSs' limitations on effectively protecting coasts has led to growing recognition of the need for a cost-effective, multifunctional and adaptable coastal protection measure (Narayan et al., 2016; Sutton-Grier et al., 2018).

In this context, coastal green infrastructure (CGI), natural or nature-based systems that protect coasts from flood and erosion, has started to gain attention due to its adaptability to change, and ability to provide multiple social, environmental and economic benefits to communities (Arkema et al., 2017; Sutton-Grier et al., 2018). CGI not only reduces the wave energy and overtopping at the coast (Arkema et al., 2017), and sediment drift from and along the coast (Silva et al., 2016); but it also provides habitat for fish and wildlife, sequesters carbon, and increases social and economic opportunities (Sutton-Grier et al., 2015). In addition, CGI responds to changes in the environmental and climatic conditions and can be altered relatively easily (Borsje et al., 2017). Consequently, there has been a growing interest in and demand for developing CGI areas for sea level rise adaptation (Sutton-Grier et al., 2018). Communities around the world have started to investigate where and how they can implement CGI to increase their adaptation to sea level rise (Ruckelshaus et al., 2016).

The literature, however, frequently recognizes that CGI may not be applicable to all coastal areas, or may not yield its full potential benefits in all settings (Catenacci and Giupponi, 2013; Narayan et al., 2016). The functionality of CGI and thus the array of benefits that can be obtained depends heavily on the environmental, social, economic, and institutional contexts in which CGI is implemented. Therefore, the use of CGI as a sea level rise adaptation measure requires an understanding of the context-dependency of CGI. However, little is known about the context-dependency of CGI. Even though the degrees to which CGI can provide coastal protection benefits have frequently been investigated, in which contexts CGI can be used as a sea level

[1] In this dissertation, the term "traditional" refers to conventional coastal engineering practices, rather than the traditional practices of the Indigenous peoples of North America. Indigenous peoples have observed the changes in climate for a long time, and have developed traditional practices to address these impacts. There are specific climate change assessment frameworks such as Black et al. 2017 and Justice Institute of British Columbia 2015 to help Indigenous communities to understand their vulnerability and develop appropriate adaptation actions.

adaptation measure has been largely absent from the CGI research. Considering the adaptation need is urgent, understanding the contexts in which CGI can be utilized is essential to protect communities from the impacts of sea level rise (Langridge et al., 2014), as well as to ensure that the natural processes, critical habitats, and social and recreational opportunities at coasts are preserved and enhanced.

Therefore, in this dissertation I aim to understand the environmental, local and institutional contexts in which CGI can be used as a sea level rise adaptation measure. In the next sections, I outline my research goals (Section 1.2); situate my research in the broader literature (Section 1.3); highlight the overarching research question, the subsequent research questions for each of the three empirical studies (Section 1.4); describe the research design, data and methods of the three studies (Section 1.5); and describe the chapters of the dissertation via brief synopsis (Section 1.6).

1.2 Goals of the dissertation

Adaptation to sea level rise is not a choice but a requirement for most coastal communities. CGI overcomes the short-comings of THSs and provides important coastal protection and other benefits to communities. In addition, there has been a growing interest in the use of CGI to adapt to sea level rise. However, there remains a gap in identifying when and where CGI can be implemented as a sea level rise adaptation measure. Therefore, the overarching goal of this dissertation is *to understand the contexts in which CGI can be used as a sea level rise adaptation measure*.

To achieve this goal, I undertake three empirical studies within the coastal regions of British Columbia (BC) and the Washington State (WA), an area with high projected sea level rise impacts exacerbated by subsidence, and increased population exposure and community sensitivity to these impacts (Okey et al., 2012; Adelsman et al., 2012). I organize these studies into three respective themes: Theme 1 - Environmental, Theme 2 - Local, and Theme 3 - Institutional. In the first theme, I aim to develop a methodology to understand CGI's potential coastal protection benefits in the Salish Sea region. In the second theme, I seek to highlight the trade-offs between CGI and other sea level rise adaptation strategies in a local community. In the third theme, I seek to better understand the institutional factors that disable or enable the implementation of CGI in BC and WA.

1.3 Situating the research in the literature

I situate my dissertation in the fields of coastal green infrastructure (CGI) and sea level rise adaptation. I draw from a number of different disciplinary perspectives such as urban planning, environmental science and geography, and sociology.

Therefore, this dissertation builds on key CGI and adaptation literatures, including CGI terminology and overall benefits (i.e. Sutton-Grier et al. 2015; Narayan et al. 2016; Morris et al. 2018); CGI's flood (i.e. Koftis et al. 2013; Anderson and Smith 2014; John et al. 2015) and erosion (i.e. Silva et al. 2016; Borsje et al. 2017; Mendoza et al. 2017) protection benefits; CGI's vulnerability to changing environmental conditions (i.e. Feagin et al. 2015; Osland et al. 2015; Kirwan et al. 2016); sea level rise adaptation (i.e. Adger et al. 2007; Matthews et al. 2015; Hagen et al. 2018); resilience and resilience perspectives in adaptation (i.e. Gersonius et al. 2016; Cinner et al. 2018); sea level rise adaptation strategies (i.e. Catenacci and Giupponi 2013; Cooper 2016), and evaluation methods (i.e. Cutter 2016; Gersonius et al. 2016; Azevedo de Almeida and Mostafavi 2016); and institutional barriers to and facilitators of adaptation (i.e. O'Donnell et al. 2017; Hopkins et al. 2018; Sutton-Grier et al. 2018). In each empirical chapter, I review and synthesize the relavant and up-to-date literature. In this section, I present an overaching review of the literature as they relate to the goals of this dessertation.

1.3.1 Sea level change: causes, impacts, and projections

Sea level change refers to the temporal and spatial changes of the "height of the ocean surface", and is measured as relative sea level[2] or geocentric sea level[3] (IPCC, 2014, pg.1142).

Historic and anthropogenic causes
Changes in natural processes related to earth's surface, atmosphere and oceans have been occurring due to long-term changes in the climate before the pre-industrial period[4] (IPCC, 2014; Devoy, 2015). For example, the global mean sea level was approximately 120 meters lower in the last glacial period, than its present level (Tamisiea, 2011). However today, anthropogenic factors are known to be the main drivers of these changes (Shayegh et al., 2016).

[2]Relative sea level is the height of the ocean surface relative to the surface of Earth (IPCC, 2014).
[3]Geocentric sea level is the height of the ocean surface relative to the center of the Earth (IPCC, 2014).
[4]Around 1850s (Nicholls et al., 2007).

Today, anthropogenic factors are known to be the main drivers of climate change (IPCC, 2014). In the post-industrial period, increasing levels of CO_2 and other greenhouse gases are affecting atmospheric and oceanic processes (Michener et al., 1997), such as changes in air and water temperatures; storm intensity, duration, frequency and location; precipitation patterns; oceanic and atmospheric circulation; and altered timing of seasons (Okey et al., 2012; Devoy, 2015). These processes affect global and regional sea level change in the following ways (Figure 1.1):

- Changes in the relative elevation of the land (i.e., subsidence or uplift) due to natural resource extraction and compaction of soil;
- Changes in the relative elevation of the ocean due to (1) growth or decay of ice sheets and their redistribution, (2) increasing air and ocean temperatures that causes thermal expansion, (3) melting of land-based glaciers and ice sheets due to increased air and ocean temperatures, (4) low atmospheric pressure that causes the swell of ocean's surface (i.e., storm surges), and (6) hydrological cycles that cause evaporation and rain events, (7) total river discharge that traps fresh water floating on salt water, and (8) salinity levels that changes water density and thus, volume;
- Glacial isostatic uplift caused by the loading and/or unloading on the earth's crust due to the changes in the ice sheet mass (Devoy, 2015; Nauels et al., 2017; Piecuch et al., 2018);

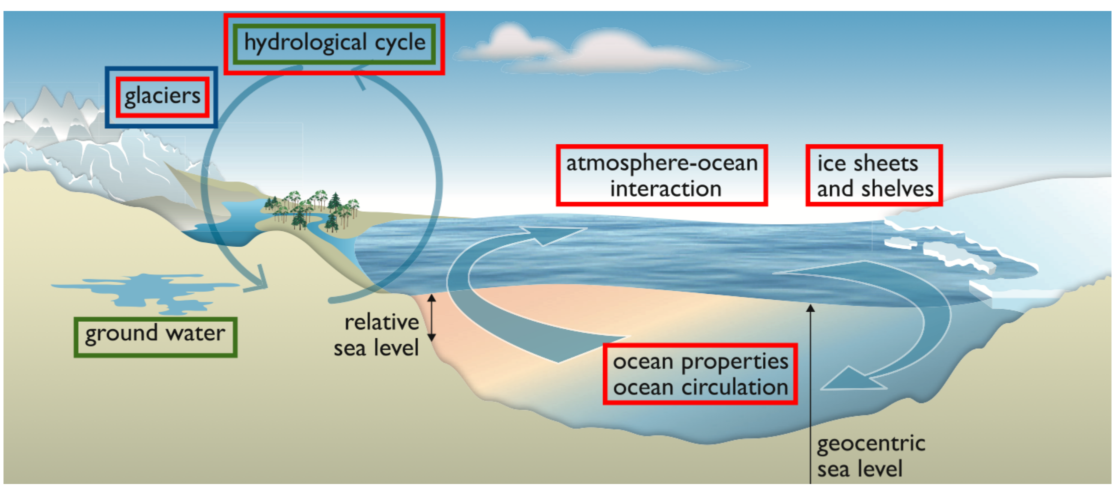


Figure 1.1: Causes of sea level changes: Changes in the relative elevation of the land (green boxes), changes in the relative elevation of the ocean (red boxes), and glacial isostatic uplift (blue box). Ocean properties include salinity and density. Modified after (IPCC, 2014).

The combined effect of these three factors and the characteristics of the coastal profile (i.e., coastal geomorphology), determine local sea level changes and impacts.

Impacts

The impacts of sea level rise are flooding, erosion, ecosystem health and integrity, salinization of coastal lands and waters, and water table levels (Nicholls, 2015). The changes in water levels influence flooding and erosion by altering the patterns (direction, zonation, extent, and impacts) of tides, storm surges, wave action, currents, and subsequent sediment deposition rates (Davidson-Arnott, 2010). Particularly in gently sloping coasts, the magnitude of these impacts is much higher. The changes in water levels cause alterations in ecosystem health and integrity due to changes in inundation patterns, sediment concentrations, and salinity levels (Devoy, 2015; Passeri et al., 2015). The salinization of coastal lands and waters are caused by the extension of the flooded areas inland (Devoy, 2015). Lastly, the changes in water levels influence the level of the water table, leading to the creation of new wetlands and inundated areas inland or compaction of soil layers (Rotzoll and Fletcher, 2013).

The impacts of sea level rise are expected to increase in future because the magnitude of climate change and the increases in sea levels are projected to accelerate throughout the 21st-century (Nicholls, 2011; Devoy, 2015; Nauels et al., 2017).

Projections

Sea level rise has been one of the most pressing impacts of climate change (Azevedo de Almeida and Mostafavi, 2016). The global mean sea levels rose about 1.7 mm per year between 1900-2010 compared to 3.2 mm per year between 1993-2010 (IPCC, 2014). However, it is very challenging to predict future sea levels because the model-based assessments have to account for the gaps in scientific knowledge, they employ different methodologies, and they are often built upon different assumptions (Devoy, 2015; Nauels et al., 2017; Sriver et al., 2018).

Intergovernmental Panel on Climate Change (IPCC), which brings scientist together to synthesize the recent literature on the impacts of climate change, is considered to be the most prominent and comprehensive report for sea level rise projections. However, even though the latest IPCC report 2014 estimates an average global increase in sea levels by 1 meter by 2100, there has been significant disparity amongst the projections of the previous IPCC reports and the studies IPCC reports are based on. The disparity over the amount of sea level rise expected by 2100 can also be seen in the findings of the other published research (Figure 1.2).

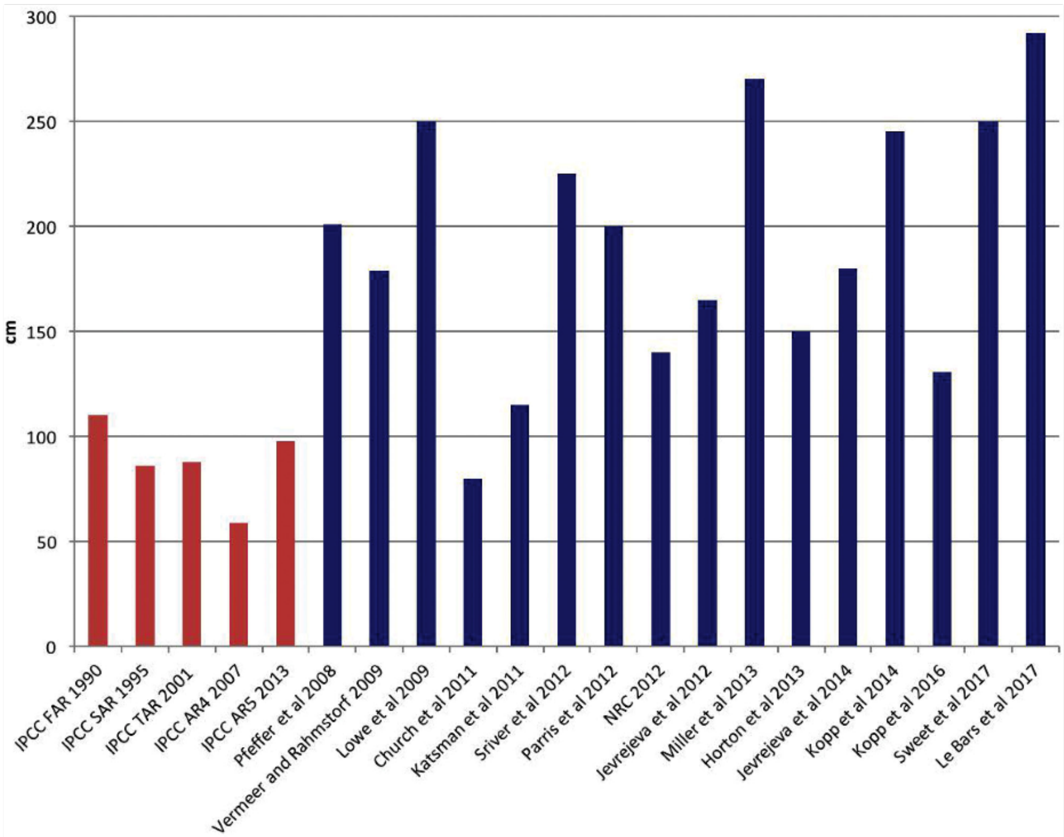


Figure 1.2: The global mean sea level rise projections of IPCC reports (red) and published research (blue) for 2100 (Sriver et al., 2018). It should be noted that the IPCC reports are based on a consensus model of reporting, therefore the reports' sea level rise projections are relatively conservative (Horton et al., 2014).

In BC and WA, communities are preparing for 1 meter of sea level rise following their national and regional guidelines (The Arlington Group et al., 2013; Adelsman et al., 2012).

The uncertainties over the amount of sea level rise expected by 2100 calls for diverse and flexible adaptation options to account for these uncertainties.

1.3.2 Sea level rise adaptation and adaptation strategies

In this dissertation, I focus on the local level adaptation to sea level rise and define adaptation as the processes of adjusting community responses to reduce the impacts of sea level rise that are observed at the local level. These processes are often in the form of planning, policy, design, and engineering strategies (Nicholls, 2015). There are six main sea level rise adaptation strategies, reflecting different motivations (Cooper, 2016). These strategies are "protect", "accommodate", "avoid", "retreat", "do nothing" and "offense" (Figure 1.3).

The Arlington Group et al. (2013), Glavovic and Smith (2014), Cooper (2016) and Manuel et al. (2016) describe these adaptation strategies as follows:

- The protect strategy refers to the use of THS and CGI measures to mitigate the impacts of sea level rise.
- The accommodate strategy describes adjustments and changes that are implemented on the existing structures to mitigate the impacts of sea level rise.
- The avoid strategy refers to the prevention of development from the high-risk areas.
- The retreat strategy describes a phased-out relocation from the high-risk to low-risk areas.
- The do nothing strategy describes the absence of a coordinated and planned action to address the impacts of sea level rise.
- The offense strategy refers to the designation of new development areas on the reclaimed coastal lands.

Each of these adaptation strategies includes different *measures*. The adaptation measures refer to the actions that vary in their nature (i.e., design, material, and method) but serve the same motivation as the strategy they represent (i.e., a, b, c and d in Figure 1.3). They define the ways in which the strategies are operationalized.

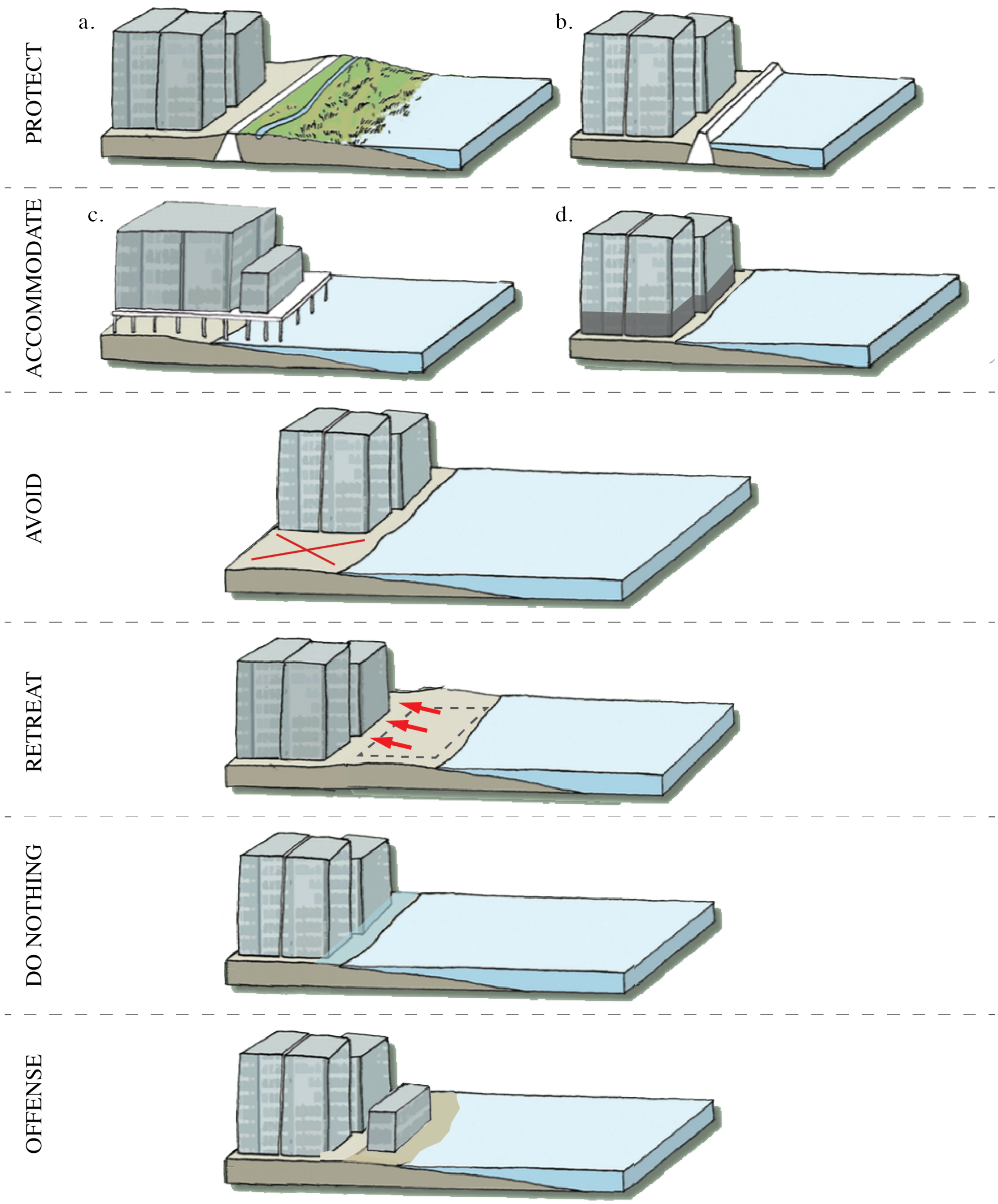


Figure 1.3: The sea level rise adaptation strategies: protect, accommodate, avoid, retreat, do nothing and offense. a. CGI, b. THS, c. Raising structures, d. Dry or wet proofing structures. Modified after Emily Underwood's illustrations [a]

[a]https://underwoodillustration.com/artwork/3819867-Sea-Level-Rise.html

1.3.3 Protect strategy measures

A range of coastal protection measures exist, from grey/structural to green/natural, to defend coasts from flooding and erosion. Table 1.1 summaries the coastal protection measures, characteristics, and types.

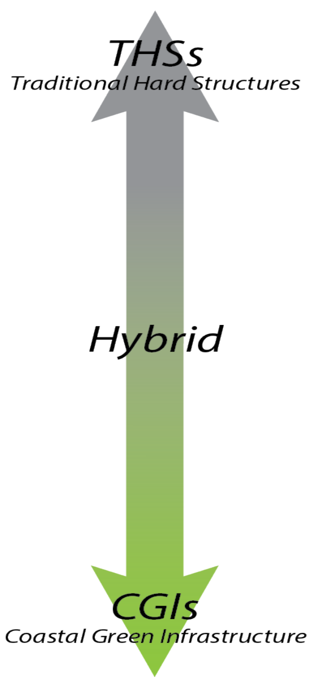
Coastal protection measures	Characteristic and types
 	• Characteristic: Structural elements Sea walls and bulkheads Dikes and super dikes Revetments and levees Emerged breakwaters, ripraps, and jetties Submerged breakwaters Groynes • Characteristic: Combined structural & natural elements Vegeteted revetments and sills Beach nourishment Textured and/or natural material breakwaters Submerged reefballs Constructed dunes • Characteristic: Natural elements Logs and woody debris placement Coastal and riparian vegetation Wetlands and estuaries Barrier islands and coastal dunes Coastal reefs

Table 1.1: Types of coastal protection measures from THSs to CGIs, adapted from (Morris et al., 2018; Sutton-Grier et al., 2018; Borsje et al., 2017; Narayan et al., 2016; Bridges et al., 2015)

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1.3.3.1 Traditional Hard Structures

Traditional hard structures (THSs) is an adaptation measure of the protect strategy. Typically, communities have prioritized the protection of coasts from flooding and erosion using THSs, such as dikes, seawalls, groins, and other built structures (Airoldi et al., 2005; Borsje et al., 2011; Renaud et al., 2013). However, there has been a growing debate on economic and environmental deficits of THSs. THSs have detrimental impacts on sensitive habitat, erosion, and sedimentation patterns (Cheong et al., 2013). They are static, immobile and not flexible enough to respond to changing conditions such as urban sprawl, climate change and new engineering regulations (Borsje et al., 2011). They require constant maintenance, and the cost of building, maintaining, and eventually rebuilding hard structures is very expensive (Möller et al., 2001). A growing amount of studies suggest that even with substantial funding, coastal communities are not always protected effectively by THSs (Klein et al., 2001).

Besides the negative implications of THSs, they have been used widely and consistently due to several important reasons. First and foremost, they protect private and public properties, and sustain the ownership, development, and occupation of the land (Tyler, 2016). Second, THSs are more tangible and easy to relate to (French, 2006), therefore, they appeal more to decision-makers. This is because they are easy to be visualized and communicated (Klein et al., 2001). Third, compared to CGIs the implementation of THSs often takes considerably less land space. Considering the high land values in coastal areas and the need and desire to utilize these valuable areas, THSs can be implemented much easier than their CGI counterparts in "in intertidal and shallow subtidal environments" (Airoldi et al., 2005, pg.1074).

1.3.3.2 Coastal Green Infrastructure

Coastal green infrastructure (CGI) is an adaptation measure of the protect strategy. CGI in this study is used as an umbrella term to describe natural or nature-based systems and processes that mimic dynamic coastal landforms, coastal vegetations, and reefs systems. CGI provides coastal protection services as well as ecosystem health, maintenance of natural processes and biodiversity, and social and economic benefits to communities. CGI protects coasts from flooding and erosion through reducing wave energy and height, attenuating floodwater, trapping sediment over soil, binding soil, and mitigating debris movement (Chenoweth et al., 2018; Morris et al., 2018). The following paragraphs refer to three main types of CGI.

Dynamic coastal landforms

Dynamic coastal landforms are formed together with vegetation and sand transported by waves, wind, currents, and tides (Davidson-Arnott, 2010). Examples include sand/gravel/rocky beaches, barrier islands, and dunes (Barbier et al., 2011; Sutton-Grier et al., 2015; The Horinko Group, 2015; Ruckelshaus et al., 2016). They reduce wave energy and trap sediments transported by water and wind. They respond rapidly to changes in sediment supply, wave action, flooding, and sea level changes (Davidson-Arnott, 2010; Feagin et al., 2010). Due to their unique position at the edge of coastlines[5], these dynamic coastal landforms have provided humans and nature with important ecosystem services (Keijsers et al., 2014).

Figure 1.4: Examples of dynamic coastal forms: a. Dunes, b. Barrier islands, and c. Sand, gravel, and rocky beaches (images from BC Stewardship Center; the National Oceanic and Atmospheric Administration (NOAA); United States Geological Survey (USGS))

Coastal vegetation

Coastal vegetation is typically characterized by the presence of macrophytes[6]. In this study, the definition of the coastal vegetation also includes the dune vegetation and coastal riparian vegetation. Situated at the interface between land and ocean (IPCC, 2014), coastal vegetation reduces wave energy and trap sediments (Figure 1.5). They are also well adapted to deal with natural stressors such as saline water, high tides, extreme temperatures, strong winds, and anaerobic soils (Kathiresan and Bingham, 2001; Davidson-Arnott, 2010; Duarte et al., 2013). Examples include kelp forests, eelgrasses, salt marshes, mangroves, and dune and riparian vegetations (Davidson-Arnott, 2010; Gutiérrez et al., 2011; Arkema et al., 2013; Sutton-Grier et al., 2015; Ruckelshaus et al., 2016; Sandi et al., 2018). Coastal vegetations are known as ecosystem engineers, as they physically modify environments and impact species, coastal processes, and overall ecosystem functioning (Bouma et al., 2009; Borsje et al., 2011; Duarte et al., 2013; Sandi et al., 2018).

[5]Coastlines are not stable therefore their exact location cannot be determined. The high water line, the visible line at the coast where the highest water level reaches, is typically used in the literature as reference (Klemas, 2011; Strauss et al., 2012; Weiss et al., 2011).

[6]Emergent, submergent or floating aquatic plants (Craft et al., 2009; Koch et al., 2009).

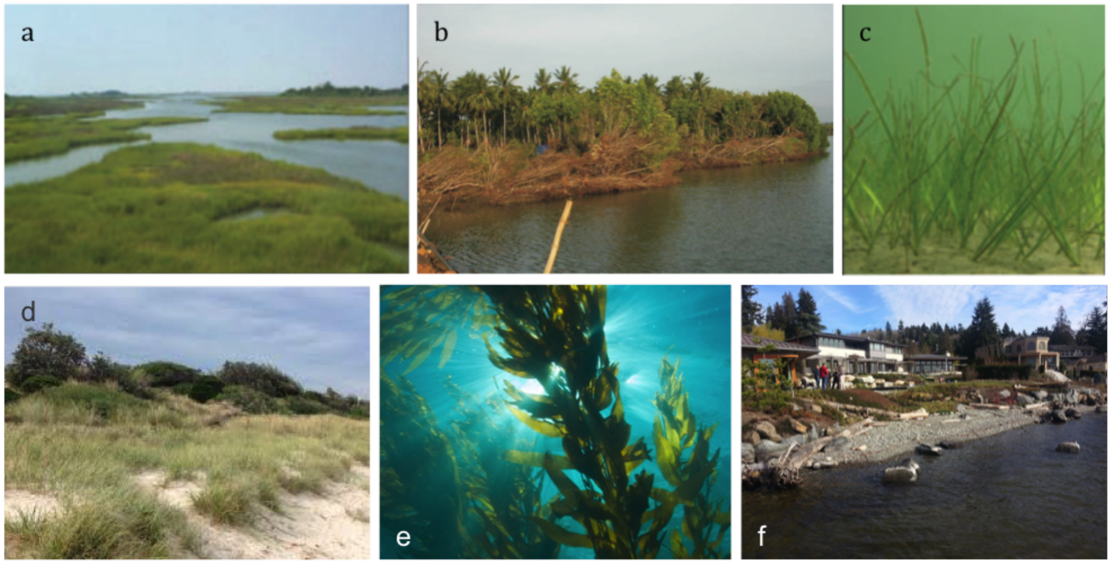

Figure 1.5: Examples of coastal vegetation: a. Salt marshes, b. Mangroves, and c. Sea grasses, d. Dune vegetation, e. Kelp forest, and f. Riparian vegetation (images from BC Stewardship Center; NOAA National Marine Sanctuaties; Sea Turtle Conservation; Dahdouh-Guebas et al. 2005; Koch et al. 2009.

Reef systems

Reef systems are dynamic ecosystems that constantly evolve and change in response to disturbances (Davidson-Arnott, 2010). They play roles in reducing wave energy at the coast by creating drag friction by providing surface roughness (Gutiérrez et al., 2011). Some examples include mussel beds, oyster reefs and coral reefs (Sutton-Grier et al., 2015; The Horinko Group, 2015; Ruckelshaus et al., 2016). Mussel beds and oyster reefs are located in the intertidal zone or low subtidal zone of coastlines (Scyphers et al., 2011).

Figure 1.6: Examples of reefs: a. Mussel beds, b. Oyster reefs, and c. Coral reefs (images from NOAA National Ocean Service Education; Southern California Coastal Water Research Project)

Even though CGI is equipped with mechanisms to deal with environmental stressors, it can also be vulnerable to changes in the land use, water levels, and storm intensities and frequencies (Osland et al., 2015). This vulnerability can alter the extent of CGI's coastal protection benefits by interfering with CGI's movement along the coastal profile and its interaction with natural processes (Khattabi and Bellaghmouch, 2009). Figure 1.7 schematizes the SLR impacts and the resulting hazardous events, the natural processes CGI interacts with, and its protection role.

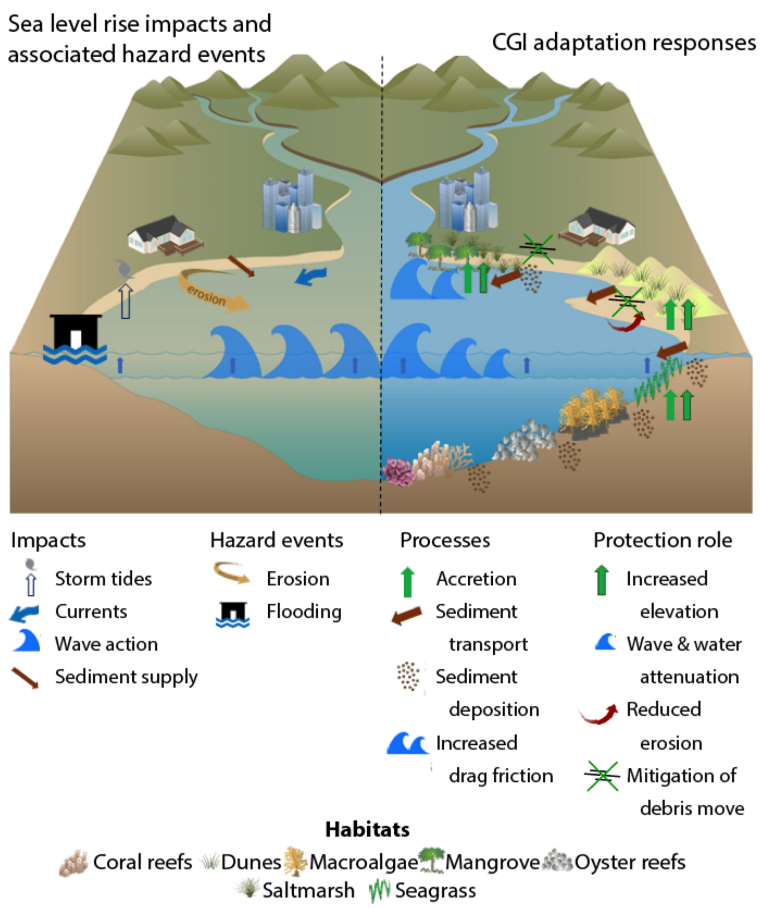

Figure 1.7: The impacts of sea level rise, associated hazardous events, coastal processes CGI interacts with, and CGI's coastal protection role. Modified after Morris et al. (2018).

1.3.4 CGI in the adaptation context

Sea level rise adaptation is a major challenge for coastal communities not only because of the rapid increase in the water levels, associated hazards, and the sensitivity and exposure of communities. The ways communities have been responding to changes (such as long-range and rigid planning practices and static engineering designs) and the increasing number of essential local services (such as mental health, social and housing, wastewater, flood management, and drinking water (Duffy et al., 2014, pg.4)) make it difficult for communities to address adaptation needs. Therefore, CGI has been a desirable adaptation measure to address these challenges, as well as other concerns coastal communities are dealing with.

Besides its ability to deal with the impacts of sea level rise by mitigating flooding and erosion impacts, the value of CGI in adaptation comes into play due to its multi-functionality, cost-effectiveness, and adaptability (Naumann et al., 2011; Narayan et al., 2016; Arkema et al., 2017). This is because the multifunctional, cost-effective, and adaptable nature of CGI help communities deal with some of the other concerns they are facing on a day to day basis. There is mounting evidence in the literature that CGI provides carbon sequestration, water filtration, biodiversity, fish and wildlife habitat, and recreational benefits (Matthews et al., 2015; Chenoweth et al., 2018; Morris et al., 2018). To start with, the multifunctionality of CGI contributes to the global efforts on greenhouse gas emissions reduction, reduces water pollution, contributes to the health and wellbeing of ecological systems, as well as enhancing human health and social life. Moreover, a growing number of studies and reports suggest that CGI is significantly cheaper to implement and to maintain than THSs (Lamont et al., 2014; Vineyard et al., 2015; Narayan et al., 2016; Onuma and Tsuge, 2018). By implementing CGI and reducing the implementation and maintenance costs, communities can allocate resources to other services. Lastly, large uncertainties exist over the rate and height of the sea level rise communities will experience (Carson et al., 2016). CGI's adaptable nature provides a dynamic and flexible adaptation measure that can deal with and adapt to these uncertainties (Nesshöver et al., 2017).

Ultimately, CGI not only helps communities adapt to sea level rise, but it also increases community resilience to it by accounting for uncertainties, multi-functionality, adaptability, community perspectives, and knowledge mobilization.

1.3.5 The context-dependency of CGI

The context-dependency of CGI has been a recent but growing field of study. The literature shows that there are various ways to investigate this context-dependency including but not limited to investigating the seasonal and temporal effectiveness (Koch et al., 2009; van Proosdij et al., 2006; van Proosdij and Townsend, 2006), cost-effectiveness (Narayan et al., 2016), flood and erosion reduction capabilities (Ruckelshaus et al., 2016), institutional arrangements (Matthews et al., 2015), social acceptability and public perspectives (Chaffin et al., 2016), and trade-offs (Catenacci and Giupponi, 2013) of CGI in different areas. In this dissertation, I focus on the following three contexts: (1) the locality of CGI, (2) the trade-offs of CGI, and (3) the institutional arrangements of CGI.

Locality of CGI

CGI is not independent of its environment. The ways in which CGI functions and provides coastal protection and other benefits are geographically relevant (Langridge et al., 2014). The CGI benefits depend on CGI's interactions with the coastal processes and the built environments (Hanley et al., 2014). For example, the biophysical conditions of an area may be right to implement CGI, but there may be other factors influencing its functionality. The rate of sea level rise expected in that area may be very high, leading to the drowning of CGI (Johnson et al., 2012). Alternatively, there may be urban development immediately after CGI at the coast, creating a "coastal squeeze" and preventing its natural migration along the coastal profile (Osland et al., 2015; Kirwan et al., 2016). There may be a situation where the sea level rise rate in an area is low, and the development does not create a coastal squeeze, but the wave action at the coast may be too high for the implementation of CGI (Ghosh and Chaudhuri, 2015). Alternatively, the sediment deposition rate at an area may be low due to the human interventions up or down the coast. The benefits of CGI and its role in adaptation, therefore, vary greatly depending on the environmental context of CGI's location (Ruckelshaus et al., 2016).

Tradeoffs of CGI

Even if all the environmental factors are favorable, there may be key built environment, social, economic and institutional trade-offs between CGI and other adaptation strategies at the local level (Catenacci and Giupponi, 2013; Oddo et al., 2015). Therefore, CGI may not be the best adaptation measure for all communities. In the built environment, CGI may lead to significant changes in the local land use, resulting in the loss of important agricultural, industrial or residential areas (Pramanik, 2017; Shayegh et al., 2016). Socially, there may be significant public pushback for CGI implementation (Flynn et al., 2018) or CGI may lead to social inequalities or exacerbate the existing ones within communities (Leichenko and Silva, 2014; Pramanik, 2017). The social trade-offs of CGI may reduce the public and political support for the use of CGI for sea level rise adaptation. Economically, other sea level rise adaptation strategies such as accommodate, avoid, or retreat may be less costly for local governments or homeowners to implement, or they may have more positive impacts on the local economy than CGI. Depending on who will pay for adaptation in the community, CGI may not be economically desirable (Gibbs, 2015). Institutionally, the local governments may not be equipped with the necessary staff, technological, and resources to undertake the implementation of an emerging adaptation measure. In the absence of the necessary institutional capacities, communities may resort to the implementation of other strategies (Patterson, 2018; Cinner et al., 2018). Having the right environmental conditions does not always lead to having the right social, economic and institutional settings for CGI. Considering that communities have different environmental, social, economic and institutional settings than each other, CGI will likely to have different trade-offs in different local contexts. Therefore, the trade-offs of CGI vary in the local community settings.

Institutional arrangements of CGI

Even if all the environmental factors and the local trade-offs are favorable, the implementation of CGI may still be hindered due to the institutional arrangements in place (Biesbroek, 2014). The implementation of CGI and any other adaptation measures rely on the institutional arrangements and the corresponding social, cultural, political and regulatory environments (Löf, 2013; Mguni et al., 2015). The reason is that the institutional arrangements can enable the governance, jurisdictional, and regulatory shifts or adjustments necessary to implement new adaptation measures such as CGI (Nesshöver et al., 2017). The institutional arrangements influence allocation of government responsibilities, jurisdictional boundaries, regulations, and programs (Barnett et al., 2013). In addition, they influence the financial resources that can be allocated, political motivations, organizational capacities, and communication strategies for CGI implementation (Ziervogel and Parnell, 2014). Communities in different regions and counties abide by different institutional arrangements than each other. The implementation of CGI in one place may not be easily replicated in another due to different local, regional, and national governments' responsibilities, jurisdiction, regulations, and programs in place. Therefore, the implementation of CGI is influenced by the institutional contexts (Eisenack et al., 2014).

1.4 Overarching and subsequent research questions

The dissertation follows a manuscript format. The overarching research question is as follows:

- In which contexts CGI can be used as a sea level rise adaptation measure?

In the attempt to answer this question, I develop three empirical studies investigating environmental, local and institutional contexts of CGI. Each of these studies corresponds to a chapter that is intended to stand alone and address the three research themes outlined in Section 1.2. Figure 1.8 shows the research chapters and the contextual concepts investigated in each of them.

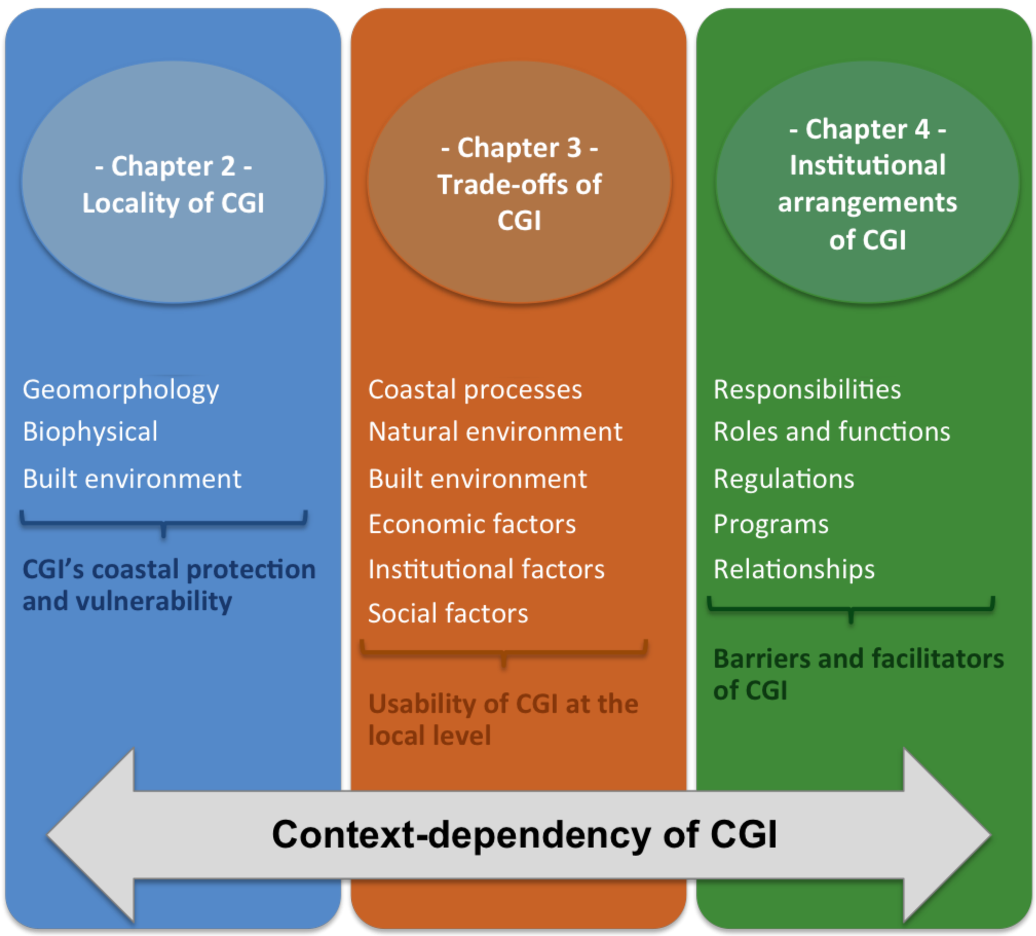

Figure 1.8: Research chapters and the contextual concepts investigated in each chapter.

In Chapter 2 (Theme 1 - Environmental), I investigate whether CGI's potential coastal protection benefits are influenced by its vulnerability to changes in environmental conditions. I develop a methodology to identify areas where CGI has more (or less) significant promise for coastal protection, using environmental indicators. The main research question of this chapter is: *How can the CGI coastal protection potential be identified, while taking into account its vulnerability to changing environmental conditions?*

In Chapter 3 (Theme 2 - Local), I investigate whether different sea level rise adaptation strategies have different local trade-offs due to local characteristics of communities. I incorporate local perspectives to create sea level rise adaptation scenarios and develop an evaluation tool to identify the trade-offs between CGI and other adaptation strategies. The main research question of this chapter is: *How can the local tradeoffs between CGI and other adaptation strategies be evaluated?*

In Chapter 4 (Theme 3 - Institutional), I investigate whether the institutional arrangements of different regions influence the implementation of the CGI projects. I explore the institutional barriers to and facilitators of CGI implementation by comparing the CGI projects, institutional arrangements, and practitioners' perspectives in BC and WA. The main research question of this chapter is: *What are the institutional barriers to and facilitators of CGI implementation?*

1.5 Research design, data, and methods

As described above, this research consists of three empirical studies, aiming to contribute to the overarching research question - in which contexts CGI can be used as a sea level rise adaptation measure? There are, of course, various ways in which one can answer this research question.

In the design of this research, I deliberately choose to employ three different studies because each study underpins different contributions to our understanding of the context dependency of CGI. In each chapter, I deliberately draw on a mix of methodological approaches because the mixed-method approaches can add insights and perspectives that may be otherwise missed, the strengths of one approach can help overcome the shortcomings of another one, and the results of different methods can be used to validate each other, thus can provide a stronger foundation for the findings.

Another deliberate decision of the research design is to conduct the research activities in the coastal regions of BC and WA in the United States. Situated at the west coast of Canada, and the northwest coast of the United States (Figure 1.9), these regions share a long border, history, and culture, and often exchange ideas and policies with each other (Simeon and Radin, 2010). They have similar yet diverse environmental, climatic and ecological characteristics and concerns (James et al., 2014). Their natural environments and the processes that affect these environments are connected and not bounded by the political boundaries. Moreover, the environmental (Okey et al., 2014), economic (Withey et al., 2015) and social (Binder et al., 2010) signs of the impacts of sea level rise are already apparent in these regions. There has also been a growing interest in and expertise with CGI in the region. In WA, many local governments, multi-organizational partnerships, and environmental non-profit organizations have been removing THSs and exploring CGI alternatives. In BC, there has been an increasing number of federal and provincial initiatives and grant programs for CGI projects in the last two years. Therefore, the coastal regions of BC and WA provide unique opportunities to investigate the use of CGI as an adaptation measure under diverse but comparable contexts.

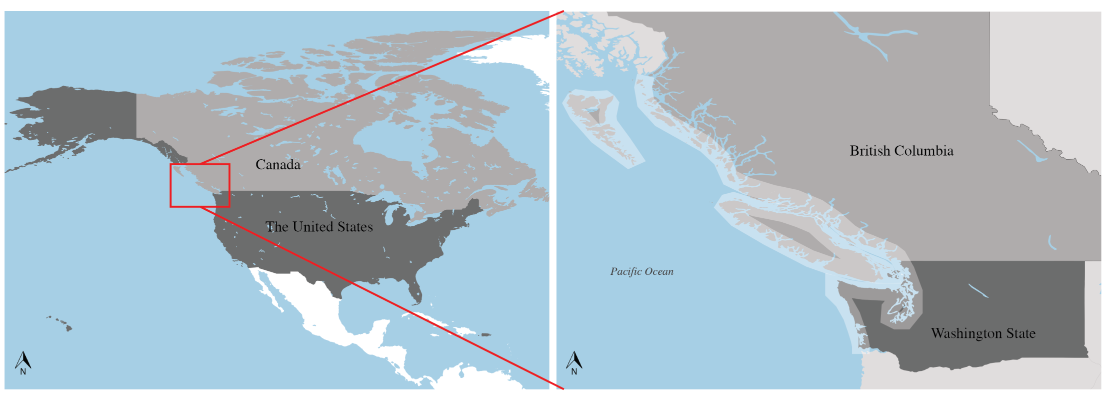

Figure 1.9: Highlighted areas are the coastal regions of British Columbia and Washington State

Each chapter includes detailed descriptions of the methods, research activities, and analysis. Here, I explain how each chapter fits into the overarching research design. Figure 1.10 schematizes the flow and summary of the research design of this study, including the organization of the themes and chapters, study areas, background driver(s) of the chapters, inputs and outputs, types of data, and methods that are used to achieve the goals outlined in Section 1.2.

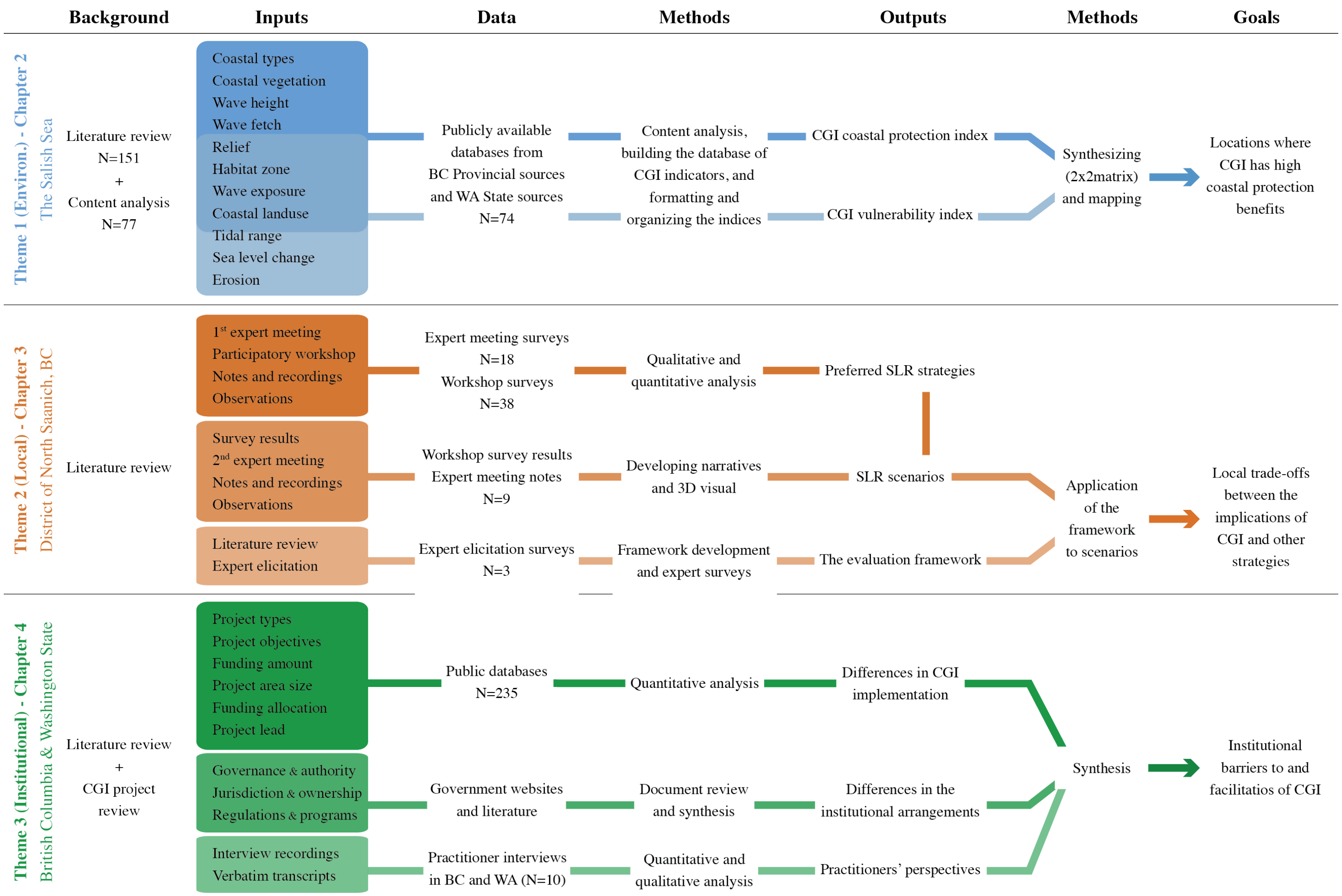

Figure 1.10: Research design of the dissertation chapters

In the first part of this dissertation (*Theme 1 - Chapter 2*), I undertake a regional level study, investigating where in the Salish Sea region CGI has the highest potential coastal protection benefits using environmental (climatic, natural and built environment) indicators. To start with, I conducted a review of the primary, secondary and grey literature to identify the various parameters used to measure CGI's coastal protection benefits and vulnerability (N=151). Next, I systematically reviewed the content of the references that contained specific parameters related to CGI's role in coastal protection and vulnerability (N=77). The results of the content analysis informed the inputs of this study. I selected coastal communities with populations over 4000 in the study area for data collection, which resulted in 74 communities in total (44 in BC and 30 in WA). I collected the input data from the publicly available BC provincial and WA state databases. Using rule-based methods and the literature, I organized the data into two indices: CGI coastal protection index, and CGI vulnerability index. I synthesized the results of the two indices using a 2x2 matrix. Lastly, I mapped the results to highlight the areas where CGI's potential coastal protection benefits are high.

In the second part of this dissertation (*Theme 2 - Chapter 3*), I undertake a local level study, investigating the trade-offs between CGI and other adaptation strategies while incorporating local perspectives. The District of North Saanich was selected to apply the research methods conceptually. I first organized an expert meeting (N=18) to review local data on sea level rise, tidal range, storm surge, and associated wave effects. Using the survey results and notes from the first expert meeting, I organized and facilitated a participatory workshop (N=38) to gather community preferences on sea level rise adaptation strategies. Using the literature and the feedback from the workshop, I developed narratives and visuals for four sea level rise adaptation scenarios. To review these scenarios, I organized a second expert meeting (N=9), where the participants reviewed the scenarios and gave feedback. Next, I developed a draft sea level rise adaptation strategies evaluation framework by reviewing the academic and grey literature. I conducted an expert elicitation survey with the experts in the region (N=3) to get their feedback on the evaluation framework. I incorporated the expert feedback on the evaluation framework. Lastly, I applied the evaluation framework to the adaptation scenarios to identify the trade-offs between CGI and other adaptation strategies I used descriptive qualitative and quantitative analysis to analyze the results of different research activities in the study.

In the third and the last part of this dissertation (*Theme 3 - Chapter 4*) undertake an institutional comparison study, investigating the institutional barriers to and facilitators of CGI implementation in BC and WA. To start with, I first reviewed the CGI projects that were implemented (or are in the implementation process) between 2008-2018 (N=235). I use descriptive quantitative analysis to understand the state of the CGI projects and the institutional roles in BC, compared to WA. Next, I reviewed the literature, government websites and documents to identify government structures and decision-making authority distributions, coastal jurisdiction boundaries, and coastal and environmental regulations and programs. I used document review and synthesis to understand the institutional arrangements in BC and WA and compare them. In the last step, I conducted semi-structured interviews with the practitioners that have been involved in the CGI implementation processes in BC and WA (N=5 in each region). Using descriptive quantitative and qualitative analysis, I aimed to provide a more in-depth understanding of the institutional barriers and facilitators and to identify CGI specific barriers and facilitators practitioners face in BC, compared to WA.

1.6 Dissertation synopsis

In Chapter 2, *Developing indicators to identify coastal green infrastructure potential: incorporating coastal protection benefits and vulnerability to changing environmental conditions*, I argue that CGI's coastal protection benefits are influenced by its vulnerability to environmental conditions and vary by location. Therefore, I suggest that investigations into where CGI provide coastal protection benefits need to include CGI's vulnerability and location-specific natural processes and built environment characteristics. I ask the question how can the CGI coastal protection potential be identified in a region while incorporating its vulnerability to changing environmental conditions? What parameters can be used to identify CGI coastal protection benefits and vulnerability? What criteria can be used to organize these parameters into CGI coastal protection and vulnerability indices? How can these indices inform where CGI has greater (or lesser) promise for coastal protection on the basis of the degree of potential coastal protection benefits and the degree of vulnerability? Drawing on Gornitz (1991)'s methodology, I develop indicators to assess CGI's coastal protection benefits and vulnerability. I synthesize them using a 2x2 matrix to identify areas with the highest coastal protection potential. Findings suggest that CGI in the large population centers in BC, and most of the communities in WA may not provide high coastal protection benefits. CGI in the smaller communities surrounding large population centers have a higher potential to provide coastal protection benefits. Besides the findings of this study, the CGI specific indices developed, and the methodology used in Chapter 2 contribute to the broader CGI literature.

In Chapter 3, *Resilience-based evaluation of the trade-offs of coastal green infrastructure in sea level rise adaptation strategies*, I argue that the adaptation and resilience contributions of CGI vary significantly with the biophysical, environmental (natural and built), economic, institutional and social environments of communities. Therefore, I suggest that there are local trade-offs between the implications of CGI and other adaptation strategies. I ask the question what are the tradeoffs of CGI as a sea level rise adaptation measure, compared to others? How can the local expert and stakeholder perspectives be incorporated in the development of the local sea level rise adaptation scenarios? What resilience concepts can be used to develop an evaluation framework to identify the local trade-offs of sea level rise adaptation strategies? Drawing on the resilience and adaptation planning literature (i.e., Picketts et al. 2012; Barron et al. 2012), I collaborate with a local coastal community to understand the local impacts of sea level rise, to identify the community's preferred adaptation strategies, and to develop community-specific adaptation scenarios. Next, drawing on the evaluation of adaptation strategies literature (i.e. Catenacci and Giupponi 2013; CAP and ICLEI 2015; Lockwood et al. 2015; Azevedo de Almeida and Mostafavi 2016; Cutter 2016; Gersonius et al. 2016), I develop a 30 component evaluation framework addressing coastal processes, natural environment, built environment, economic, institutional, and social concepts of sea level rise adaptation and community resilience. In the last step, I apply the evaluation framework to the local adaptation scenarios to identify the trade-offs between CGI and other strategies. Findings suggest that there are local trade-offs between the implications of different adaptation strategies. In this particular local context, the CGI scenario performed the best amongst all scenarios. The CGI scenario had the highest score for the coastal processes, natural environment, built environment, economic, and social components, and the lowest for the institutional component. In addition to the findings of this study, the main contributions of Chapter 2 include the methods and processes of developing sea level rise adaptation scenarios and the evaluation framework.

In Chapter 4, *Institutional barriers to and facilitators of coastal green infrastructure implementation: a comparative study in British Columbia and Washington States*, I argue that institutional arrangements of communities influence the implementation of the CGI projects. I suggest that common barriers to adaptation such as governance structures, decision-making authorities, coastal jurisdiction, and ownership, regulations and programs, as well as other CGI specific barriers impede the implementation of CGI. I ask the question what are the institutional barriers to and facilitators of CGI implementation? What are the differences between the institutional roles in CGI implementation in BC and WA? What are the differences between the institutional arrangements of different levels of governments in BC and WA? What are the practitioners' perspectives on the institutional barriers to and facilitators of CGI implementation in BC and WA? I first look at the CGI projects implemented in BC and WA between 2008-2018, to compare the institutional roles and support the CGI projects received. Drawing on the barriers to climate change and sea level rise adaptation literature (i.e. Adger et al. 2007; Moser and Ekstrom 2010; Mozumder et al. 2011; Carlsson-Kanyama et al. 2013; Löf 2013; Hansen et al. 2013; Hamin et al. 2014; Ziervogel and Parnell 2014; Hamin and Gurran 2015; Mguni et al. 2015; Reckien et al. 2015), I review the governance structures, distribution of decision-making authorities, coastal jurisdiction and ownership, and regulations and programs in BC and WA. Drawing on the same literature, I conduct semi-structured interviews with the practitioners in BC and WA. The findings suggest that CGI implementation is indeed influenced by similar barriers to and facilitators of adaptation. These are grouped under the following categories: governance structure and authority distribution; regulations; financial assistance; senior level support; organizational capacity; leadership and political will; and public knowledge and communication. The findings also suggest that several CGI specific barriers and facilitators impede or drive the implementation of the CGI projects, categorized under coastal jurisdiction and ownership; financial variation and flexibility; vision; organization efficiency and access to resources; partnerships and collaborations; NGOs; and community advocacy. Besides these results, the findings of the study contribute important details to each category, providing additional insights into the institutional barriers to and facilitators of adaptation and CGI implementation.

In Chapter 5, *Conclusion*, I synthesize the summary of findings for each chapter. Based on these findings I discuss broad conclusions and policy implications. I highlight the strengths and limitations of the dissertation. Next, I identify potential future research directions. Lastly, I conclude by noting personal reflections.

Chapter 2

Developing indicators to identify coastal green infrastructure potential: incorporating coastal protection benefits and vulnerability to changing environmental conditions

2.1 Introduction

Traditionally, coastal adaptation to climate change has prioritized the protection of coasts using hard structures such as dikes, seawalls, spillways, groins, and other built structures (Klein et al., 2001; Airoldi et al., 2005; Renaud et al., 2013; Feagin et al., 2015; Schubert et al., 2017). However, there has been a growing debate on coastal protection roles and benefits of hard structures, as well as their environmental, social and economic implications (Sutton-Grier et al., 2015).

These human-made structures are static and unable to respond to changing conditions such as urban sprawl, climate change, and new planning and engineering regulations (McGranahan et al., 2007; Borsje et al., 2011). They are often expensive to build, and they require regular maintenance (Temmerman et al., 2013; Onuma and Tsuge, 2018). They provide an inflated sense of protection and security, resulting in increases in development in flood-prone areas (Tyler, 2016; Schubert et al., 2017). Moreover, they cause significant damages to ecosystems and sensitive habitats by disrupting natural processes and preventing migration of habitat and species along to the coastal profile (Hanley et al., 2014; Onuma and Tsuge, 2018; Sutton-Grier et al., 2018). Consequently, they may have adverse implications for the coastal tourism sector, and local and regional fisheries (Onuma and Tsuge, 2018). In addition, parts of these hard structures can become loose with strong wave activity or through time and can cause significant damages to infrastructure, assets, and human lives (Tyler, 2016; Sutton-Grier et al., 2018). These unwanted effects of traditional hard structures have led to growing recognition of the need for a dynamic, safe and multi-functional ways of coastal protection (Cheong et al., 2013; Temmerman et al., 2013; The Horinko Group, 2015; Narayan et al., 2016; Sutton-Grier et al., 2018).

In response, the role of coastal green infrastructure (CGI), natural or nature-based systems that provide coastal flood and erosion protection as well as multiple social, economic and environmental benefits, have started to gain attention (Gedan et al., 2010; Arkema et al., 2017; Sutton-Grier et al., 2018). Studies of Coops et al. (1996); Mol (2003); Feagin et al. (2005, 2009); Koch et al. (2009); Borsje et al. (2011); Anderson and Smith (2014); Möller et al. (2014); Spalding et al. (2014); Wu and Cox (2015); Narayan et al. (2016); Ruckelshaus et al. (2016) and others indicate that CGI is an effective practice of protecting coasts from flooding and erosion. Although these studies did not use the CGI terminology, their research concluded that CGI practices protect coasts from flooding through reducing the wave energy by drag friction, reducing wave overtopping by eliminating vertical barriers, and absorbing floodwaters in soil (The Horinko Group, 2015; Ruckelshaus et al., 2016; Narayan et al., 2016; Arkema et al., 2017); and from erosion through reducing wave transmission, increasing soil elevation through vertical accretion and binding soil properties (Shepard et al., 2011; Hettiarachchi et al., 2013; Spalding et al., 2014; The Horinko Group, 2015; Silva et al., 2016). Besides its coastal protection benefits, CGI enhances natural coastal processes, sequesters carbon, provides habitat for wildlife, increases economic activities such as fishing and tourism, creates recreation opportunities, and improves aesthetics of coastal communities (Davidson-Arnott, 2010; Barbier et al., 2011; Barnhill and Smardon, 2012; Sutton-Grier et al., 2014, 2015).

Although CGI is now widely recognized for its value in coastal protection and providing various other benefits, it is also considered to be vulnerable to changes in the environments they interact with (Osland et al., 2015). For example, changes in the land use, water levels, and storm intensities and frequencies can have significant implications on the health and integrity of CGIs and the services they provide (Khattabi and Bellaghmouch, 2009). Therefore, CGI's coastal protection benefits are not solely affected by the physical characteristics of and changes in the natural and built environments, and the intensity of the hazards they are exposed to. CGIs adaptability to these changes can also significantly affect their coastal protection benefits. Especially with climate change, and the associated increases in the global sea levels and acceleration of storm intensities and frequencies, the vulnerability of CGI can potentially reduce, if not eliminate, its coastal protection benefits (Duarte et al., 2013; Langridge et al., 2014; Osland et al., 2015).

Hence, the type and extent of benefits acquired from CGI depend on the location it is implemented (Ruckelshaus et al., 2016). Because CGI and its interactions with coastal processes and built environments are context-depended (Hanley et al., 2014) and vary spatially and temporally (Koch et al., 2009; Barbier et al., 2011; Feagin et al., 2015). Yet, despite this place-specific dependency, identifying where to utilize CGI in coastal areas has been largely absent from the literature (Ruckelshaus et al., 2016). Filling this gap entails understanding where along the coasts CGI can provide protection benefits, and where it is likely to be vulnerable to changing environmental conditions. Considering CGI vulnerability, identifying coastal areas with the highest potential CGI protection benefits is important because it allows for prioritizing restoration efforts and new CGI implementation. Such an approach can also make it easier for local and regional level governments to allocate funds and other resources to areas with the highest potential of CGI benefits.

Therefore, this study aims to answer the following research questions. What parameters can be used to identify CGI coastal protection benefits and vulnerability? What criteria can be used to organize these parameters into CGI coastal protection and vulnerability indices? How can these indices inform where CGI has greater (or lesser) promise for coastal protection on the basis of the degree of potential coastal protection benefits and the degree of vulnerability? The study uses the Salish Sea region as a case study area to demonstrate the methods of this research.

Chapter 2 is organized as follows. Section 2.2 provides a literature review of CGI, its coastal protection benefits, and vulnerability. Section 2.3 describes the study area. Section 2.4 explains the methodological approach of this study. Section 2.5 provides and explains the results. Section 2.6 discusses the implications of the findings and the limitations of the methodology. Section 2.7 offers concluding remarks.

2.2 Coastal green infrastructure (CGI)

The green infrastructure terminology has been used by natural resource professionals (i.e., coastal zone management) (Cooper and McKenna, 2008), planners, and engineers in the last 40 years (Liquete et al., 2015). There are three main groups of green infrastructure: urban green infrastructure, which deals mainly with water and stormwater management in urban areas; watershed-based green infrastructure, which protects, fosters and connects networks of green spaces and forests; and coastal green infrastructure, which refers to the practices that aims to deal with flooding and erosion (The Horinko Group, 2015). This study focuses solely on the coastal green infrastructure (CGI).

Although CGI is a growing practice, its definition is not uniformly accepted and depends on the context that it is studied. Some of the most common definitions are as follows:

Benedict and McMahon's definition of CGI was "an interconnected network of natural areas and other open spaces that, (...), provides a wide array of benefits to people and wildlife" (2006, pg.1). Tzoulas defined CGI as "all natural, semi-natural and artificial networks of multi-functional ecological systems, (...), at all spatial scales" (2007, pg.1). Edwards et al. (2013) uses the term "blue infrastructure" to define coastal and riparian habitats that maintain coastal processes and ecological functions, and provide various ecosystem services. The European Commission (2013) defines CGI as natural and semi-natural areas that are strategically planned, designed and managed to provide various ecosystem services. The Conservation Leadership Council's 2015 report refers to CGIs as "nature-based systems and processes" (2015, pg.1). The Environmental Protection Agency (USEPA, 2015) and the US Army Corps of Engineers (Bridges et al., 2015) in the USA define CGI as natural areas and processes, or nature-based (designed and engineered) systems that mimic natural processes that provide coastal protection, habitat and other services. Recently, Soz et al., defined CGI as an approach that uses natural processes to manage flooding while providing other ecosystem services (2016, pg. 1). Narayan et al., uses the term "nature-based defenses" and defines it as "existing coastal habitats within which wave reduction has been measured" (2016, pg.1).

Driven from these definitions, CGI in this study refers to natural or nature-based systems and processes that mimic dynamic coastal landforms, vegetations, and reefs to provide coastal protection services as well as various ecosystem health, maintenance of natural processes and biodiversity, and social and economic benefits to communities.

Common types of CGI are:
(1) dynamic coastal landforms such as sand/gravel/rocky beaches, barrier islands, and dunes (Barbier et al., 2011; Sutton-Grier et al., 2015; Ruckelshaus et al., 2016), including beach nourishment practices (Brown et al., 2016);

(2) coastal vegetation such as mangroves, eelgrasses, dune vegetation, salt marshes and kelp forests (Davidson-Arnott, 2010; Arkema et al., 2013; Duarte et al., 2013; Sutton-Grier et al., 2015; The Horinko Group, 2015; Ruckelshaus et al., 2016); and

(3) reef systems such as mussel beds, oyster reefs and coral reefs (Gutiérrez et al., 2011; Cheong et al., 2013; Sutton-Grier et al., 2015; Ruckelshaus et al., 2016).

2.2.1 CGI coastal protection benefits

CGI's coastal protection benefits are mainly two folds: flood protection and erosion protection. CGI protects coastal areas from flooding by reducing the fetch for the wind to form waves, absorbing wave energy through surface roughness and drag friction, leading to a reduction in wave height and velocity, and absorbing floodwaters through impermeable natural or engineered surfaces (Davidson-Arnott, 2010; Cheong et al., 2013; Spalding et al., 2014). Erosion protection is achieved by maintaining or increasing surface elevation by trapping sediments and build-up from decaying vegetation on soil, and binding soil particles through vegetation roots (Barbier et al., 2011; Bryant et al., 2017).

Flood protection

Fonseca and Cahalan (1992) studied seagrasses and their role in reducing wave energy over a one-meter test section. They concluded that the percentage of average wave reduction by four species of seagrasses was approximately 40% and wave energy reduction was significantly cut when water depths become higher or equal to twice the mean leaf length. Coops et al. (1996) found that through a 4m wide profile of wave tank, wave heights over areas without salt marshes ranged from 71% to 129% more of the height of waves for areas with salt marshes. Möller et al. (2001) found that salt marshes reduced wave heights in all observations at rates 27% to 98%. They also found that the total energy dissipation rates were on average 82% over salt marshes compared to on average 29% on sand flats. In another study Möller and Spencer (2002) suggested that on average 92% wave height attenuation was obtained over a 310 m coastal profile of salt marshes, and the first 10 m of the canopy provided the most rapid reduction in wave height. Later, Möller (2006) suggested that salt marshes could effectively reduce up to 33% of wave height over a 10m coastal profile, depending on the salt marsh canopy height and density, and water depth conditions.

Loder et al. (2009) used numerical models for their study and found that a 400-km^2 salt marsh area is effective to reduce less than 2 m of storm surge (35% to 70% surge decrease). Bradley and Houser (2009) concluded that over a one m water depth range, wave heights wave height decreased on average by 30% after the first 5 m over 39 m, and decreased exponentially over the remainder of the bed. Similarly, Koftis et al. (2013) suggested a 35% reduction in wave heights by seagrasses in an extensive experimental study. Anderson and Smith (2014) suggested that artificial seagrasses attenuated the wave energy in all wave frequency conditions. John et al. (2015) suggested an exponential reduction in wave height over a 50 m long wave flume of submerged artificial seagrass vegetation.

Studies after Indian Ocean Tsunami of 2004 and Hurricane Katrina of 2005 suggested that presence of wetlands and mangroves reduced the infrastructure damage, injuries and fatalities caused by extreme events (Chang et al., 2006; Barbier et al., 2013). Supporting the abovementioned studies, Narayan et al. (2016)'s meta-analyses of CGI's wave reduction suggested that CGI play key roles in reducing wave heights, on average 35% and 71% reduction in wave heights, and the extent of coastal protection achieved varies with the location and local conditions.

Erosion protection

CGI reduces erosion directly by reducing wave transmission, capturing sediments and indirectly through stabilizing soil properties (Feagin et al., 2009; Silva et al., 2016; Bryant et al., 2017; Mendoza et al., 2017). Coops et al. (1996) suggested that different types of CGI reduced erosion at different rates. Examining different types of salt marshes, they noted that *P. austrulis* salt marshes showed higher aboveground biomass and reduced erosion by 82%, while *S. lucustris* salt marshes reduced only 33%, compared to not vegetated areas. Piazza et al. (2005) found that coastal erosion was 0.08 $\pm 0.02 m$/month at oyster reef present sites as compared to 0.12 $\pm 0.01 m$/month at oyster reef absent sites. In another study area, Scyphers et al. (2011) found that oyster reefs successfully mitigated erosion by more than 40% over two years. Levin et al. (2007) suggested that the sand deposition, thus accumulation was much higher in areas with taller coastal vegetation, compared to shorter vegetation.

More recently, in a study investigating the dune erosion, KobayashiI et al. (2013) concluded that wooden dowels and wide dune vegetation reduced the dune erosion by decreasing the wave overtopping and overwash rates. In a large-scale implementation and monitoring study, Stive et al. (2013) suggested that sand nourishment will increase the width of the beach and will increase the beach area approximately 200 ha in 20 years after implementation. In physical model experiments on the effects of vegetation on dune erosion, Figlus et al. (2014) suggested that the vegetation reduces eroded dune volumes and concluded that the vegetation root maturity plays a significant role on reducing erosion. Martinez et al. (2016) found that vegetation effectively reduces coastal erosion in three different storm conditions, through 24 experiments of two coastal profiles. Silva et al. (2016) investigated the role of vegetation cover on the sediment movement along two coastal profiles and concluded that vegetation reduces net coastal erosion regardless of different wave and morphological conditions, and prevents shoreline retreat. Borsje et al. (2017) suggested that coastal erosion can be prevented and functions of the coastal areas and processes can be maintained with beach nourishment. Mendoza et al. (2017) stated that vegetation effectively contributes to the resistance of the coastal profile during storms through trapping sediments and strengthening soil.

2.2.2 CGI vulnerability

There is now numerous evidence on CGI's role in coastal protection (i.e., Koftis et al. 2013; Anderson and Smith 2014; John et al. 2015; Silva et al. 2016; Arkema et al. 2017. At the same time, there is a growing interest in using CGI for coastal protection (Ruckelshaus et al., 2016). It is widely recognized that CGI is more effective in specific contexts than others that its coastal protection benefits can vary in depending on the context they are utilized. It is also recognized that CGI itself can be vulnerable depending on the context it is located in, and the rate and magnitude of the environmental changes in that environment become too high for CGI to adapt to. Thus, this vulnerability can lessen CGI coastal protection benefits.

In the past 50 years, around 25% to 50% of the coastal areas with essential landforms, vegetations, and reef systems have been lost globally due to changing environmental conditions such as increased pollution, changes in coastal land use, and climate change (Duarte et al., 2013; Feagin et al., 2015). Notably, the impacts of climate change such as increased frequency, duration and intensity of storms, and rising sea levels have intensified the hazards CGI is exposed to (Johnson et al., 2012; Ghosh and Chaudhuri, 2015). However, CGI has response mechanisms such as accretion or migrating along the coast to deal with these hazards (Feagin et al., 2015). What makes CGI vulnerable, however, are the external interventions that disable these response mechanisms. These interventions are often in the form of extensive occupation of coastal areas, where CGI has no or insufficient physical space to move and adjust ('coastal squeeze') (Feagin et al., 2005; Osland et al., 2015; Kirwan et al., 2016); construction of human-made structures or human activities that intervene with the natural sediment flow to the coasts (Feagin et al., 2010); or rapid acceleration of sea level rise due to climate change, or local water levels due to engineering activities that change coastal profile (Duarte et al., 2013).

Feagin et al. (2005), investigated the vulnerability of dune vegetation to rising sea levels in a spacial model on Galveston Island, Texas, USA. The study concluded that in the low sea level rise scenario (0.09m by 2100), dune vegetation was able to fully develop and cope with the increase in sea level. However, in the high sea level rise scenario (0.88m by 2100), only a thin strip of dune vegetation was developed due to high stressor level. Moreover, in the high-rise scenario, the thin dune vegetation was neither able to block winds nor accumulate new soil layers. Feagin et al. (2005) also stressed that human developments along the coasts which restrict migration of CGI landwards are key determinants of vulnerability. Khattabi and Bellaghmouch (2009) found in a simulation study that with a 0.5 m sea level rise a loss of 478.7 ha and with a 2 m sea level rise a loss of 1400 ha may be observed by 2100 in a wetland in the North East coastal zone of Morocco.

Similarly, Kirwan and Temmerman (2009) and Kirwan et al. (2010), investigated CGI's surface accumulation while facing sea level rise in modeling studies. Their results concluded that at sea level rise rates more than 20mm per year; salt marshes in medium to high tidal ranges and sediment concentrations survive, while salt marshes in low tidal ranges and sediment concentrations fully submerge. They suggested that full submergence occurs approximately 30-40 years after the threshold sea level rise rates are exceeded. Later, Kirwan et al. (2016) suggested a threshold rate of 10 to 50 mm/yr for the relative sea level rise and marsh survival, and vegetation areas with less than 1 m tidal range and less than 20 mg/L sediment concentrations will be vulnerable to even the moderate rate of sea level rise. Kirwan et al. (2016) also suggested that gently sloping coastal profile enhances and fosters marsh expansion. They stated that even at high sea level rise rates, marsh survival could be achieved, only if the vegetation is able to migrate inland and is not limited by natural or human-made barriers.

Thorne et al. (2013) investigated the ability of a 309 ha tidal marsh area to increase its surface elevation over 13 years to keep up with the rising water levels using two elevation surveys. Their result concluded that 63% of the salt marsh area did not accrate at a rate that exceeded sea level rise, and therefore drowned. They also stated that the long distance to sediment source was the most significant factor in the lack of accretion. Mariotti and Carr (2014) also supported previous findings, stating vegetation is likely to drown when sea level rise is fast, and access to sediment is low. They suggested a 0.3 (mm/yr)/(mg/L) ratio of sea level rise and sediment concentration is a threshold for vegetation drowning, and a sediment concentration of at least 50 mg/L would be needed to prevent vegetation retreat even in cases where sea levels are stable.

Literature shows that the extent of CGI benefits varies significantly depending on the geomorphological, wave and CGI related characteristics of their environment. Similarly, the degree of CGI vulnerability differs depending on the geomorphological, land use and CGI related characteristics as well as environmental change types and rates.

2.3 Study Area

The Salish Sea region is selected to identify areas with highest potential CGI. The Salish Sea is a body of water that encompasses south of British Columbia in Canada and north of Washington States in the United States. The area includes the Strait of Georgia, the Puget Sound, and the Strait of Juan the Fuca (Figure 2.1).

The Salish Sea region is an important international body of water that is home to many coastal communities with diverse economic, and built and natural environment characteristics. The coastal communities of the Salish Sea range from small towns with only a few hundred residents and single sector economy, to large metropolitan areas such as Vancouver and Seattle with complex economies. The coasts range from low-lying sand flats to coasts with cliffs, from salt marsh fields to dunes and rocky beaches. The variation of the characteristics of Salish Sea communities provides a diverse setting for this study and demonstrates the spatial variation in CGI benefits and vulnerability in the region.

Coastal communities with populations over 4000 were identified from both British Columbia and the Washington States. 44 Coastal communities from British Columbia and 30 coastal communities from Washington State were selected for this study. The unit of analysis of this regional level study is the Canadian Census Subdivision (CSD) units for British Columbia communities, which is the equivalent to a municipality, and the American Census City/Urban Growth Areas (UGA) for the Washington States communities, which is the incorporated city boundaries and unincorporated Urban Growth Areas. These units are comparable, and publicly accessible data are available for both geographic units in the federal and provincial/state databases.

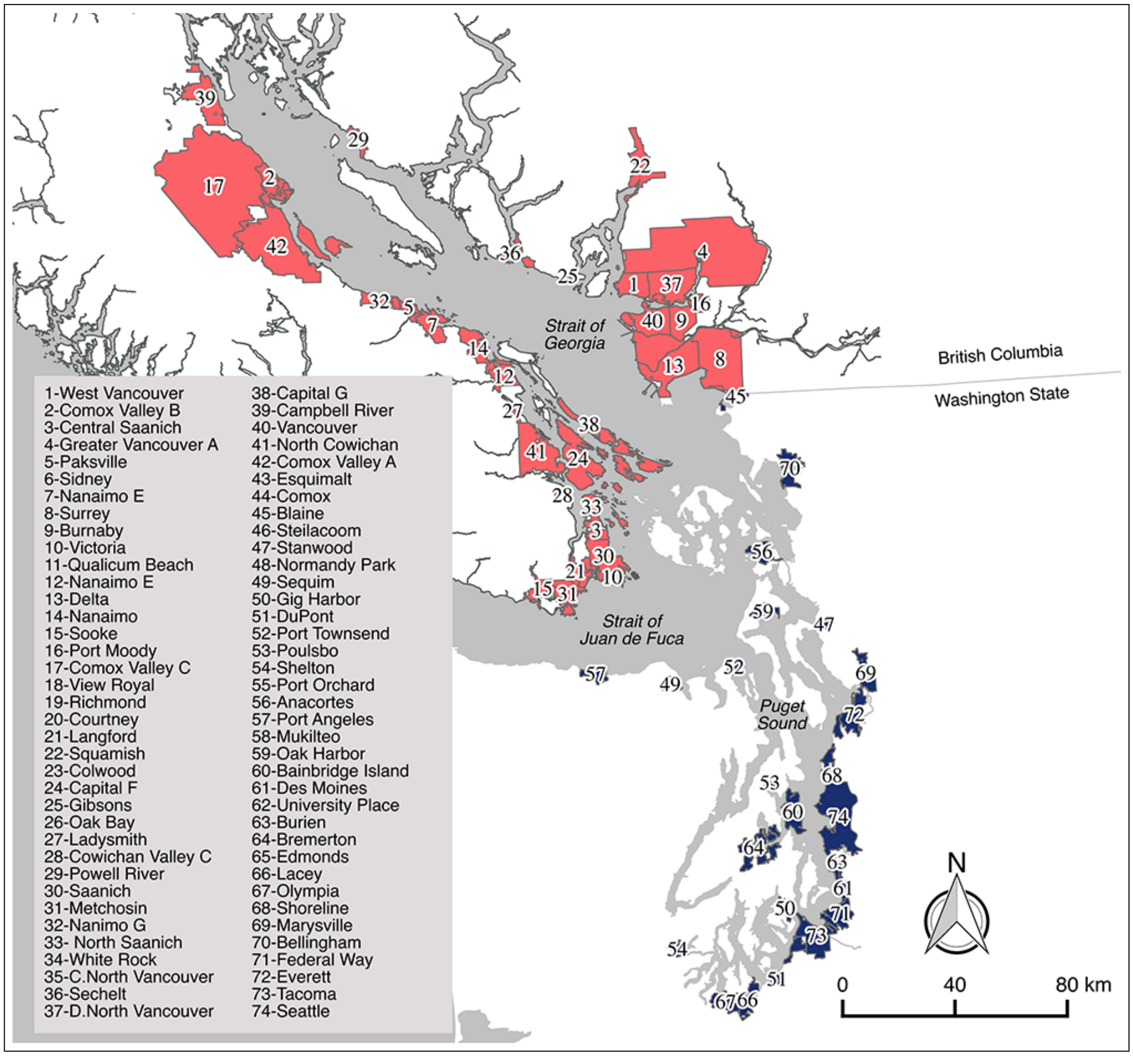

Figure 2.1: The Salish Sea and the study area communities. Numbers are in no particular order.

Besides its importance and diversity, the Salish Sea region is an important area for this study because the governments and communities in this region have a high level of interest in CGI projects. Particularly in the Washington State, numerous county governments (i.e., Skagit and Kitsap Counties), multi-organizational partnerships (i.e., Puget Sound Partnership) and environmental non-profits (i.e., Northwest Straits Foundation) have been initiating projects that remove human-made structures such as bulkheads and restore habitats and beaches. Besides, already several important CGI initiatives such as Green Shores BC and Green Shores Program of Washington State exist in the region and educate local governments, community groups, and waterfront property owners in ways they can utilize CGI. Even though such initiatives are limited in British Columbia compared to Washington State, recent federal and provincial initiative such as green infrastructure grant program creates an increased push for CGI projects.

2.4 Methods

This study uses an indicator-based approach to identify areas with the highest CGI potential in the study area. Indicator-based approaches were used, amongst others, in fields such as disaster risk reduction (i.e. Cutter et al. 2003), emergency management (i.e. Flanagan et al. 2011), sustainable development (i.e. Tanguay et al. 2010) and coastal zone management (i.e. Martí et al. 2007). CGI related indicators were often used along with other social, economic and institutional indicators to assess or compare vulnerability of places (i.e., Chang et al. 2015), or along with other natural indicators to assess the environmental vulnerability of coastal communities (i.e., Shaw et al. 1998; Gornitz 1991; Tibbetts and van Proosdij 2013).

Using the indicator-based approaches for understanding CGI's coastal protection benefits and vulnerability is relatively new in the CGI research as studies typically field studies or lab experiments. This approach has been mainly applied in cost-benefit analyses of CGIs (i.e., Narayan et al. 2016; Capotorti et al. 2017), rather than understanding coastal protection benefits of CGIs or their vulnerability to changes. However, the indicator approach provides a high-level framework that can be mapped and applied in other regions, and its findings can be easily understood and interpreted by decision-makers (Hinkel, 2011; Chang et al., 2018).

The methodology of this study comprises of the following four systematic steps: (1) literature search to identify CGI studies; (2) content analysis on the selected studies to identify parameters used in the CGI literature; (3) developing indices based on the parameters identified in Step 2 to assess CGI coastal protection benefits and vulnerability to changing environmental conditions, and mapping; and (4) synthesizing the indices developed in Step 3 into a classification system to identify areas where CGI can potentially be used as a coastal protection tool. Step 1 and 2 address the research question “What parameters can be used to identify CGI coastal protection benefits and vulnerability?” Step 3 answers the research question “What criteria can be used to organize these parameters into CGI coastal protection and vulnerability indices?” Lastly, step 4 answers the research question “How these indices can inform where CGI has greater (or lesser) promise for coastal protection on the basis of the degree of potential coastal protection benefits and the degree of vulnerability?”

2.4.1 Literature review

CGI studies have used various parameters in the way they measure CGI’s role in coastal protection and its vulnerability. To identify these parameters, a literature search using the Web of Science, Google scholar and Jstor databases (1970-2015, cut off date December 2015) was conducted to target references on CGI’s coastal protection benefits and vulnerability. Numerous keywords were used in the literature review. These keywords were determined through the initial review of the CGI literature and include the following: coastal protection, (coastal) green infrastructure, nature-based protection, wave attenuation, shore stabilization, flood protection, erosion protection, vegetation accretion, coastal habitats, coastal defenses, soft engineering, bioshields, and nature-based solutions.

In total, 151 primary, secondary and grey literature references matched the search criteria and were selected for review. Amongst the 151 references reviewed, 77 references were identified that contain specific parameters related to CGI’s role in coastal protection and vulnerability, and therefore were selected for this study.

2.4.2 Content analysis

A content analysis was conducted on the 77 references to identify the parameters used to measure the CGI’s role in coastal protection and its vulnerability. These parameters were recorded and coded in groups to reflect larger themes. For example, parameters related to wave height, frequency, direction, and other wave features were grouped under ‘wave characteristics’ theme. Figure 2.2 displays the themes and the frequency of use in the 77 selected CGI references.

The content analysis revealed that a large variety of parameters had been used in the CGI research. For example, Möller et al. (2001); Möller and Spencer (2002); Möller (2006); Möller et al. (2014) studies used water depth, wave characteristics, and CGI characteristics to investigate whether or not vegetation can reduce wave heights. On the other hand, Costanza et al. (2008) used CGI cover and monetary damages associated with storm surges to investigate flood protection from CGI. Similarly, Kirwan and Temmerman (2009); Kirwan et al. (2010) investigated erosion reduction rates provided by CGI through sediment concentration, sea level rise rate, tidal range, and CGI characteristics parameters; while Feagin et al. (2005, 2009) used sediment concentration, accretion, CGI characteristics, and wave/storm characteristics parameters.

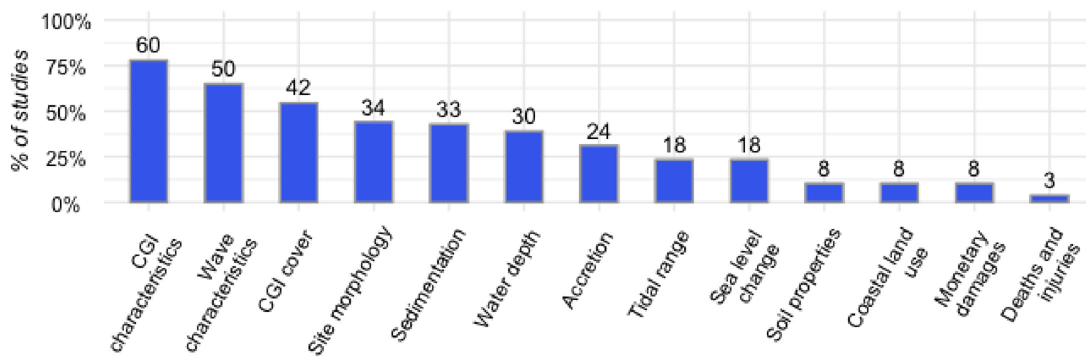

Figure 2.2: Themes used to measure CGI coastal protection benefits and vulnerability

As seen in Figure 2.2, the most commonly used theme is the CGI characteristics. 60 out of 77 references reviewed included an indicator related to CGI characteristics. The CGI characteristics theme refers to CGI types, vegetation densities and length, surface roughness provided by different types of CGIs and other specific features of CGI. The second most used theme is the wave characteristics, which includes measures such as wave length, height, frequency, period, direction and other wave characteristics. Both the CGI characteristics and wave characteristics themes have been primarily used to determine the degree of the interaction there could be between waves and CGIs. The third indicator theme is the CGI cover. This theme refers to the area or percentage of the CGI that exists at the coast where the CGI habitat exists, or the CGI practices are implemented (i.e., beach nourishment area). This indicator theme was separated from the green infrastructure characteristics because it does not directly refer to the properties of CGI; instead, it indicates the space they cover at the coast. This theme determines the stretch of the CGI that interacts with the coastal processes.

The sedimentation theme, which indicates the sediment concentration or the amount of sediments deposited at the coast, was also commonly used in the CGI studies. They are mainly used to investigate CGI's vulnerability to changing environmental conditions because the amount of sediment deposited at coast impacts CGI's ability to accrete. Another important theme that is used in the CGI studies is the water depth. Kirwan et al. (2010), Koch et al. (2009), Möller et al. (1999, 2001); Möller and Spencer (2002); Möller (2006); Möller et al. (2014), Stone et al. (2005) and others suggested that the water depth is an important indicator for CGI's coastal protection benefit as it determines the depth CGI can interact with the wave and reduce its energy. These studies suggested that when the threshold CGI height/water depth is passed, CGI's ability to attenuate wave energy decreases because CGI can no longer interact with the waves.

Following the water depth theme is the site morphology theme such as relief, slope and type of coast (i.e., sand, gravel, and rock), and the accretion theme such as changes in soil elevation and organic decomposition. The site morphology theme is a crucial part of CGI studies since the features and position of the coasts can provide protection from wave action. The accretion theme is often used to determine the vulnerability of CGI because CGI can accrete and increase their soil elevation to keep up with the rising water levels. Commonly, the sea level change and tidal range themes were used along with the accretion theme to investigate CGI vulnerability, as the speed and rate of the sea level change and associated changes in the tidal range impact CGI's ability to accrate.

Although not used widely in the literature in the past, soil properties, coastal land use, and monetary damages themes also emerged through the literature review. The soil properties theme determines how much water can be held in the soil in occasional flooding events and the risk of erosion at the coast. The coastal land use theme is used to indicate the extent of development that needs protection, and how much space is available on the coast for green infrastructure to adapt to various water levels. The monetary damages after extreme events can also indicate the benefits CGI provides as a defense mechanism at the coast. And lastly, the damages on human lives after an extreme event can be used to measure the effectiveness of CGI.

2.4.3 Development of the CGI indices

Building the CGI database

A CGI database was created using the themes identified above. The British Columbia and Washington State spatial data databases were searched to gather publicly available data on the themes and corresponding indicators. Of the 13 themes, data were available for the following nine themes: CGI characteristics, wave characteristics, site morphology, sedimentation, water depth, accretion, tidal range, sea level change, and coastal land use. These themes, 12 correspondent indicators, and their data sources are shown in the Table 2.1.

Themes	**Indicator(s)**	**Sources**
CGI characteristics	- Coastal vegetation (i.e., kelp, sea grass, salt marsh, dune vegetation)	BC-PSZMS[a] and WA-SZI[b]
Wave characteristics	- Wave exposure (i.e., exposed to very protected coasts) - Max. wave height (m) - Max. Wave fetch (km)	BC-PSZMS, WA-SZI and The Geomorphology of Puget Sound Beaches[c]
Site morphology	- Relief (m) - Coastal types (i.e., estuaries, flats, beaches, cliffs, and human-made coasts)	CanCoast[d], BC-PSZMS, WA-SZI, and WA Dep. of Transportation[e]
Sedimentation	- Sediment concentration at coast. A relative index of sediment abundance (abundant, moderate and sparse)	BC-PSZMS and WA-SZI
Water depth	- Habitat zone (i.e., subtidal, lower tidal, intertidal, mid/high tidal, supratidal)	BC-PSZMS and WA-SZI
Accretion	- Erosion/change (m/y)	CanCoast and WA-SZI
Tidal range	- Tidal range (m)	CanCoast and WA-SZI
Sea level change	- Sea level changes (cm) in the past 100 years	CanCoast and WA Dep of Ecology[f]
Coastal land use	- Coastal land use. Green (5) to gray (1) scale refering to the use of the coast where green refers to mostly agricultural or natural uses, and gray refers to mostly commercial and infrastructure uses	DMTI Spatial Inc [g] and WA Dep. of Natural Resources [h]

Table 2.1: CGI themes and indicators, and their data sources

[a]Physical Shore-Zone Mapping System for British Columbia, 2009
[b]The Washington State Shore Zone Inventory, 2006
[c]Technical Report (Finlayson et al., 2006).
[d]CanCoast: A National-scale Framework for Characterising Canada's Marine Coasts, 2013
[e]https://gisdata-wsdot.opendata.arcgis.com/datasets/wsdot-major-shorelines
[f]Sea Level Rise in the Coastal Waters of Washington State, 2008
[g]https://www.dmtispatial.com/canmap/
[h]http://data-wadnr.opendata.arcgis.com

For each indicator, the coastal segments and corresponding data were aggregated to the unit of analysis of this study (CSDs and UGAs). The dominant features for each community were identified and recorded. Although the data for sediment concentration was available it was incomplete; thus it was not included in the study. The remaining 11 indicators collectively represent the composition of the coastal areas and the interaction between landforms, built environments, and coastal processes.

Formatting and organizing the indices

The indicators (n=11) from the CGI database were used to create the CGI coastal protection and vulnerability indices. First, the indicators from Table 2.1 were assigned to either the CGI coastal protection index and/or the CGI vulnerability index. Second, the rule-based method - if a, then b, where a is the property of an observation and b is the group it is assigned to - was applied to the indicators to rank them from very low (1) to very high (5), as shown in Table 2.3 and Table 2.4. Third, the CGI coastal protection and CGI vulnerability indices were computed. The methodology used to compute the indices was adopted from that of Gornitz (1991), which combines data on indicators and ranks them from 1 to 5 to compute the "Coastal Vulnerability Index (CVI)". The CVI method is defined by Gornitz (1991) as the square root of the geometric mean divided by the total number of variables.

$$CVI = \sqrt{\frac{a^1 \times a^2 \times a^3 \times \ldots \times a^n}{n}}$$

Fourth, the total range of computed values was divided into normal distribution quantiles, providing four range groups. These groups were assigned to very low, low, medium and high categories. The four range groups and corresponding categorical groups for both indices are provided in the (Appendix A.1 and A.2). And lastly, the spatially linked data were mapped using Geographic Information Systems (GIS).

The CVI methodology has been used in many other studies investigating environmental vulnerability and sensitivity such as Shaw et al. (1998), Gornitz (1991), Gornitz et al. (1992, 1994) as well as Thieler and Hammar-Klose (1999) but it has not been applied to the CGI coastal protection research.

2.4.4 Synthesizing the indices

After the CGI coastal protection and vulnerability indices were created, computed, and mapped, they were synthesized using a 2x2 matrix (Table 2.2) to identify coastal protection potential in the study area. CGIs with low coastal protection benefits and high vulnerability; low coastal protection benefits and low vulnerability, high coastal protection benefits and high vulnerability, and high coastal protection benefits and low vulnerability were grouped. The spatially linked data was mapped using GIS.

		CGI Coastal protection	
		Very low/low	High/medium
CGI Vulnerability	*Very low/low*	*Low potential*	*High potential*
	High/medium	*Very low potential*	*Medium potential*

Table 2.2: CGI coastal protection potential matrix

2.5 Results

2.5.1 CGI coastal protection index

Quantitative and qualitative data on eight indicators were used to create the CGI coastal protection index. These indicators are the relief, coastal types, coastal vegetation, habitat zone, wave exposure, maximum wave height, maximum wave fetch, and coastal land use. Each variable for these indicators was assigned a rank from 1 to 5, where 1 represents very low, and 5 represent very high existing coastal protection benefits (Table 2.3). The coastal protection scale here does not represent an absolute very low to high protection benefits; rather it represents the relative CGI protection benefits in the study area. In addition, these indicators assess the existing features of coasts, wave action, and land use, therefore the potential benefits claimed through this index is based on the existing conditions.

As discussed previously, the wave energy is attenuated through the surface roughness of the coasts and drag friction provided by the properties of coastal profile and coastal vegetation. The indicators that address this interaction through CGI properties and therefore used in the coastal protection index are the relief, coastal types, and coastal vegetation. Habitat zone indicator addresses the magnitude of this interaction. While wave indicators such as wave exposure, maximum wave height, and maximum wave fetch reflect the wave energy that is to be attenuated at the coast. Lastly, coastal land use reflects the extent of the development that needs protection.

INDICATORS	**Very low** 1	**Low** 2	**Moderate** 3	**High** 4	**Very high** 5
Relief (m)	0-5	6-10	11-20	21-30	>30
Coastal types	Sand, gravel and mudflats	Human-made	Estuaries, beaches, and dunes	Rocky beaches	Rocky cliffs and platforms
Coastal vegetation	No vegetation	Kelp forests	Sea grasses	Marsh or dune veg.	Mixed vegetation
Habitat zone	Sub-tidal	Lower tide	Inter-tidal	Higher tide	Supra-tidal
Wave exposure	Exposed	Semi-exposed	Semi-protected	Protected	Very-protected
Maximum wave height (m)	> 6.1	5.1 - 6.0	4.1 - 5.0	2.1 - 4.0	< 2.0
Maximum wave fetch (km)	> 200	200 - 150	150 - 100	100 - 50	< 50
Coastal land use	Mostly gray	Mixed green and gray (commercial)	Mixed green and gray (residential)	Mostly green with agriculture	Mostly green

Table 2.3: CGI coastal protection index

The relief indicator in the CGI coastal protection index represents wave attenuation through coastal slope. Coops et al. (1996), Nicholls (2004), Wamsley et al. (2009) and Barbier et al. (2011), highlight the importance of coastal slope as a controlling factor for wave attenuation at coast. High relief increases the wave attenuation; therefore provide more coastal protection benefits. Coastal types attenuate wave energy through providing rough surfaces for the wave to go over (Möller, 2006; Loder et al., 2009; Wamsley et al., 2010; Möller et al., 2014). This indicator shows the dominant coastal types for the study area communities. Coasts with sand, gravel, and mudflats provide less roughness compared to estuaries, beaches, dunes, and rocky platforms; therefore, provide less coastal protection. Surface roughness increases with sloped beaches, rocky beaches, and cliffed coasts. Human-made structures, although provide a degree of protection, often cause more damage due to their vertical alignment, wave over-topping, and parts of the structure becoming loose over time or with wave energy.

Coastal vegetation attenuates waves through drag friction the vegetation stems and leaves provide. Different vegetation types provide different drag friction because of density, length, and other structural differences (Koch et al., 2009; Anderson and Smith, 2014; Möller et al., 2014). Kelp forests are dense, and the vegetation has long stems, yet their interaction with waves are often limited because they are often located deeper than the wave break zones. As discussed in the literature review, seagrasses can effectively provide wave attenuation but their ability is often limited because of their short stems and less dense cover, and the wave height and the water depth ratio discussed previously(Mork, 1996). Salt marshes and dune vegetation provide higher degrees of wave attenuation because they have higher degrees of interaction with the waves (Bradley and Houser, 2009; Manca et al., 2012). The presence of multiple types of vegetation increases the drag friction at the coast and improves wave attenuation (Möller et al., 2014).

Habitat zone refers to the water depth that the dominant CGI is located. The literature suggests decreases in vegetation elevation or increases in depth results in less attenuation (KobayashiI et al., 1993; Nicholls, 2004; Möller, 2006; Loder et al., 2009; Anderson and Smith, 2014; John et al., 2015). CGIs at the inter-tidal and supra-tidal zones are more efficient in dissipating wave energy than CGIs at the sub-tidal zones due to the relationship between vegetation height and water depth.

Wave exposure indicates the frequency and intensity of wave action at the coast. This indicator refers to the tear stress CGI is exposed to. When the wave exposure increases, CGI's coastal protection benefits decrease. The maximum wave height indicator refers to the one-year highest wave height. The literature suggests that CGI is more effective in dampening the energy of small (0-2m) to moderate height waves (2-4m) (Wamsley et al., 2010; Duarte et al., 2013; Möller et al., 2014; John et al., 2015). Therefore increases in wave height lower CGI's coastal protection benefits. The maximum wave fetch indicator refers to the water surface area available for the wind to form waves. High wave fetch indicates higher and stronger waves (Bradley and Houser, 2009; Shepard et al., 2011), therefore reduces CGI's coastal protection benefits.

Lastly, the coastal land use indicates the extent of development at the coast that is at risk and needs protection. More development and infrastructure at coast increases the assets that are exposed to flooding whereas green and agricultural lands reduce the exposure and can further help CGI with attenuating wave energy and absorbing floodwater.

Based on this classification, CGI's coastal protection benefits are expected to be high where the coastal relief is high; the coastline consists of material that provides high roughness, and vegetation that attenuates wave energy; the habitat zone is in the higher sections of the tidal range; wave exposure, wave height and fetch are low; and the land use at the coast consists mostly of green spaces. After the indicators were ranked and applied to the study area communities, the CGI coastal protection benefits index was computed and mapped.

Figure 2.3 shows that the distribution of CGI's coastal protection benefits at present is not homogeneous among the Salish Sea communities. The CGI in British Columbia has higher coastal protection benefits in general than the CGI in the Washington States. CGI in the 59% of the communities in BC and 37% of the communities in WS have medium to high coastal protection benefits. This is partially the result of the more dense and intensive occupation of the coastal areas in the Washington State, which impacts the coastal types and coastal land use indicators. Approximately 17% of the total Washington State coastline is hardened with human-made structures (Gittman et al., 2015), where only about 3% of the British Columbia coastline has human-made structures, reflecting the differences in degree of human intervention in both coastal areas.

Examining Figure 2.3 shows some interesting patterns in the region. For example, CGIs in big urban centers such as Vancouver, Seattle, Victoria, and Tacoma have different coastal protection benefits: very low, medium, low and high, respectively. The results of the coastal protection index show that even in communities with extensive areas of CGIs such as Squamish and Port Townsend, the implications of high wave fetch, height and exposure reduces CGI's coastal protection benefits (Appendix A.1). Similarly, in communities with low wave exposure such as Poulsbo, coastal types undermines the role of the CGI in providing coastal protection benefits.

Coastal protection benefits of CGI is one part of identifying areas with the highest potential coastal protection benefits. As mentioned in the previous sections of this chapter, the vulnerability of CGI to changes in the environment needs to be considered as well.

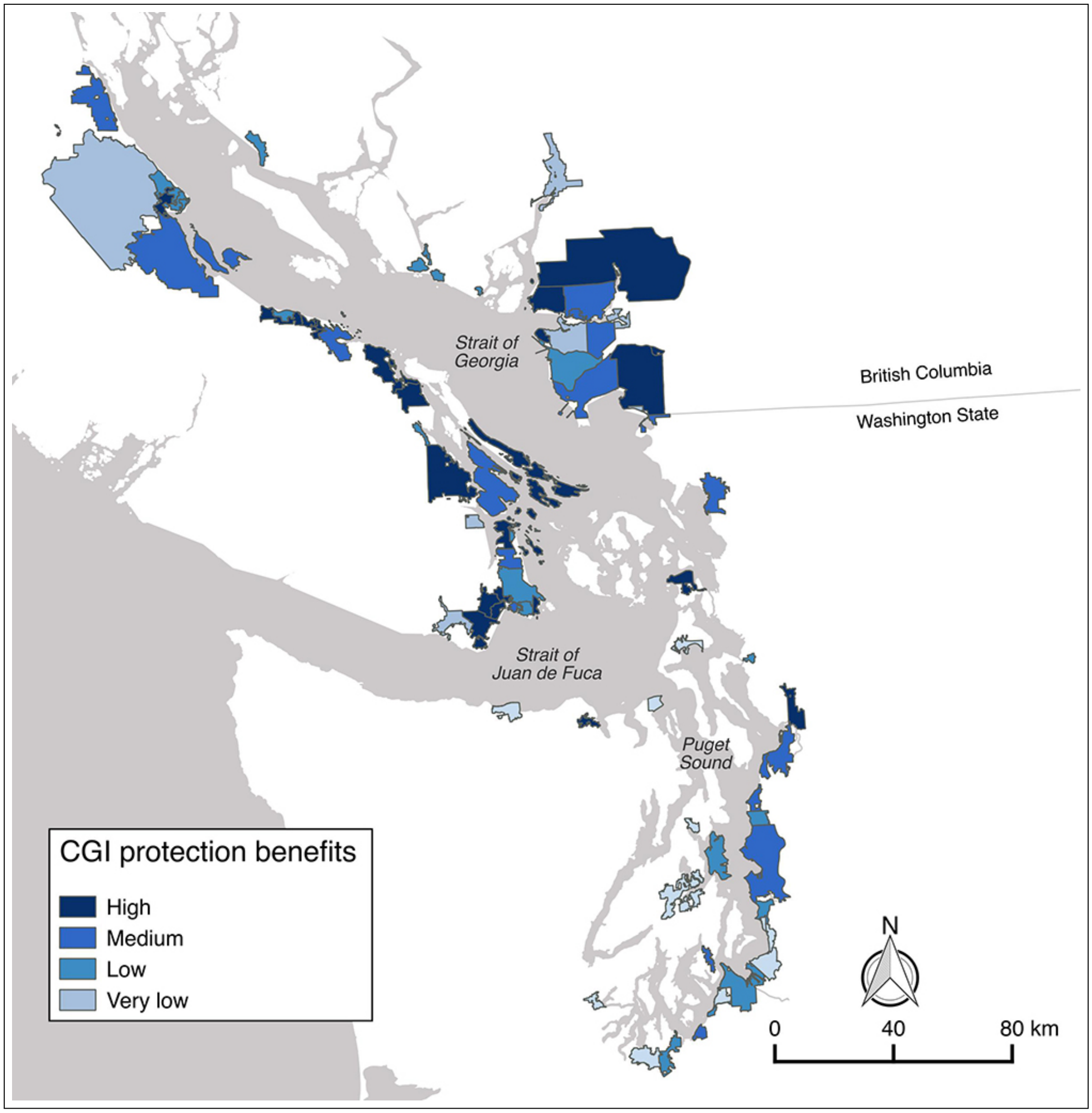

Figure 2.3: Distibution of the CGI coastal protection benefits in the Salish Sea

2.5.2 CGI vulnerability index

Quantitative and qualitative data on seven indicators were used to create the CGI vulnerability index. These indicators are the relief, tidal range, habitat zone, sea level change, erosion change, wave exposure, and coastal land use. Each variable is assigned a rank from 1 to 5. Different from the CGI coastal protection index, here 1 represents very low, which is a positive construct and 5 represent very high existing vulnerability of CGI (Table 2.4). The vulnerability scale also does not represent an absolute very low to high vulnerability; rather it represents the relative CGI vulnerability in the study area.

INDICATORS	**Very low** 1	**Low** 2	**Moderate** 3	**High** 4	**Very high** 5
Relief (m)	>30	21-30	11-20	6-10	0-5
Tidal range	>6.0	4.1-6.0	2.0-4.0	0.5-1.9	<0.50
Habitat zone	Supra-tidal	Higher tide	Inter-tidal	Lower tide	Sub-tidal
Sea level change (cm/100 years)	<-50	-50 to -20	-19 to +20	21 to 40	>40
Erosion change (m/y)	>+0.1	0	-0.1 to -0.5	-0.6 to -1.0	>-1.0
Wave exposure	Very protected	Protected	Semi-protected	Semi-exposed	Exposed
Coastal land use	Mostly green	Mostly green with agriculture	Mixed green and gray (residential)	Mixed green and gray (commercial)	Mostly gray

Table 2.4: CGI Vulnerability Index

It has been discussed in the literature review section that factors such as coastal characteristics, coastal land use, and risks induced by climate change such as sea level rise (Duarte et al., 2013) are associated with CGI vulnerability. The indicators that address the coastal characteristics factors are the relief, tidal range, and habitat zone. Sea level rise, erosion and wave exposure indicators reflect the risks induced by climate change. The coastal land use reflects the intensity of the development at the coast which limits the amount of space CGIs have to migrate upland.

The relief indicator was used in the coastal protection index to reflect the slope and steepness of the coastal areas, which can help to attenuate wave energy. In the vulnerability index, the relief indicator reflects inundation risks throughout coastal slope. Low relief indicates larger areas with low elevation that is under inundation risk, therefore increases the vulnerability. The tidal range indicator shows the zone of the coast that is frequently inundated. It impacts the habitat zone and sediment deposition zone at coasts. The literature suggests that vegetation at the meso and macro-tidal range can accrete and deal with rising sea levels better due to the availability of this sediment deposition zone (Morris et al., 2002; Fitzgerald et al., 2008; Craft et al., 2009). The habitat zone indicator is related to the zone CGIs are in the tidal range. CGIs at the lower tidal zones are more vulnerable to the changing conditions because of the availability of the sediments throughout the tidal range is lower in the lower-tidal zones (Craft et al., 2009; Kirwan and Temmerman, 2009; Davidson-Arnott, 2010).

The sea level change indicator shows the changes in the water levels over the past 100 years. It includes sea level rise and vertical land movement adjustments. The negative values indicate land uplift, thus decrease in the sea levels, where the positive values indicate increases in the sea levels. Many studies discussed in the literature review section suggested that rapid rates of sea level rise will likely to cause CGI drowning (Feagin et al., 2005; Kirwan and Temmerman, 2009; Kirwan et al., 2010; Mariotti and Carr, 2014). The erosion change indicator refers to the stability of coastlines. Accretion is one of the most critical mechanisms CGIs use to deal with environmental stressors such as rising water levels (Feagin et al., 2015). The positive values indicate accretion, therefore low CGI vulnerability where the negative values indicate coastal erosion, thus high vulnerability. The wave exposure indicator in the CGI vulnerability index refers to the frequency and duration of inundation. High wave exposure can result in the loss of CGI due to tear stress, therefore increases vulnerability (Gedan et al., 2010).

The coastal land use indicator in the vulnerability index reflects the human development and activities at the coast that can confine CGI to a small zone, affecting its ability to move and adapt to changing conditions (Feagin et al., 2009). Greener, less developed coastal areas provide more room for CGI to migrate upland, therefore reduce CGI vulnerability. Gray and densely developed coastal areas create a ‘coastal squeeze’ (Osland et al., 2015; Kirwan et al., 2016), therefore increase CGI vulnerability.

Based on this classification, CGI’s vulnerability is expected to be high if the coastal relief and tidal range are low; the habitat is located at the low parts of the tidal range; sea level change over the 100 years is high; the coast is erosional and exposed to high wave action; and land use at the coast is densely occupied with mostly of commercial and residential structures. After the indicators were ranked and applied to the study area communities, the CGI vulnerability index was computed and mapped.

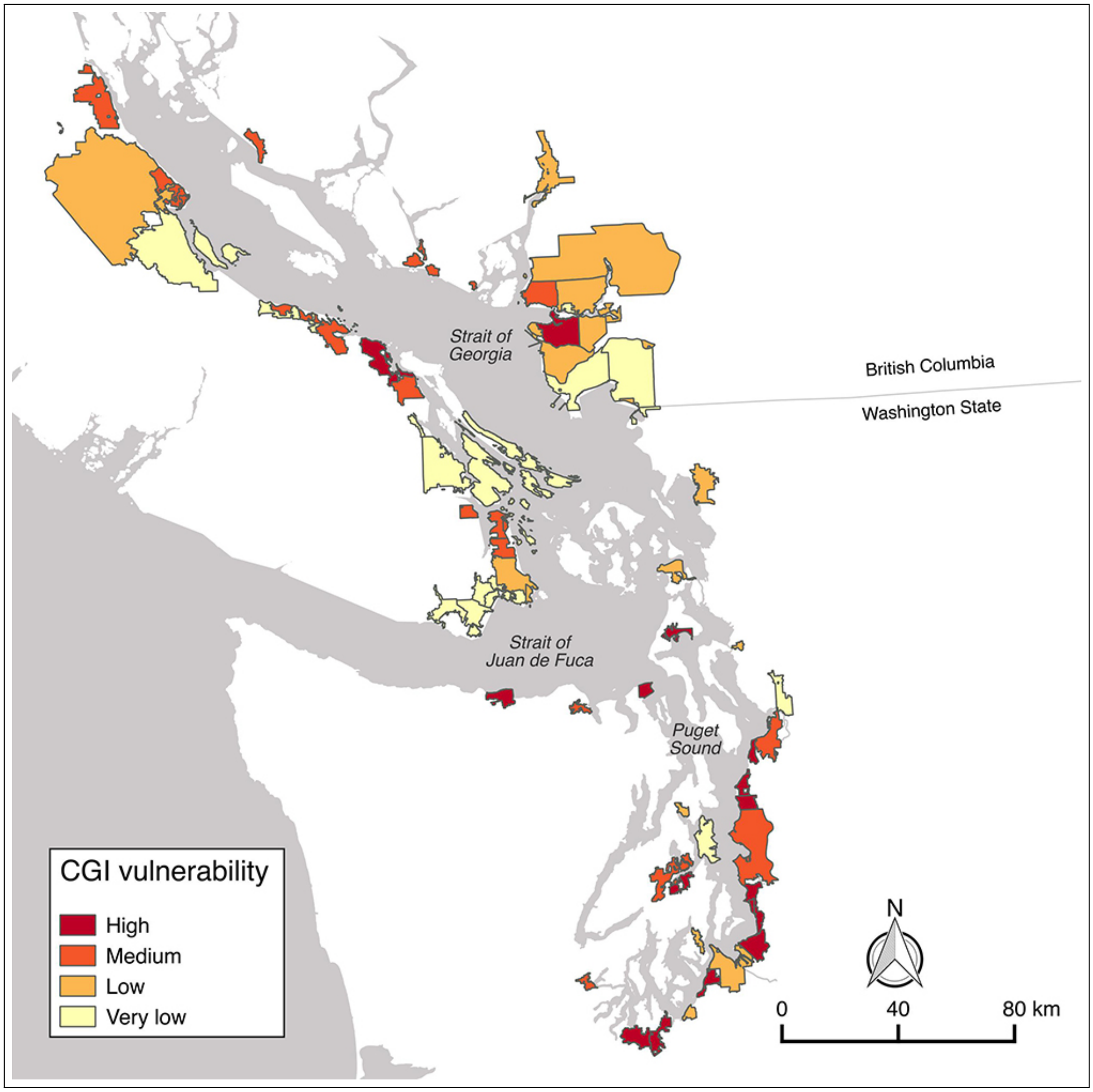

Figure 2.4: Distibution of the CGI vulnerability in the Salish Sea

Figure 2.4 shows that the distribution of CGI vulnerability at present also varies significantly in the Salish Sea. CGI in British Columbia is less vulnerable in general than the CGI in the Washington States. CGI in the 61% of the communities in BC and 33% of the communities in WS have low to very low vulnerability to changing environmental conditions. Relatively lower relief values of Washington State communities have a significant contribution to higher

CGI vulnerability. Besides, higher rates of net sea level rise in the Washington State, which is mainly due to the subsidence of the land, contributes to the CGI vulnerability. Moreover, the most developed and dense coastline of Washington State also increases the vulnerability of CGI.

Examining Figure 2.4 also shows some interesting patterns in the region. Amongst the large urban centers, the CGI in Vancouver and Seattle have a high and medium vulnerability, respectively. CGI vulnerability in Vancouver is due to tidal range, wave exposure, and coastal land use, while in Seattle CGI vulnerability is caused by sea level rise and coastal land use. In other large urban centers such as Victoria and Tacoma, CGI has a low vulnerability (Appendix A.2).

2.5.3 Synthesizing the indices

The results of the CGI coastal protection and vulnerability indices were synthesized to identify CGI's coastal protection potential in the region. A 2x2 matrix (Table 2.2) was used to organize the indices into four categorical groups. These groups were defined and their descriptions are provided as follows.

- "Very low potential": CGI vulnerability is high, and coastal protection benefits are low.

The "very low potential" area can be defined as the worst area for CGI in the study area. CGI may not be the best course of coastal protection and climate change adaptation action for the communities in this area. Rather, hybrid uses of hard structures and CGIs can be explored. Where applicable, adjusting the hard structures in a way to accommodate new CGI production can help to utilize other benefits of CGI other than coastal protection (i.e., adding texture to concrete seawalls can foster vegetation and oyster population). Also, communities in the "very low potential" area can focus on limiting coastal development to non-essential uses.

- "Low potential": CGI vulnerability is low but coastal protection benefits are low as well.

The communities in the "low potential" area have low potential to utilize their CGI in the study area. Therefore, they can explore ways to increase their CGI coastal protection benefits since the CGI vulnerability is low. These communities can focus their efforts on actions such as rehabilitating coastal vegetation or creating new habitats in the riparian areas to increase coastal protection opportunities. Where there are already hard protection structures, the hybrid uses of CGI and adjusting existing structures to allow the creation of new CGI can be explored.

- “Medium potential” : CGI vulnerability is high, but coastal protection benefits are high as well.

The communities in the “medium potential” area have a higher potential to utilize their CGI compared to the very low and low potential areas, but their efforts should focus more on reducing the CGI vulnerability. This could be done by limiting land use and developments and removing barriers at the coast to ensure that CGI has space to move upland and adjust to changes. Also, beach nourishment and other rehabilitation strategies such as replanting vegetation can be used to reduce CGI vulnerability. Site-specific investigations can look into replacing existing hard structures with CGI, where it is not safe or feasible to replace hard structures, hybrid uses of CGIs and hard structures can be explored.

- “High potential”: CGI vulnerability is low, and protection benefits are high.

The “high potential” area can be defined as the best area for CGI in the study area. The communities in the “high potential” area have the greatest potential to utilize their CGI for coastal protection as the CGI vulnerability is low. These communities can focus their efforts into site-specific investigations to outline how and where in their coastlines CGIs can be incorporated in the community’s sea level rise adaptation strategies and flood management practices. The communities in the “high potential” area can undertake habitat enhancement, hard structure removal, and CGI replacement projects. Also, they can hold public workshops to inform waterfront homeowners on how to implement nature-based solutions in their properties.

Figure 2.5 shows that the big population centers in British Columbia, such as Vancouver, Richmond, Victoria, and Saanich fall under “very low potential” and “low potential” areas, suggesting CGI may not be the most appropriate tool for coastal protection in these communities. Hybrid CGI solutions with hard structures can be used to mitigate the environmental impacts of hards structures. Communities surrounding the large urban centers mostly fall under “medium potential” and “high potential” areas in British Columbia, indicating that the British Columbia communities in the Salish Sea region have high potential to utilize CGI for coastal protection. About 59% of the communities in British Columbia are either “medium potential” (18%) or “high potential” (41%) areas. On the other hand, only about 36% of the communities in the Washington States fall under “medium potential” (16%) or “high potential” (20%) areas. Communities in Washington State, particularly in the south of the Puget Sound, have low potential to utilize their CGI. Unlike in Vancouver, the CGI in Seattle falls under “medium potential” area, and communities surrounding Seattle has lower CGI potentials.

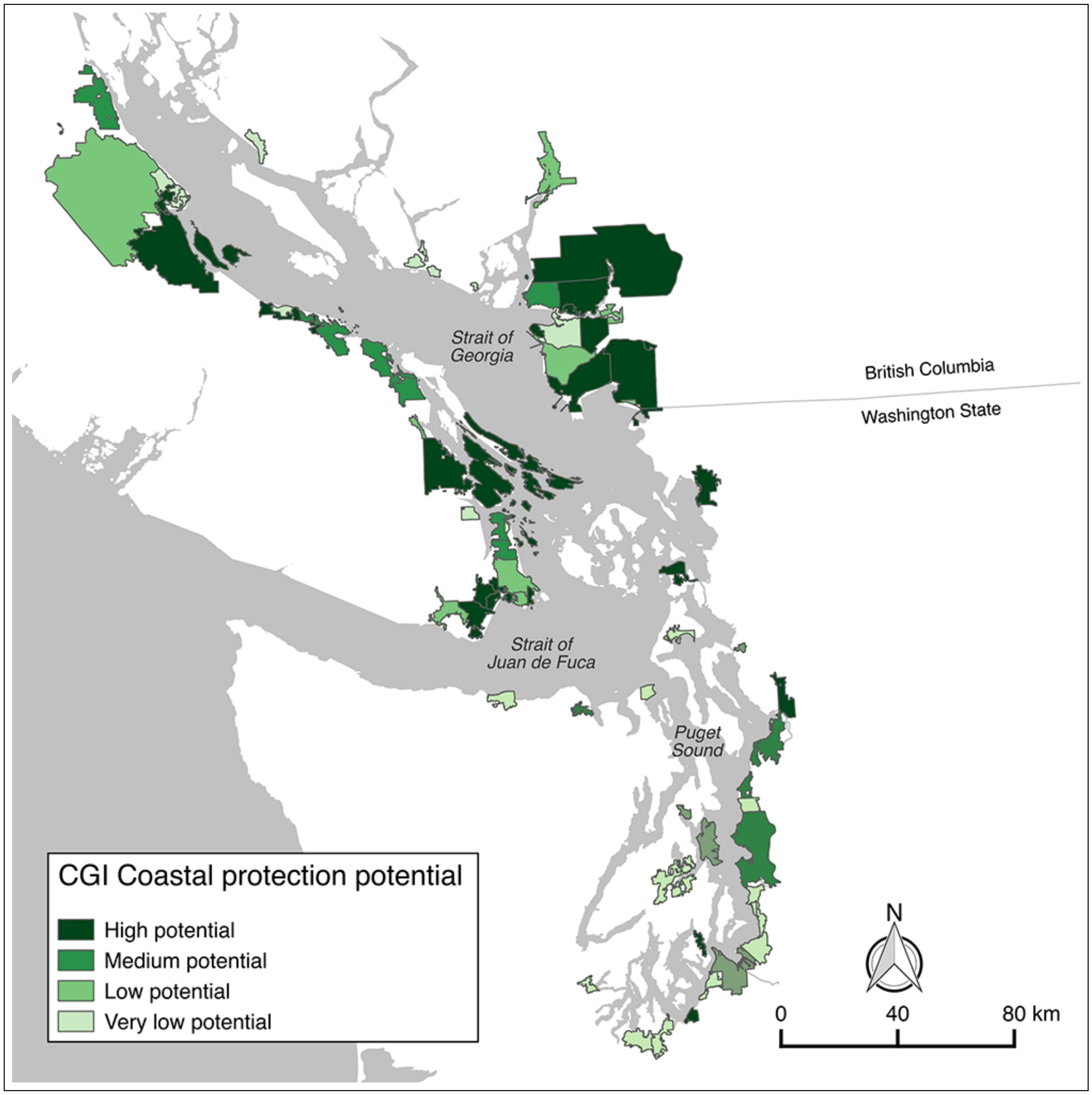

Figure 2.5: Distribution of the CGI coastal protecton potential in the Salish Sea

2.6 Discussion

Hard structures have been the preferred coastal protection method for centuries. Klein et al. (2001) suggests that the more tangible and easy to visualize the nature of hard structures makes them more appealing to decision makers. Yet, hard structures provide a false sense of security as their vertical interaction with waves create wave over-topping, resulting in damage and flooding. The static and maladaptive nature of hard structures contributes to their structural inefficiency for coastal protection. The costs associated with the implementation and maintenance of hard structures create a significant economic burden on communities. In addition, the environmental implications of hard structures on coastal processes, ecosystem health and integrity, and wildlife have been significant. There have been growing concerns over the economic, physical and environmental implications of hard structures.

As an alternative, CGI has been considered as a viable coastal protection method for the last few decades, and a growing number of studies have provided evidence of CGI's coastal protection benefits. Although, it should be noted here that most of these studies were conducted before the use of natural assets as coastal protection methods were called CGI. These studies have paved the way to wide-range consideration of CGIs both in research and practice. Especially after disasters such as Hurricane Katrina and Sandy, there has been a growing interest from governments to invest in nature-based coastal protection methods (Sutton-Grier et al., 2015). However, even though CGI has started to gain popularity as a coastal protection method in the literature, compared to the hard structures the extent of CGI benefits in different environmental conditions has not yet well established. Also, how vulnerability can limit, if not dimish CGI coastal protection benefits has not been studied.

Increasingly, federal, state/provincial and regional government documents on sea level rise adaptation and coastal flood management, in general, have started to include the use of CGI rather than or in addition to traditional hard structures. These high-level guidance documents do not always foster the implementation of CGI because they do not outline where and where not CGI can be potentially useful in providing coastal protection benefits. This study fills this gap by providing a methodological approach and a regional level assessment of CGI coastal protection benefits and vulnerability. This paper uses the 74 most populated coastal communities in the Salish Sea region to demonstrate the methodological framework. The contributions of this study can be summarized in four main points.

First, investigating where CGI can yield high coastal protection benefits while considering its vulnerability is a novel and actionable approach. Traditional CGI studies study specific sites to estimate coastal protection benefits of the CGI at that location. This approach is useful to set an understanding of the rate of wave attenuation or accretion that can be achieved by CGI in that specific environment. Most of these studies often disregard the vulnerability CGI may be experiencing or could experience in future, yet his vulnerability can drastically alter potential coastal protection benefits. Including a vulnerability framework helps to identify CGI that has potential to provide coastal protection benefits but is facing high vulnerability. For example, communities under "medium potential" area are characterized as where the potential CGI coastal protection benefits are high, but vulnerability is high as well. These communities should use caution in determining where to implement CGI, and whether they can provide environmental conditions or interventions that reduce CGI vulnerability. A misplaced CGI for coastal protection purposes can be a costly mistake communities should avoid.

Second, besides the CGI coastal protection potential areas, the indices developed in this study can be used independently and still be useful. The methodology and the indices used in this study can be used to investigate CGI in multiple scales, from individual property level to national level, and in various coastal areas around the world. The indicators of the indices can be customized to reflect specific features of different study areas. For example, mangroves and/or reef systems can be incorporated in the coastal vegetation indicator, if the study area is in the tropical and the lower latitudes of the sub-tropical coastlines. In addition, more indicators can be added to the indices, if data is available. For example, sediment concentration indicator can be included in the vulnerability index, since it has been deemed very important for determining CGI vulnerability but was not included in this study due to missing data.

Third, the results of a regional level CGI assessment can be a valuable contribution for multiple levels of governance in the region. The relative nature of scale used in both indices and the final synthesis of the indices could inform management and operational issues, and resource and funding allocation. These actions can aim to reduce vulnerability and increase coastal protection benefits through projects such as coastal rehabilitation, beach nourishment, and others. This level assessment would also help to prioritize such decisions by highlighting areas with high CGI coastal protection benefits but high vulnerability ("medium potential"), or areas with low CGI vulnerability but low coastal protection benefits ("low potential"). Moreover, a regional level CGI assessment can help protect essential coastal habitat in some places and can help the creation of new ones in others, therefore contributes to the overall regional environmental sustainability. It should be noted that the management and operational recommendations provided in this study are preliminary. More detailed studies would be needed to explore specific prioritization and conservation and rehabilitation actions.

Fourth, this study can help regional knowledge sharing and collaboration amongst communities. The study area consists of two countries and state/provincial governments, making it difficult to implement similar measures. However, communities in similar CGI typologies can nevertheless share knowledge, resources and best practices on their coastal flood management strategies and sea level rise adaptation programs. For example, "very low potential" and "medium potential" communities can learn ways to reduce CGI vulnerability from "low potential" and "high potential" communities. Information sharing on habitat rehabilitation or relocation to change the existing habitat zone, beach nourishment and planting more vegetation to reduce erosion, and land use practices to ensure suitable habitat for CGI can be beneficial for communities seeking to reduce their CGI vulnerability. Besides, neighboring communities with similar CGI typologies can collaborate on projects. Especially for smaller communities with limited resources, knowledge sharing and opportunities for collaboration can provide various economic, social and institutional benefits.

Besides its contributions, the limitations of this research can be summarized as follows. It has been argued that a significant contribution of this research is the consideration of CGI vulnerability while investigating its coastal protection benefits. However, this work does not explain the extent of the vulnerability impact on the protection benefits, nor the magnitude of the impact. The vulnerability of CGI can have distinct manifestations depending on the existing natural and built environment conditions, and the type(s) of CGI present. Therefore, CGI vulnerability can have various implications for the coastal protection benefits of CGI in different locations. Investigation of the extent and magnitude of CGI vulnerability on coastal protection benefits is beyond the scope of this study.

Besides, the data availability and gaps, common issues of indicator-based models, have restricted the indicators used in the creation of the indices. Amongst the 13-parameter themes identified, only eight themes and 11 correspondent indicators were used in this research. Some important themes such as sedimentation or CGI cover were not included in the analysis because of missing or incomplete data. This limitation has direct impacts on the results as the number of indicators and values of indicators are properties of the equation used to compute the indices.

However, it should be noted here that Gornitz et al. (1994) suggested that the formula used in this paper was relatively insensitive to variations and was able to produce usable results when changes occur in the variables.

The benefits of a regional level CGI assessment were discussed above. It is important to note that the high-level nature of regional assessments makes it challenging to capture variations at the local level. While there is consistent evidence in the literature on the positive coastal protection role of CGI, for a given environmental, morphologic and biological condition, CGI may not be the best course of action (Wamsley et al., 2010) for every segment of a community's coastline. The local variations influence CGI's functionality, and the regional scale of this study prevents understanding the local variations in the study area. For example, this study identified low coastal protection potential of CGI in WA; however, a number of governmental and non-governmental initiatives that have been developing small to large scale CGI projects in WA coastlines over the last two decades. The project objectives may be different from the provision of coastal flood and erosion protection, but the disparity between the results of this chapter and the current CGI practices in WA highlights that local variations are significant to understand where CGI projects can be implemented. More detailed studies focusing on coastal segments that can identified through common features (i.e., bare portions of a beach can be a coastal segment, when the vegetation starts, the vegetated portion can be treated as a new segment) are needed in order to assess the localities and highlight where in each communities CGI can yield the highest protection benefits. Lastly, the findings of this study should be considered in the relative context of the Salish Sea study area as they do not reflect an absolute low or high potential areas.

2.7 Conclusion

This study develops a methodology to identify areas where CGI has more significant (or less significant) promise for coastal protection. It does so by incorporating potential coastal protection benefits and vulnerability to changing environmental conditions, using an indicator-based approach. This study provides a methodology that could help regional and local governments in decision-making for flood management and sea level rise adaptation. Moreover, it can facilitate knowledge sharing and collaboration within a region.

The methodological approach presented in this study and the findings of the research highlights the need for further research. A potential area of research includes identifying alternative approaches to indicator-based methods. Lying between policy, practice, and research what other methods can produce outcomes that are easy to understand and implement? In addition, more research is needed to deal with data gaps effectively. Moreover, comparative studies investigating the results of different computation methods can help in understanding both the shortcomings and benefits of the Gornitz's CVI methodology used in this paper. Another research area includes the local level application of the methods and indices of this work. For example, can a similar approach be used in the local scale to identify areas of highest CGI potential in a community's coastline? Advancing the CGI research in various scales and perspectives would be valuable for its implementation for coastal protection.

Chapter 3

Resilience-based evaluation of the local trade-offs between coastal green infrastructure and other sea level rise adaptation strategies

3.1 Introduction

The consequences of sea level rise pose significant threats to coastal communities (Muis et al., 2015). The local impacts of sea level rise, however, vary greatly depending on the characteristics of coastal areas, and the sea level rise adaptation strategies in place (Michener et al., 1997). The adaptation strategies (protect, accommodate, avoid, (managed) retreat, do nothing and offense) aim to reduce or eliminate the impacts of sea level rise and community exposure (Catenacci and Giupponi, 2013). Under the protect strategy, coastal green infrastructure (CGI), the natural and nature-based processes that protect coasts from flooding and erosion (Narayan et al., 2016), have recently started to gain significant attention as an adaptation measure (Ruckelshaus et al., 2016). However, it is recognized that CGI may not always be the most appropriate adaptation option for a community depending on the local characteristics. This is because CGI has different benefits, impacts and resilience contributions at different local contexts (Ruckelshaus et al., 2016). It entails different local trade-offs. The local trade-offs are not unique to CGI or the protect strategy, but are shared amongst all strategies (Catenacci and Giupponi, 2013). Thus far, there is limited research on how CGI and other adaptation strategies fit in the biophysical, environmental, economic, institutional and social environments of communities. The local trade-offs between CGI and other adaptation strategies are typically not considered, and decision-makers are often in the dark when deciding on one course of action over another one.

CGI provides a sustainable, adaptable and multi-functional adaptation to sea level rise. It plays important roles in coastal protection, provision of ecosystem services, and contributing to the overall community resilience and well-being (Naumann et al., 2011; Narayan et al., 2016; Arkema et al., 2017; Sutton-Grier et al., 2018). CGI's effectiveness, benefits, and contribution to local resilience vary significantly with the biophysical, environmental, economic, institutional and social environments of communities (Langridge et al., 2014).

Besides CGI, the effectiveness and benefits of other adaptation strategies also depend on the local characteristics of communities (Catenacci and Giupponi, 2013) because each community faces different levels of risks, and have different capacities to undertake adaptation actions. There are local trade-offs between CGI and other adaptation strategies (Catenacci and Giupponi, 2013; Oddo et al., 2015) and decision-makers need to consider these trade-offs to make informed decisions on adaptation actions. Most of the existing assessment frameworks focus on strategy impacts on one aspect of the local communities such as the cost implications or the environmental impacts (i.e., French 2006; Hino et al. 2017; Schubert et al. 2017; Onuma and Tsuge 2018). There remains a gap in holistically assessing the local biophysical, environmental, economic, institutional and social trade-offs between different strategies.

There is an increasing demand for understanding in which contexts CGI is a meaningful and sustainable sea level rise adaptation measure (Langridge et al., 2014). Consequently, there is a growing need to understand the local trade-offs between CGI and other adaptation strategies (Catenacci and Giupponi, 2013). In addition, there is a gap in the methods and tools that would help decision-makers assess these trade-offs. Facilitating a sustained adaptation needs tools such as frameworks, indices, or scorecards that would help decision-makers understand and evaluate a wide range of impacts of different strategies and prioritize community values (Nelson et al., 2007; Little and Lin, 2017; Garner and Keller, 2018). Therefore, this chapter presents an evaluation framework developed to investigate the local trade-offs between CGI and other sea level rise adaptation strategies, applied in a case study community in British Columbia. It provides a methodological process and an assessment tool to help decision-makers identify 'win-win' solutions and understand how different strategies can interact with coastal processes, natural and built environments, and economic, institutional and social factors.

The chapter is organized as follows: Section 2 provides a background literature review including the role of the resilience perspective in adaptation, sea level rise adaptation strategies and CGI as a sea level rise adaptation measure, and adaptation strategies evaluation methods. Section 3 explains the methodological approach and the corresponding research activities. Section 4 presents the results of this study, following the format of the methods section. Section 5 discusses the research findings, limitations and contributions to the literature, and Section 6 provides concluding remarks.

3.2 Background

This section provides a review of the key concepts and literature that are used to shape the research design, methods, and research activities of this chapter. These concepts and literature are the resilience perspective in adaptation, sea level rise adaptation strategies, CGI as a sea level rise adaptation measure, and adaptation strategies evaluation methods and concepts.

3.2.1 Considering the resilience perspective in adaptation

Adaptation to sea level rise refers to the planning, policy and engineering strategies and measures that are in place to minimize, if not eliminate, the impacts of sea level rise. Adaptation allows communities to identify development trajectories to prepare for the impacts of sea level rise (Glavovic, 2014; Gregg et al., 2015) and to exploit opportunities posed by changing environmental conditions (Glavovic, 2014; Shayegh et al., 2016). The resiliency of coastal communities refers to community capacity to cope with and respond to the adverse impacts of sea level rise (Dolan and Walker, 2006), and to self-organize and learn to preserve natural, economic, social and institutional functions (Klein et al., 2003). The resilience perspective refers to the shift in approaches from a static response to a disturbance, to dynamic management of the system as a whole before, during and after a disturbance (Folke, 2006). Using the resilience perspective as an objective of adaptation makes communities more robust in dealing with the implications of sea level rise (Gersonius et al., 2016).

As an objective for adaptation, the resilience perspective addresses the dynamism and complexity of coastal areas. Despite significant scientific advancements, there is still considerable uncertainty in the sea level rise projections (Little and Lin, 2017). Coupled with complex coastal processes such as tides, waves, currents, storm surges, and sedimentation, predicting the exact implications of sea level rise, and adaptation to it are challenging (Cazenave et al., 2014;

Shayegh et al., 2016). Sea level rise adaptation, therefore, has to account for uncertainty and be adaptable to change (Glavovic and Smith, 2014). Besides its impacts on built and natural environments, other factors are also affected when sea levels are rising, such as land use, environmental integrity, local economy, and evacuation and emergency responses (Gersonius et al., 2016). Therefore, sea level rise adaptation has to address diverse factors and be integrated. The resilience perspective brings multi-functionality to sea level rise adaptation. Strategies and measures used for adaptation are diverse and have different motivations (Cooper, 2016). They can provide various additional environmental, economic, institutional and social benefits (Cooper and Pile, 2014; Wamsler et al., 2016). Therefore, sea level rise adaptation has to consider the co-benefits of strategies and measures. Lastly, the resilience perspective adds a learning domain to the adaptation (Wardekker et al., 2010; Cinner et al., 2018). The field and practice of adaptation are growing, and new knowledge is being created rapidly. Communities around the world are implementing various adaptation actions and monitoring their effectiveness while dealing with rapid change and uncertainty. Communities' ability to learn from each others' experiences and to absorb new knowledge on climate change and adaptation are critical for improving resilience (The William D. Ruckelshaus Center, 2017; Cinner et al., 2018). Thus, a continuous effort for learning has to be a part of sea level rise adaptation.

3.2.2 Sea level rise adaptation strategies

There are no one-size-fits-all approaches available for adaptation (Eisenack et al., 2014). Nonetheless, actions for sea level rise adaptation are commonly grouped under several diverse strategies reflecting various motivations (Cooper, 2016). The British Columbia Sea Level Rise Adaptation Primer (2013) identifies protect, accommodate, avoid, retreat, do nothing and offense as main adaptation strategies and defines them as follows. The *protect* strategy uses the THSs or CGI to protect people, assets, and infrastructure from sea level rise. The *accommodate* strategy implements adjustments in the existing infrastructure and retrofits structures to adapt to changes. The *avoid* strategy prevents new development from flood-prone areas. The *retreat* strategy phases the withdraw from flood-prone areas and relocates private or public assets in low-risk areas. The *do nothing* strategy understands the risks but does not propose subsequent adjustments in community responses. The *offense strategy* reclaims land from the sea for development purposes.

To date, the protect, accommodate, do nothing and offense strategies have been the most common choices for coastal communities, as they sustain the economic and social activities that coastal communities rely on. The avoid and retreat strategies, however, have been discussed more recently as the sea level rise projections show that the continued occupation of coastal areas is no longer a viable or safe option for some coastal communities. However, the implementation of these strategies has been slow due to the economic, social and institutional difficulties associated with limiting the development and relocation of communities (Hino et al., 2017).

The adaptation strategies entail different trade-offs. For example, the protect and accommodate strategies can prevent flooding damages to buildings and infrastructure, but their economic implications may be very high for property owners and local governments, or they may cause significant damages to the natural environment. Similarly, the retreat strategy can provide long-term solutions for flood-prone coastal areas, but the social and economic implications for communities may be devastating. However, these trade-offs are not well understood yet.

Coastal green infrastructure (CGI) as a sea level rise adaptation measure

CGI, also known in the literature as 'nature-based solutions', 'soft protection measures', and 'green or soft shores', is now widely considered as a viable and sustainable sea level rise adaptation measure of the *protect* strategy. CGI has started to gain attention due to the recognition of the Traditional Hard Structures' (THSs)[1] degrading impacts on coastal processes, built and natural environment and lack of long-term social and economic benefits (Wild et al., 2017).

Different from the other green infrastructure practices, such as urban green infrastructure (i.e., stormwater management) and water-shed based green infrastructure (i.e. networks of green spaces and forests), CGI refers to the natural and nature-based systems and processes that mimic dynamic coastal landforms (i.e., dunes, barrier islands, and beaches), coastal and riparian vegetation (i.e., salt marshes, eelgrasses, kelp and mangroves), and reef systems (i.e., mussel and oyster beds) at coasts (The Horinko Group, 2015).

As an adaptation measure, CGI contributes to the community resilience by providing multiple essential ecosystem services to humans and nature, such as increasing recreational and educational opportunities; reducing implementation and maintenance cost of adaptation; improving built environment aesthetics; providing raw materials and food for humans and animals; habitat for primary and secondary production; filtering and storage of water; reducing nitrogen input

[1]Here, the term "traditional" refers to conventional coastal engineering practices such as dikes, seawalls, and other types of engineered structures

to estuaries and aquifers; and sequestring carbon (Barbier et al., 2011; Lafortezza et al., 2018). Moreover, CGI plays a critical role in coastal flooding and erosion protection through the wave and floodwater attenuation, accretion, binding soil particles, and the mitigation of debris movement (Hettiarachchi et al., 2013; Spalding et al., 2014; Chenoweth et al., 2018). Models and field research investigating CGI suggest that approximately 33% to 80% erosion reduction can be obtained through appropriate implementation of CGI (Feagin et al., 2009; Kirwan and Temmerman, 2009; Kirwan et al., 2010). Similarly, 7% to 96% wave attenuation can be achieved, depending on the site-specific conditions (Barbier et al., 2013; Wu and Cox, 2015).

Despite its benefits, it is recognized that some coastal areas may not offer the appropriate biophysical conditions (Narayan et al., 2016), or the built environment may not be suitable for CGI (Ruckelshaus et al., 2016). Similarly, the social and institutional context may not provide the best environment for sustained and successful implementation of CGI. The local contexts in which CGI is considered, including the coastal processes, natural and built environment conditions, and socio-economic and institutional factors are recognized to be the key determinants of CGI's value as a resilient adaptation measure (Narayan et al., 2016; Ruckelshaus et al., 2016).

3.2.3 Adaptation strategies evaluation methods and concepts

Most communities have limited guidance in their decision-making processes to choose adaptation strategies, and little is known about how communities make these decisions (Brody et al., 2010). Most of the existing assessment tools focus on the cost-effectiveness of different adaptation measures, such as traditional hard structures and coastal green infrastructure (Naumann et al., 2011; Byrne et al., 2015; Narayan et al., 2016; Wild et al., 2017; Schubert et al., 2017; Onuma and Tsuge, 2018), or different strategies, such as the cost of managed retreat (French, 2006; Hino et al., 2017). The lack of structured ways of assessing the local trade-offs between different strategies may influence the ability of local governments to undertake adaptation processes (Bronen, 2015), but also to choose strategies that increase community resilience to sea level rise.

Although limited, there has been a recent acceleration of studies attempting to (1) develop methodologies that evaluate adaptation strategies, and (2) identify concepts that need to be captured in the evaluation. However, there is hardly any consensus on the methods as well as the resilience and adaptation concepts that are appropriate or sufficient for evaluation of adaptation strategies (Cutter, 2016). For example, Little and Lin (2017) developed a decision support framework that targets three elements of adaptation: objectives that highlight the need for management decisions, an array of adaptation options, and system characteristics. Cutter (2016) identified economic, social, institutional, information/communication, infrastructure and environmental attributes as the components of resilience. Gersonius et al. (2016) developed an analytical framework and used a scorecard to assess effectiveness, side-effects, cost-efficiency, and institutional feasibility of adaptation strategies. Azevedo de Almeida and Mostafavi (2016) used the coastal protection, transportation, water, wastewater, and energy infrastructures factors to evaluate impacts on sea level rise and adaptation strategies. CAP and ICLEI (2015) developed an extensive list of forty indicators covering four sectors: coastal management, flood management, infrastructure, and health. Lockwood et al. (2015) used social capital, human, financial, and physical capital, management approaches, and governance components to measure adaptation. Catenacci and Giupponi (2013) developed a flexible framework that includes climatic, physical, ecological and socio-economic components to help decision-makers in their adaptation strategy assessment processes. Lastly, Plummer and Armitage (2007) proposed an analytical framework to evaluate adaptation through three components: ecological, livelihoods, and process and institutional conditions. Even though these studies have developed various frameworks, there remains a need for an evaluation framework that includes a comprehensive list of resilience and adaptation concepts, and allows for comparison of different adaptation strategies.

Drawing from these recent studies, this research provides an alternative framework for assessing sea level rise adaptation strategies to identify local trade-offs. This evaluation framework consists of the following concepts: coastal processes, natural and built environment, and economic, institutional and social factors.

3.3 Methods

The objective of this study is to evaluate the local trade-offs between CGI and other adaptation strategies. It aims to understand how CGI and other adaptation strategies interact with the local characteristics of communities. To be able to achieve this objective, a coastal community in British Columbia was selected to conceptually illustrate the methods of this study. Even though this community was chosen for illustrative purposes and represented a conceptual coastal area, real elevation, land use, and water levels data were kindly provided by the study area community.

This study uses a mix of research methods, incorporating local perspectives and expertise when possible. This is because adaptation to sea level rise concerns a wide array of sectors, expertise, levels of governments, organizations, and local businesses and residents. Therefore, most of the reported successful adaptation approaches have been achieved through engagement with local experts and stakeholders (Picketts et al., 2012), and understanding local characteristics of communities (Barron et al., 2012). Studies at the local level engaging with local experts and stakeholders can improve the understanding of the context-specific social, environmental and economic conditions; increase local knowledge on climate change impacts and adaptation options; and enable transparency and local participation in the decision-making processes (Zhang et al., 2008; Picketts et al., 2012; Manuel et al., 2016).

This study operationalizes three research activities to achieve its objective. The three research activities, labeled as Step 1, 2 and 3, are illustrated in Figure 3.1.

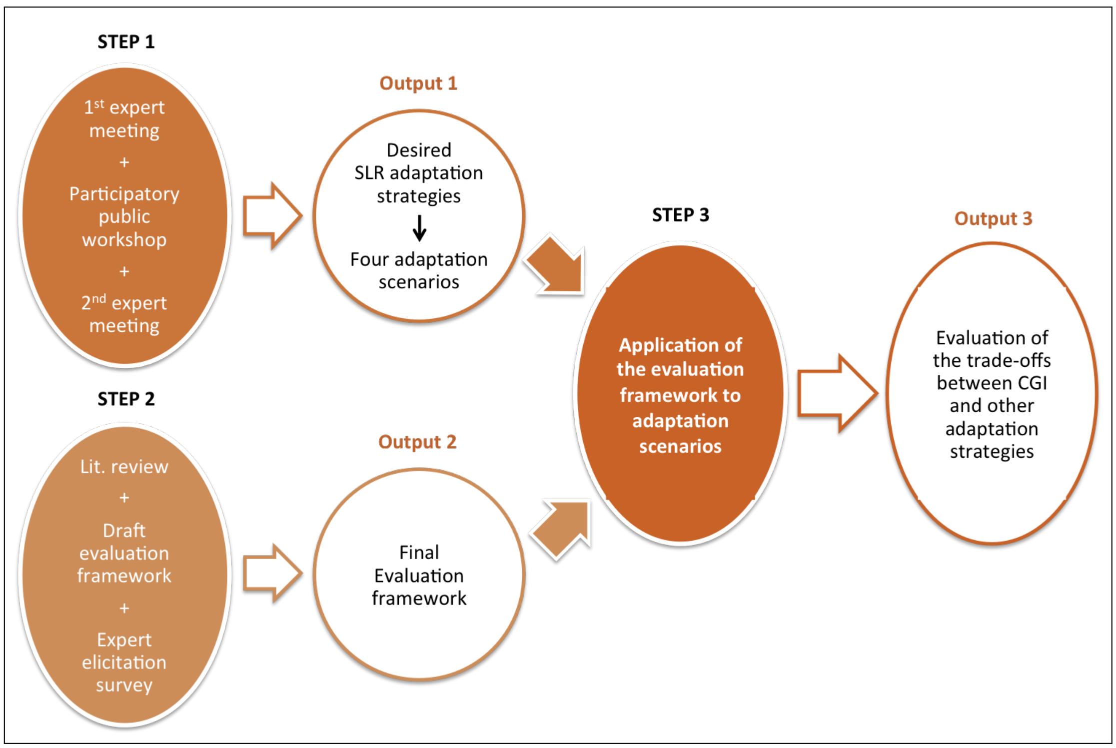

Figure 3.1: Methods diagram showing the research steps and outputs.

In the first step, the research objectives were to identify the sea level rise adaptation strategies that are preferred by the study area community and to develop corresponding adaptation scenarios. The participatory methods and public outreach activities such as meetings and participatory workshops are recognized as essential parts of the adaptation planning (Flynn et al., 2018). For this reason, a set of two expert meetings and a participatory workshop were organized with the public and experts in the study area over a period of 15 months. These meetings enabled the review of the local data on sea level rise, tidal range, storm surge and associated wave effects, and identification of the community preferences on sea level rise adaptation strategies. The inputs and feedbacks from these meetings are used to develop adaptation scenarios. Scenarios provide structured ways to describe narratives of future conditions based on designated adaptation strategies (Barron et al., 2012). They provide storylines that cover social, economic and institutional implications of adaptation actions and decisions. Therefore, four sea level rise adaptation scenarios were developed for the selected strategies.

In the second step, the research objective was to develop an evaluation framework to assess the trade-offs between sea level rise adaptation strategies. Assessment tools such as frameworks, indices, or scorecards help the evaluation of a wide range of impacts of adaptation decisions (Nelson et al., 2007; Little and Lin, 2017; Garner and Keller, 2018). Therefore, an extensive review of the academic and grey literature was conducted to outline concepts that are considered in the other evaluation frameworks but also to identify new concepts that are relevant to coastal community resilience and adaptation to sea level rise. Based on the findings of these reviews, a draft evaluation framework was developed. An expert elicitation survey was conducted to gather feedback on the draft evaluation framework from the experts in the field. At the end of the second step, the expert feedback was incorporated, and the final version of the evaluation framework was completed.

In the third step, the research objective was to apply the evaluation framework developed in the second step to the sea level rise adaptation scenarios developed in the first step. The results were calculated and illustrated to assess the trade-offs between CGI and other adaptation strategies.

3.3.1 The study area

The study area is located on the west coast of the District of North Saanich, a coastal community in the province of British Columbia (Figure 3.2). This area was selected to implement the research methods and conceptually illustrate the scenario models. The study area is on a small bay and is primarily single-family residential. Some other land uses include marinas, a school, and green spaces. It has a low-lying coast that is mostly protected from wave events, yet it has been experiencing occasional coastal flooding during the king tide and heavy storm events.

Municipal experts in the District of North Saanich participated in the expert meetings and participatory workshop. They also generously shared their expertise, data (i.e., the Geographic Information Systems (GIS) layers and maps), and the local Flood Construction Levels (FCL) study. The District of North Saanich did not participate in the application of the evaluation framework to the four adaptation scenarios developed for the study area. Please see the disclaimers at the end of this chapter.

Figure 3.2: The location of the study area.

3.3.2 Step 1 - The expert meetings and participatory workshop

The research objectives of this step were to identify the sea level rise adaptation strategies that are preferred by the study area community and to develop corresponding scenarios. Over a period of 15 months (from June 2016 to September 2017), an expert meeting, a participatory workshop, and another expert meeting were organized to achieve the research objectives.

The first expert meeting

The first expert meeting was organized to prepare for the participatory workshop. 18 experts from the regional district, the provincial government, and environmental organizations; coastal engineer; municipal staff (planners, engineer, and emergency manager); and local politicians attended the meeting.

The primary objectives of the first expert meeting were to come to a consensus on the designated flood level (DFL) elevation for the study area and to identify relevant stakeholders for the participatory workshop. The DFL elevation refers to the still water levels, which include the sea level rise allowance, maximum high tide, and the estimation for 1 in 500-year storm surge levels. It does not include the wave effects (SNC LAVALIN, 2016) and the associated wave effects zone at the coast. For the first objective, participants were presented with the provincial and regional relative sea level rise projections, local tidal range, 1 in 500 storm surge levels, and the wave effects estimates. They were asked to review the information and answer the questions listed in Appendix B.1. For the second objective, the participants were asked to join the open discussion on identifying the relevant stakeholders in the region and the workshop format.

The participatory workshop

The participatory workshop aimed to understand community knowledge on climate change impacts and preferences on sea level rise adaptation strategies. The information about the workshop was posted on the community's official website, and invitations were sent to two main resident groups approximately 45 days prior to the workshop date. 38 people from the residents, community groups, businesses owners, municipal staff, and politicians; provincial and regional governments, transportation authorities, a coastal engineer, and environmental law and NGOs attended the workshop.

The participants were asked to fill out a pre-workshop survey (Appendix B.2) before the event began, and the materials were presented. The survey included questions on personal information (such as age and education), knowledge on climate change impacts, perceived hazard risks, and perceptions of the effectiveness of different adaptation strategies and measures. Then, information on the processes affecting sea level rise, and the local sea level rise projections were presented. The impacts of sea level rise on water levels in the study area were presented using data from the Flood Construction Levels study (SNC LAVALIN, 2016). These impacts were presented using conceptual visuals. The main adaptation strategies recommended by the provincial government and the regional district were presented.

After the presentation, workshop participants were asked to form groups to discuss their preferences on the adaptation strategies and tools they preferred to see implemented in the study area. The participants were provided with color-coded moveable cards and maps to discuss different adaptation strategies and tools, and their potential implications beyond coastal flooding. A post-workshop survey was administered at the end of the meeting (Appendix B.3). This survey included questions aiming to measure changes in the knowledge, perception, and preferences.

The second expert meeting

The second expert meeting was organized after the participatory workshop. Nine experts from the regional district and the provincial government; a coastal engineer consulting firm; and local municipality (planners and engineers) attended the meeting. The objective of the meeting was to review the wave effects zone estimates and the sea level rise adaptation scenarios developed based on the strategies selected at the participatory workshop.

The wave effects zone in this study refers to the conceptual illustration of the inland expansion of wave action (wave overtopping) at the coast. The wave effects zone depends on the interactions of the waves with the human-made and natural features at the coast. Conceptual methods that can be used to represent the wave estimate zones were discussed in the meeting. Participants agreed on a method that would be appropriate to use for the purposes of this study.

The participants were also presented with the visual illustrations of the scenarios that showed the physical attributes of the community, such as roads, structures, land use, and the DFL elevation that was agreed in the first expert meeting. The visual illustrations of the scenarios aimed to conceptually communicate the potential physical implications of strategies such as the highest water levels, high flooding risk areas, and changes in built and natural environment. To visually illustrate the scenarios, the local elevation data was converted from GIS to a 3D Sketch Up model. Structures, roads, and other infrastructure in the study area were conceptually placed on the 3D models using google maps and site visit images. Characteristics of each strategy were incorporated in the 3D models. For example, if the strategy includes the use of the THS measures, then a seawall was added to the edge of the property lines. Next, the DFL was added to the 3D models. Lastly, the wave effects zones were added to the corresponding models. Participants were asked to discuss the iterations of the strategies into scenarios and the associated wave effects zones for each scenario. These discussions were used to improve the scenarios and their visual illustrations.

3.3.3 Step 2 - Sea level rise adaptation strategies evaluation framework

The research objective of this step was to develop an evaluation framework that can be used to assess the local trade-offs of sea level rise adaptation strategies. To achieve this objective, a literature review was conducted to develop a draft evaluation framework, an expert elicitation survey was administered to get feedback on the draft evaluation framework, and lastly, the expert feedback was incorporated to complete the final evaluation framework.

Literature review and the draft evaluation framework
An extensive review of the published academic and grey literature was conducted to develop the draft evaluation framework. This review focused on the attributes of resilience, community resilience to sea level rise, and sea level rise adaptation. The literature review highlighted specific concepts that were commonly considered in the studies and identified new ones. The concepts drawn from the literature were developed into components of the evaluation framework.

The draft evaluation framework included 35 components. Criteria for each of the thirty-five components were developed based on the literature review and organized to provide a three-point scoring system. These components were then grouped into six modules. These modules are coastal processes, natural environment, built environment, economic factors, institutional factors, and social factors.

A three-point scoring system, from +1 to -1, is used in the evaluation framework to provide a straightforward structure. The -1 score indicates a negative impact, and the +1 score indicates a positive impact on resilience, while the 0 score indicates minimal to no impact, compared to baseline conditions. An N/A option is provided to be used when the criteria are not applicable to an area or the strategy. For example, if an area does not have any commercial or industrial structures, the impacts of a strategy on these structures cannot be scored; therefore the N/A option should be selected.

Expert elicitation survey

An expert elicitation survey was designed using the draft evaluation framework to gather feedback on the draft evaluation framework's modules, components and criteria used for scoring. In addition, the expert elicitation survey sought guidance on the weighting system of the framework.

The survey was sent to the experts from the provincial government, regional government and organizations, and local governments. The participants were asked to mark their agreement with the framework's modules, components and criteria, and to provide comments and suggestions. Three experts who are involved in the climate change adaptation field in the region, two from the provincial government and one from a regional organization, participated in the survey.

Final evaluation framework

The experts provided detailed and comprehensive feedback on the evaluation framework modules, components, the criteria of the components, the scoring system and the weighting of the modules and components.

The experts agreed with the framework modules and the criteria used to assess each component and recommended minor changes to some of the components. These changes were recommended to improve the comprehensibility of the evaluation framework and to ensure the three-point score can be applied meaningfully. The expert elicitation survey feedback was reviewed and incorporated into the final evaluation framework.

The feedback from the expert elicitation survey was incorporated to modify the framework contents and to develop a weighting system. Based on the recommendations, two new components were added, five components were removed, and four components were merged into two. In the end, the final framework contained 30 components. The summary of the changes made after the expert feedback are listed in Table 3.1. Since the recommended changes were minor, only the final evaluation framework is presented in the results section and in Appendix B.4.

Module	Component	Changes
Built Environment	Specific land use loss due to strategy implementation	Added
Built Environment	Private property/land loss due to strategy implementation	Removed
Built Environment	Flooding risks on public areas at the coast	Removed
Economic Factors	Economic benefits to communities Economic benefits to local governments	Merged
Economic	Lifetime of strategy	Removed
Institutional Factors	Municipal authority	Added
Institutional Factors	Usability with and support to other documents	Removed
Social Factors	Opportunities for public education Opportunities for community involvement	Merged
Social factors	Benefits to vulnerable populations	Removed

Table 3.1: Summary of changes in the evaluation framework components.

Using the expert feedback, a two-step weighting system was developed, giving the users flexibility to prioritize their objectives, while limiting exclusion of any modules or components. In the first step, users need to allocate 60 points to six modules. The minimum point that can be allocated to a module is set at six, and the maximum is set at 30 so that no module receives more than 50% and less than 10% of the points. If one module is allocated 30 points, then the other modules have to be allocated six points, so that the sum of all the module weighting is 60 points. Users cannot give 0 or 60 to any module. If all the modules are weighted equally, then each module would be allocated 10 points. In the second step, users need to allocate 25 points to five components within each module. The minimum point that can be allocated to a component is set at 2.5, and the maximum is set at 12.5 so that no component receives more than 50% and less than 10% of the points. If one component is allocated 12.5 points, then the other components have to be allocated 2.5 points. Users cannot give 0 or 25 to any component. If all the components are weighted equally, then each component would be allocated 2.5 points. The calculation of the framework can be found in Appendix B.5.

3.3.4 Step 3 - Application of the evaluation framework to sea level rise adaptation strategies

In this last step, the final evaluation framework was applied to the sea level rise adaptation scenarios that are developed using the community inputs and expert feedback. This step of the research consisted of two main activities.

First, the final evaluation framework was applied to the four adaptation scenarios. The 3D models, GIS land use maps, document reviews (such as the Official Community Plans (OCPs)), and the researcher's knowledge of the study area were used to complete the evaluation framework. Second, the results of the application were calculated and illustrated to assess the benefits and disadvantages and to highlight the trade-offs of the different adaptation strategies.

3.4 Results

3.4.1 The expert meetings and participatory workshop

3.4.1.1 The first expert meeting

The first expert meeting was organized to identify the DFL elevation of the study area and the list of community groups, stakeholders, and First Nations communities to be invited to the workshop. The expert meeting participants decided the DFL by reviewing and discussing the existing information on the baseline data. The participants came to a consensus that the DFL should include a 1m relative sea level rise allowance. They also suggested that a 1.5 m highest high tide level and a 1.3 m storm surge estimate, which are both based on the local buoy measurements, should be included in the DFL. Based on these recommendations, the DFL consisted of the following:

DFL = Sea level rise (1 m) + Highest high tide level (1.5 m) + Storm surge (1.3 m) = 3.8 m

The discussion on the upcoming workshop provided a detailed list of community groups, stakeholders, and First Nations communities to be invited to the workshop. This list included the adjacent municipalities and First Nations municipal councils; the regional district and provincial government; local school districts; transportation authorities (i.e., ferries, highways, and airports); local NGOs and other organizations; environmental and engineering consultants; and local businesses, residents, and residents associations.

3.4.1.2 The participatory workshop

The participatory workshop was organized to understand community knowledge on climate change impacts and preferences on adaptation strategies. Most of the workshop participants, 65%, were homeowners, where 41% of the participants owned waterfront properties. Participants indicated that the general concerns over sea level rise impacts and being prepared for those impacts were the main reasons they attended the workshop. The consequences of sea level rise adaptation on the rights of waterfront property owners was another important reason they attended the meeting.

A pre-workshop survey (Appendix B.2) was administered at the beginning of the workshop. A total of 29 people completed the survey. The results are as follows:

- 34% of the participants have observed increases in the storm intensity over time, where 27% observed increases in the storm frequency and 25% in the wave heights.
- 85% of the participants perceived 0-40% chance of extreme coastal flooding events over the next fifteen years (due to the combination of sea level rise, high tides, and heavy storms) in their community. The risk perception increased for the next fifty years. 61% of the participants perceived more than 60% change of extreme coastal flooding events.
- 41% of the participants thought the potential impacts of climate change would be significant on sea levels, storm/wave effects, real estate values, and damage to private property.
- 44% of the participants indicated that they consider THS (sea walls & dikes), and 41% CGI (coastal vegetation) as effective coastal erosion and flooding protection measures.
- 76% of the participants rated *avoid* as an effective sea level rise adaptation strategy while 55% rated *retreat*, and 45% rated *protect* and *accommodate* strategies.
- 78% of the participants thought the community participation in the sea level rise adaptation planning is very important.

A post-workshop survey (Appendix B.3) was administered at the end of the workshop. A total of 25 people completed the survey. The results are as follows:

- 60% of the participants reported increased knowledge on climate change and its implications in the local context.
- Particularly, their knowledge on sea level rise and associated storm and wave impacts, potential damages to private property and infrastructure, and implications on local real estate values increased the most.
- 52% of the participants thought sea walls and dikes are effective measures to protect coastal areas, while 58% groins, 45% revetments and soft structures, and 50% thought coastal vegetation are effective coastal protection measures, but when asked which measures they want to see implemented in the study area, the results were very close.
- The *accommodate* (52%) and *protect* (47%) strategies were the most favored for the study area, even though the *avoid* and *retreat* strategies were rated the most effective strategies in the pre-workshop survey. The *retreat* and *avoid* strategies were much less preferred, rated 35% and 30%, respectively.
- There was about 4% increase in the participants' views (up to about 82%) on the importance of the community participation to adaptation planning and policies.
- Participants stated that the workshop provided an environment for people to make new connections, and an inclusive and transparent place for raising their concerns and discussing adaptation options with other stakeholders and municipal staff.

The workshop brought together a wide diversity of participants. It appeared to increase participants' knowledge on climate change implications, and their views on the importance of the community participation to adaptation processes. The workshop also showed that the participants favored the *accommodate* and *protect* strategies, even though they initially selected the *avoid* and *retreat* strategies as most effective options. The workshop also enabled an open and transparent environment for conversation of sea level rise concerns, options, and preferences.

Based on the results of the workshop, the *protect*, *accommodate*, and a joint *retreat & avoid* strategies were the selected for the scenario development. The *protect* strategy included two separate options; one included a THS protection measure, and the other included a CGI measure.

Lastly, a *do nothing* strategy was also added to illustrate the baseline conditions and to compare the scenarios. As a result, a total of four sea level rise adaptation strategies, and a baseline strategy were selected for the scenario development.

3.4.1.3 The second expert meeting

The second expert meeting was organized to review the wave effects zone estimates and the sea level rise adaptation scenarios developed based on the selected strategies.

The wave effects zone estimates
As described in the methods section, the wave effects zone in this study conceptually reflects the inland expansion of wave action at the coast. The estimation of the wave effects zone is very complex and requires engineering expertise to assess but moreover, it is beyond the objectives of this study. Therefore, the participants, which included municipal engineers and an external coastal engineer, agreed that the following simple method would be appropriate for purposes of this research.

Wave effects zone = Wave effects x Wave effects factor (f)

The participants agreed that a 0.9 m wave effects should be included in the wave effects zone estimates in each scenario. This wave effects value was suggested in the local flood construction levels report for this study area. The wave effects factors were discussed separately for each of scenario, as they illustrate a different type of intervention at the coast. Based on these discussions, the wave effects zone for each strategy were estimated as described in Table 3.2.

Strategies	Wave effects	Wave effects factor	Wave effects zone
Do nothing	0.9 m	3	2.7 m
Protection with THS	0.9 m	10	9 m
Protection with CGI	0.9 m	n/a	0.9 m
Accommodate	0.9 m	3	2.7 m
Avoid & Retreat	0.9 m	3	2.7 m

Table 3.2: Wave effects zone estimates for the selected strategies.

For the protect strategy, two different wave effects factors were used. For the traditional hard structure (THS) protection measure f=10 was decided, due to the increases in the wave action on the vertically hardened shorelines. For the coastal green infrastructure (CGI) protection measure, the participants decided that there wouldn't be a wave effects factor, because the wave energy would not be amplified by the coastal green infrastructure. For the do nothing and accommodate strategies f=3 was decided, due to the existing partially hardened shoreline. Similarly, for the avoid & retreat strategy f=3 was decided because no further action was proposed at the shoreline. In addition to the expert meeting participants, an independent water resources engineer also confirmed the method used here to illustrate the wave effects zone conceptually.

Sea level rise adaptation scenarios

A total of four adaptation scenarios and a baseline scenario were developed using the input gathered at the participatory workshop and the second expert meeting. They were developed for purposes of illustrating how the framework could be applied to evaluate alternative adaptation scenarios. The illustrative visuals for each scenario are provided in Figure 3.3.

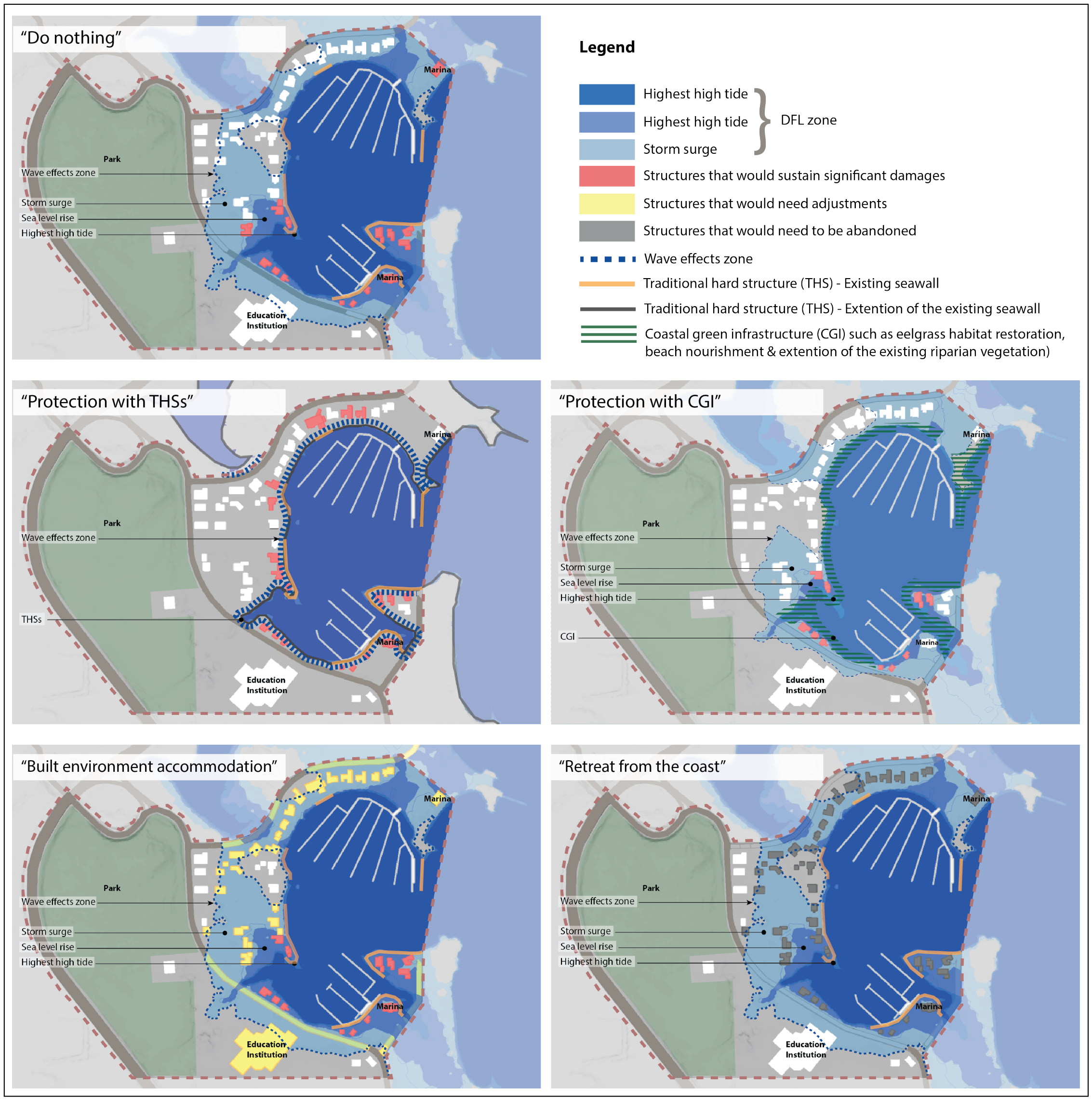

Figure 3.3: Sea level rise adaptation scenarios conceptual visual illustration. Drawings and illustrations are not to scale. Please see the disclaimer at the end of this chapter.

These conceptual scenarios included a number of quantitative (i.e., DFL and the wave effects zone) assumptions that were explained in the previous sections. They also included various qualitative assumptions that are described below.

Baseline scenario - Do nothing

The 'Do nothing' scenario depicts a future where no adaptation actions were taken to deal with the sea level rise, and illustrates the corresponding implications. This scenario is the extension of the baseline conditions over time. In this scenario, there are no physical interventions on the coastline. So the coast will still be partially protected with seawalls in front of some of the residential and commercial properties. In this future, the sea level rise, coupled with the high tide levels, threatens several private properties, all of the commercial properties, and some local roads and underlying infrastructure. A 1 in 500-year storm surge, however, impacts most of the structures, roads, and infrastructures in the study area.

Scenario 1 - Protection with traditional hard structure (THS)

The 'Protection with THS' scenario depicts a future where the protect strategy is adopted, and all of the coastline is hardened with seawalls. This scenario extends the existing partial seawalls throughout the community's coastline. In this future, the seawalls are built and maintained by the private property owners on the landward side of their property boundaries, as it is currently done. The extended seawalls are expected to protect the community from the still waters, such as high tides, sea level rise and storm surges, assuming that the seawalls are structurally in stable condition. However, the interaction of the storms and waves with the seawalls is expected to amplify the wave effects zone and to increase the associated flooding and damages (The Horinko Group, 2015).

Scenario 2 - Protection with coastal green infrastructure (CGI)

The 'Protection with CGI' scenario also depicts a future where the protect strategy is adopted. However, in this future, the eelgrass in the foreshore will be restored; the sandy beach between the foreshore and the private properties will be nourished, and large woody debris will be placed, and the riparian shore (the edge of the private property boundaries) will be restored using native plants and shrubs. The provincial government will implement the foreshore restoration, and beach nourishment as the land is under the provincial jurisdiction. The private property owners will implement the riparian restoration. The drag friction gain from the eelgrasses, beach slope, woody debris, and the riparian vegetation is expected to reduce to wave energy, thus the wave effects zone. Howes et al. (1994)'s 'The Physical Shore-Zone Mapping System for British Columbia' identifies the soil conditions of the study area as stable and sediment supply as abundant. Therefore, the restoration of habitat in this study area can help to accumulate soil at the cost and prevent the rising water levels from reaching further in the coastal areas (Houston and Dean, 2016). Thus, the CGI intervention is expected to help with the accretion processes, increasing the coastal soil elevation (Kirwan et al., 2010).

Scenario 3 - Built environment accommodation

The 'Built environment accommodation' scenario depicts a future where structures, roads, and infrastructure are retrofitted by elevating, and/or dry and wet-proofing structures. In this scenario, the flooding risks are known, but the primary objective is to either completely avoid the flooding impacts or to minimize damages. Elevating structures, although costly, can prevent flood waters from entering structures. Dry proofing involves using waterproof sealants to prevent floodwaters from entering through the walls and windows; while wet proofing involves modifying the lower floors of the structures to allow occasional flooding without significant damage to the property and materials (FEMA, 2007). Roads and infrastructure will also need to be floodproofed by elevating on top of a bank or floating roads (ECAP, 2015). This strategy will be implemented and maintained by private owners and local governments. Local governments may build partnerships with other levels of governments to create cost-sharing solutions. This strategy does not impact the area that will be impacted by the sea level rise but reduces the number of structures and infrastructures that may be damaged due to flooding.

Scenario 4 - Retreat from the coast

The 'Retreat from the coast' scenario depicts a future where the avoid and retreat strategies are adopted. In this scenario, no future development is allowed in the DFL and wave effects zones. Moreover, the community is planning for the strategical and phased retreat from these zones. This retreat is complex, and there is no precedence to help guide the process. In this future, the local government is responsible for implementation and maintenance of the strategy. Therefore, this scenario involves the collaboration of many levels of governance. The community also has to develop partnerships to finance the project because the avoid and retreat strategies are very expensive as they involve large areas of land acquisition and loss of economic activities (Gray, 2017). The DFL area will not change in this scenario since there are no interventions at the coast, but the flooding risks on the built environment will be eliminated.

3.4.2 The final evaluation framework

The evaluation framework developed in this study aims to assess sea level rise adaptation strategies for the purposes of identifying the local trade-offs of sea level rise adaptation strategies.

It can be used to review the benefits, challenges, and trade-offs between different adaptation options to help to prepare recommendations for adaptation actions.

The evaluation framework is designed to be implemented by a planning or project team. This team should include municipal planners, engineers, emergency managers, sustainability coordinators, utility managers, and other relevant municipal departments, as well as regional, provincial, and federal experts. Depending on the community's adaptation planning objectives, the evaluation framework can be implemented either before or after a public stakeholder workshop. For example, it can be used as an initial screening tool to review various adaptation options prior to a public workshop. The planning/project team then can use this tool to help identify few adaptation strategies that can be brought up in a public stakeholder meeting to discuss with the participants in greater detail. Alternatively, the implementation of the tool can follow a public stakeholder workshop, where the public preferences on adaptation strategies are obtained. The planning/project team then can use this tool to review the benefits, challenges, and trade-offs each option to help to prepare recommendations for adaptation actions.

As described in Section 3.3, a three-point scoring system, +1 (positive impact), 0 (minimal to no impact), and -1 (negative impact), is used in the evaluation framework to provide a straightforward structure. An N/A option is provided to be used when the criteria are not applicable to an area or the strategy.

Also described in Section 3.3 is the weighting system of the evaluation framework. The evaluation framework includes a two-step weighting system: in the first step, users need to allocate 60 points (minimum 6 and maximum 30 points) to six modules; and in the second step, users need to allocate 25 points (minimum 2.5 and maximum 12.5 points) to five components within each module.

The final evaluation framework consists of six modules, reflecting varying concepts of community resilience and adaptation to sea level rise (Cutter, 2016). These modules are coastal processes, natural environment, built environment, economic factors, institutional factors, and social factors. There are a total of 30 components, five in each module, aiming to identify the different aspects of the module. Each module includes criteria to assist with scoring. Table 3.3 displays the evaluation framework modules and components. The final evaluation framework, which also includes the three-point scoring system and the corresponding evaluation criteria can be found in Appendix B.4.

Modules	Components
Coastal Processes (CP)	CP1 Protection from short-term high energy events
	CP2 Protection from long-term low energy events
	CP3 Protection from coastal erosion caused by drag friction
	CP4 Protection from coastal erosion caused by disruption to sediment processes
	CP5 Protection from secondary threats
Natural Environment (NE)	NE1 Habitat migration along the coastal profile
	NE2 Coastal habitat and biodiversity
	NE3 Inland habitat and biodiversity
	NE4 Natural movement of organic and inorganic sediments
	NE5 Regionally important and sensitive coastal habitats
Built Environment (BE)	BE1 Specific land use loss due to strategy implementation
	BE2 Flooding risks on private property
	BE3 Flooding risks on businesses and other commercial or industrial structures
	BE4 Flooding risks on roads and infrastructure
	BE5 Visual aesthetics of the strategy
Economic Factors (EF)	EF1 Economic benefits to communities
	EF2 Implementation costs to local governments
	EF3 Implementation costs to waterfront property owners
	EF4 Maintenance cost to local governments
	EF5 Maintenance cost to waterfront property owners
Institutional Factors (IF)	IF1 Support in planning documents
	IF2 Municipal authority
	IF3 Availability of information, data and tools
	IF4 Availability of technical expertise
	IF5 Adaptability to changing environmental conditions
Social Factors (SF)	SF1 Acceptability of the strategy
	SF2 Opportunities for community involvement
	SF3 Access to coastal areas
	SF4 Preserving ecological and cultural values
	SF5 Displacement of populations

Table 3.3: The final evaluation framework modules and components. The three-point (+1/0/-1) scoring system and the evaluation criteria for each components can be found in Appendix B.4.

The importance of the natural and built environment, and economic factors for coastal community resilience to sea level rise have been well covered in the published academic and grey literature (Gibbs, 2015; Working Group on Adaptation and Climate Resilience, 2016; Cook et al., 2016; Azevedo de Almeida and Mostafavi, 2016; Sánchez-Arcilla et al., 2016; Wild et al., 2017; Hagen et al., 2018). The evaluation framework developed in this study contributes to the three other important concepts: coastal processes, and institutional and social factors. These concepts have often been overlooked or dismissed either because they were deemed unimportant, irrelevant, or difficult to assess. The coastal processes module reflects protection from the physical changes that occur between the built environment and natural processes such as flooding and erosion, and the interaction between the proposed adaptation measures and these processes (Frazier et al., 2013; Burton, 2014; Yoon et al., 2015). The institutional factors module reflects the overall capacity of communities' decision-making organizations. There are now numerous studies citing the vital role of institutions in dealing with change and uncertainty, and adaptation to sea level rise (Bronen, 2015; Gersonius et al., 2016; Oulahen et al., 2017; Patterson, 2018). The social factors module reflects the implications of sea level rise adaptation decisions on communities' perceptions, involvement, and development. Adaptation to sea level rise will have different implications on communities' social fabric, values, and equality (Sánchez-Arcilla et al., 2016). The descriptions of each module and component are provided below.

Coastal Processes (CP)

The main consequence of sea level rise is the increased risk of coastal flooding and erosion (Azevedo de Almeida and Mostafavi, 2016; Passeri et al., 2015). Therefore, the coastal processes module addresses how different adaptation strategies would affect the processes that occur at the coast.

The CP1 & CP2 components deal specifically with the interaction of the adaptation strategies with processes that result in flooding events. Coastal flooding events are separated into two parts based on their impact time and impact force. The short-term high-energy events describe flooding caused by low-pressure weather systems that lead to storm surges and powerful waves (Flather, 2001). These events last hours or days at most, and are responsible for most of the damage coastal communities suffer (Cox et al., 2018). The long-term low-energy events describe flooding caused by the changes in tidal range and mean water levels over time (Wesselman et al., 2018). These events are difficult to observe as significant changes are manifested over decades. However, they can have significant impacts on low-lying coastal areas (Hagen et al.,

2018) because they can increase the land area that is affected.

The CP3 & CP4 components deal specifically with the impact of the adaptation strategies on coastal processes that result in erosion events. The coastal erosion events are also separated into two parts. First is the erosion caused by drag friction, which is the result of the backwash of the wave, current and tidal oscillations that transports loose sediment, soil, rock, and vegetation patches away from coasts (Siegle et al., 2008; Ruckelshaus et al., 2016). Second is the erosion caused by disruption to sediment deposition processes, which leads to the decreased accretion at the coast (Sandi et al., 2018). Accretion is the process that increases surface elevation through organic and inorganic sediment trapping, root accumulation, primary production, and plant decay (Kennish, 2001), and is an essential natural defense mechanism of coastal areas.

The CP5 component addresses the secondary threats from loose materials that break apart from the protection measures due to strong wind and wave action. Storm surge and waves can tear parts of the coastal protection structures (such as sea walls, ripraps or breakwaters), and these loose parts can result in unintended damages (Klein et al., 2001), and can pose significant threats to human lives (Perdok, 2002).

Natural Environment (NE)

Sea level rise impacts and human action (or inaction) can alter the resilience of the natural environments (Sánchez-Arcilla et al., 2016; Devoy, 2015) by disrupting habitat area, habitat migration, biodiversity, and sediment transportation through the coastal profile (Comer et al., 2012). Therefore, the natural environment module addresses the effects of the different adaptation strategies on habitats, biodiversity, and coastal functionality.

The NE1 component targets the impacts of the adaptation strategies on the habitat migration along the coastal profile. This migration enables habitats to survive changes in the mean water levels by migrating landward or seaward (Doody, 2013; Pontee, 2013). Rapid or drastic changes in the coastal slope and water levels can alter the ability of the habitat to migrate along the coast. In addition, human interventions such as hard structures or dense development at the coast can limit this migration (Doody, 2004).

The NE2 & NE3 components deal with the impacts of the adaptation strategies on coastal and riparian habitat and biodiversity. The NE2 addresses explicitly the coastal habitat and biodiversity. Coastal habitats are amongst the most valuable and productive areas in the world as they provide numerous ecosystem services (Wamsler et al., 2016; Sandi et al., 2018). Decreases in habitat and associated changes in biodiversity can have social, economic and environmental consequences (Nicholls, 2004; Sandi et al., 2018). The NE3 component addresses the riparian and inland habitat and biodiversity. Riparian and inland habitats are also essential for sustainable communities as they provide various environmental, social, health and economic benefits (Li et al., 2015). Preserved and enhanced riparian and inland areas can help promote habitat and biodiversity while serving as a buffer during inundation events and absorbing floodwater (Eastern Research Group, 2013).

The NE4 component addresses the movement of sediments throughout the coastal profile. It is different from the CP3 & CP4 components, which are related to the sediment transport to the coastal areas. This process is affected by the geomorphology, currents, winds, tides, and human interventions at the coast (Temmerman et al., 2013). Therefore, strategies can alter the rate of sediment transferred and the location of the deposition throughout the coastal profile (Siegle et al., 2008). Lastly, the NE5 component targets the regionally important and sensitive coastal habitats. The ecosystem services of some coastal habitats exceed the boundaries of their local communities. Alterations to these coastal habitats would have much broader social, economic and environmental impacts in the region (Burcharth et al., 2007).

Built Environment (BE)

Population density is typically higher in coastal areas (Neumann et al., 2015), which increases the number and type of land, assets, and infrastructures that are at risk of flooding due to sea level rise. The resilience of the built environment is essential for the safety and functioning of daily life in coastal communities (Azevedo de Almeida and Mostafavi, 2016). Therefore, the built environment module deals with the effects of the different strategies on land use, assets and infrastructure, and the aesthetics of the built environment.

The BE1 component addresses the impacts of strategies on local land use. Some land uses may be disproportionally affected by strategies, and this may lead to the loss of essential economic or social activities and livelihoods in the community. For example, changes in the areas dedicated to food production, rental housing units, or industrial areas (CAP and ICLEI, 2015; Shayegh et al., 2016; Pramanik, 2017) can alter the built environment fabric of communities.

The BE2 & BE3 & BE4 components deal the strategy impacts on the flooding risks of assets and infrastructure. The BE2 component focuses on private properties as the physical damage to homes in coastal areas are expected to increase with rising sea levels and changing storm patterns (Burcharth et al., 2007). Private property owners can face threats to personal safety and experience significant losses and damages if the risk of flooding is not reduced (CAP and ICLEI, 2015). The BE3 component focuses on commercial and industrial structures. Flooding of the commercial/industrial structures can result in disruptions of economic activities, thus can have short and long-term financial impacts on coastal communities (CAP and ICLEI, 2015; Azevedo de Almeida and Mostafavi, 2016). The BE4 component focuses on the flooding risks on roads and infrastructure. Roads and infrastructure are critical systems as they connect people and services; therefore, disruptions to roads and infrastructure systems can lead to cascading impacts on the safety of residents, rescue, clean up and rebuilding and efforts, and functioning of services (Azevedo de Almeida and Mostafavi, 2016)

The BE5 component deals with the aesthetic consequences of strategies. Coastal areas are often prime real estate locations offering residents and visitors scenic coastal views. Strategies can block or significantly alter these coastal views, therefore may have significant impacts on the aesthetics and scenic quality of the built environment, and the real estate prices (Berte and Panagopoulos, 2014; Wamsler et al., 2016).

Economic Factors (EF)

Coastal areas have always been economic hubs due to the benefits of logistical, cultural, and recreational activities at the coasts (Neumann et al., 2015). Coastal communities rely on these activities for their tax revenues. However, flooding and erosion risks associated with the rising water levels pose threats to coastal communities' ability to sustain these activities (Hinkel et al., 2014). The adaptation strategies can provide various benefits and challenges to coastal communities' economic resilience. The decision-makers should understand the cost and benefits of the different strategies (Eastern Research Group, 2013; Fu and Song, 2017) both on private properties and local governments. Therefore, the economic factors module addresses the impacts of the adaptation strategies on local economic activities, and life-cycle costs to private property owners and local governments.

The EF1 component deals with the economic benefits of strategies. Tax revenues from properties are the main contributors to local governments' budgets; therefore, the provision of municipal services. However, sustaining and improving economic activities, while providing safety and protection is a challenging task for local governments (Duffy et al., 2014). Understanding the implications of strategies on the coastal economic activities is therefore essential.

Coastal areas consist of a mixture of private and public ownership and different government jurisdictions. This ownership and jurisdictional arrangements creates different responsibilities and economic capacities to pay for the adaptation strategies (Gibbs, 2015). Therefore, the EF2 & EF3 & EF4 & EF5 components address the life-cycle cost of the strategies on private property owners and local governments. The EF2 & EF4 components focus on the implementation and maintenance costs of the strategies on local governments. Local governments are responsible for the strategies under their jurisdictions. However, the local governments in British Columbia have direct access to only property tax, and they are restricted in their ability to raise revenue, and access financial resources (Dewing et al., 2006). Therefore, the financial burden of strategies on local governments can be significant. However, the cost of some strategies (i.e., accommodate) may qualify for federal and provincial cost-sharing programs, grants and partnerships, which may lessen local governments' financial responsibilities (Frazier et al., 2010; CAP and ICLEI, 2015). Maintenance cost, however, is often neglected, and not covered in most of the cost-sharing programs. On the other hand, the EF3 & EF5 components focus on the costs of the strategies on private properties. Even though flood insurance is now becoming available, at of the time this research was conducted, private property owners did not have access to coastal flood insurance coverage (see Oulahen 2014. Besides the coastal flood insurance, there is hardly any financial assistance available for small-scale projects to help them adapt to rising water levels. Although there are some technical and conceptual reports available, waterfront property owners are often alone in financing their intervention at the coast. Therefore, the economic implications of strategies should be considered.

Institutional Factors (IF)

Institutions influence the decision to adopt one strategy or policy over another one (Patterson, 2018). The institutional attributes of communities, such as the capacity, access to resources, and regulations in place influence how communities adapt to sea level rise (Oulahen et al., 2017; Chang et al., 2018). However, institutions are facing significant challenges to improve their ability to assess and deal with change and uncertainties, risks and knowledge requirements (Patterson, 2018). Therefore, the institutional factors module deals with the impact of the adaptation strategies on institutional attributes such as plans and policies, jurisdictional authority and dependency, and access to knowledge, tools, and data.

The IF1 component targets the planning documents. Local governments use various planning documents to plan and regulate within their boundaries. The regional districts provide various services and support to local governments, and provincial governments provide regulatory context, information, and instructional materials (MoMAH, 2018). The degree to which the strategies are aligned with the goals of the local and regional planning documents can indicate how easily a strategy can be implemented. The IF2 component targets the municipal authority of local governments in implementing the adaptation strategies. Coastal jurisdiction and ownership are therefore significant in determining which strategies can be undertaken by local governments. The consideration and adoption of a strategy can be more challenging if the local governments do not have the authority to implement it.

The IF3 & IF4 components focus on the availability of resources such as information, data and tools, and technical expertise required to undertake the adaptation processes. The strategy implementation depends on reliable and continuous access to these resources (Working Group on Adaptation and Climate Resilience, 2016). The availability of these resources within the local government or through regional, provincial and federal sources can effectively support decision-making.

The IF5 component deals with the adaptability of the strategies and the institutional attributes to change and uncertainties. Change and uncertainty are expected parts of social and ecological systems. Therefore strategies that are adaptable to changing and unexpected environmental conditions, and can be amended/modified easily within the existing institutional arrangements enhance community resilience (Cinner et al., 2018; Patterson, 2018).

Social Factors (SF)

The consequences of sea level rise and adaptation to it will have various social implications (Sánchez-Arcilla et al., 2016). Providing safety and continued occupation of coasts may require significant efforts and resources from local governments (Working Group on Adaptation and Climate Resilience, 2016), and may result in the unequal access to services in the community. In some coastal areas, the risk of flooding and erosion may force the relocation of some neighborhoods or the entire community (Working Group on Adaptation and Climate Resilience, 2016). Therefore, the social factors component of the evaluation framework deals with the social implications of the strategies.

The SF1 component addresses to the acceptability of the strategies. Local governments may face challenges in communicating and discussing some strategies due to the unequal social and economic implications of strategies, and the emotional toll of imagining a future where people may lose their homes, livelihoods and communities (Rijsberman and van Velzen, 1996; Barron et al., 2012). Although challenging, the acceptability of the strategies should be included in the adaptation processes (Flynn et al., 2018). The SF2 component targets the additional social opportunities and community benefits strategies may provide during the development, implementation and maintenance phases. These benefits may include increased community awareness and education on the impacts of climate change, natural and sensitive environments, and social and ecological relationships. The additional benefits may also include increases in social networks and trust within the community. Strategies can foster opportunities for knowledge sharing and transfer within the community members, contributing to the community's willingness to act, capacity, preparedness, and overall resilience (The William D. Ruckelshaus Center, 2017).

The SF3 component focuses on the public access to coastal areas. As the coastal populations grow and impacts of sea level rise increase, public access to coastal areas decrease (Higgins, 2008). Providing and improving safe and continuous public access to coasts is vital for promoting tourism and recreational opportunities, and contributes to individual and community health (Kim and Nicholls, 2017). The SF4 component addresses the preservation of the ecological and cultural values. Sea level rise will impact the cultural and ecological heritage sites such as archaeological sites, historical monuments, and structures threatened by coastal erosion (Marzeion and Levermann, 2014). They can be barriers of the adaptation strategies (Burcharth et al., 2007; Graham et al., 2013); therefore the decision-makers should consider the implications on strategies on these significant sites.

Lastly, the SF5 component focuses on the displacement of populations. As the flooding and erosion risks increase, the socio-economically disadvantaged populations will likely be unevenly impacted by the impacts of such events and may be forced to relocate (Leichenko and Silva, 2014; Pramanik, 2017). The decision-makers should carefully consider the implications of different strategies on the displacement of populations and specific population groups.

The evaluation framework assesses the effects of an adaptation strategy across a range of community resilience concepts: coastal processes, natural and built environments, and economic, institutional and social factors. Using the framework, decision-makers can identify the different types of advantages and disadvantages an adaptation strategy may offer and can highlight the tradeoffs between them.

3.4.3 Application of the evaluation framework to the adaptation strategies

The evaluation framework was applied to the 'Protection with THS', 'Protection with CGI', 'Built environment accommodation', and 'Retreat from the coast' scenarios. In the evaluation framework, the +1, 0, and -1 evaluation scale is based on how the strategy's impact would compare (increases, no impact or decreases) to the baseline scenario. Therefore, the 'Do nothing' scenario was used to compare other scenarios to the baseline conditions. The literature and planning document reviews, illustrative scenario visuals, and researcher knowledge of the study area were used to complete the evaluation framework. For the purposes of demonstration, modules and components were weighted equally. The completed evaluation framework and scores of the scenarios can be found in Appendix B.6 and summarized in Figure 3.4.

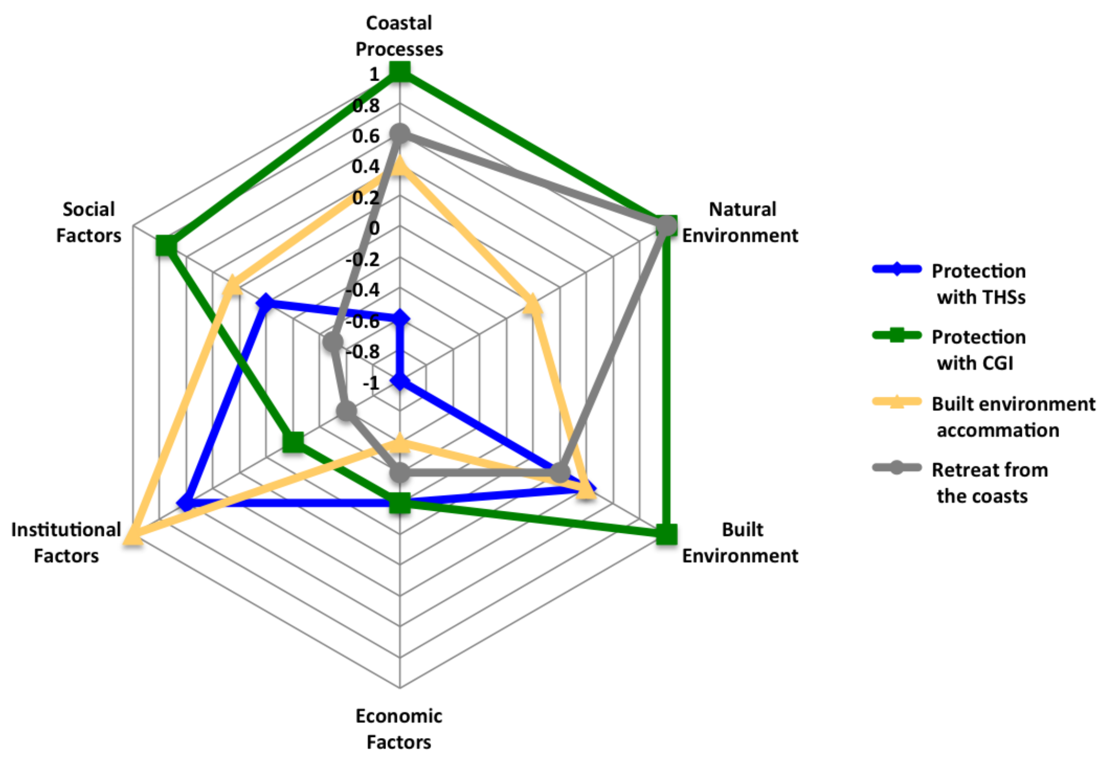

Figure 3.4: Diagram showing the results of the evaluation framework application to four sea level rise adaptation scenarios.

The results show that overall, the ‘Protection with CGI’ scenario scored the highest followed by the ‘Built environment accommodation’, and ‘Retreat from the coast’ scenarios. The ‘Protection with THS’ scenario scored the lowest overall. However, the scores for individual modules were different.

- For the coastal processes and natural environment modules the results were similar to the overall scores: the ‘Protection with CGI’ scenario scored the highest and the ‘Protection with THS’ scored the lowest. The ‘Retreat from the coast‘ scenario also scored high for the natural environment module.
- For the built environment module, the ‘Protection with CGI’ scenario scored better than the other scenarios. The ‘Retreat from the coast’ scenario had the lowest score, but was very close to the ‘Protection with THS’ and ‘Built environment accommodation’ scenarios.
- For the economic factors module, both of the protection scenarios scored the highest, even though the overall score for the economic factors module was very low compared to other modules. The ‘Built environment accommodation’ scenario scored the lowest.
- For the institutional factors module, the ‘Built environment accommodation’ scenario had the highest score, followed by the ‘Protection with THS’ scenario. The ‘Retreat from the coast’ scenario had the lowest score in this module.
- For the social factors module, the ‘Protection with CGI’ scenario scored better than the other scenarios, and the ‘Retreat from the coast’ scenario scored the worst.

The results indicated that overall CGI is a valuable adaptation measure with high benefits to coastal processes, natural and built environment, and economic and social factors, but low institutional benefits. The results also showed that the ‘Built environment accommodation’ scenario had significant economic and institutional trade-offs. The trade-offs of the ‘Retreat from the coasts’ scenario were between the coastal processes and natural environments, and the economic, institutional, and social factors. Lastly, the results showed that even though the ‘Protection with THS’ scenario had positive impacts on the institutional and economic factors, it had significant negative implications on the local coastal processes and natural environment.

3.5 Discussion

This study incorporated public perspectives and expert inputs to develop place-appropriate sea level rise adaptation scenarios and a resilience-based evaluation framework to assess benefits and trade-offs of different adaptation strategies. The expert participation in this study pooled diverse expertise from local, regional and provincial governments. It allowed for a more robust review of the technical data used in the study. The public participation helped to enhance knowledge on the local impacts of sea level rise, and the adaptation strategies available to deal with these impacts. Besides, it helped to identify the local perspectives on the adaptation strategies and the ones that are most preferred.

The incorporation of the community's concerns and desires improves local adaptation (Barron et al., 2012), but it may not always reflect the community's best options to reduce risks associated with sea level rise. As seen in the participatory workshop, the managed retreat and avoid strategies were rated as the most effective adaptation strategies, yet when asked which strategies the participants would like to see implemented in their community, the protect and accommodate strategies were rated higher than the managed retreat and avoid strategies. Considerations such as the emotional and cultural connections to places, desire to have waterfront properties, fears of decreases in real estate prices, and group or individual agendas, can influence decisions on sea level rise adaptation (Burch et al., 2010). Even when some coastal areas are more likely to experience flooding events regardless of the adaptation strategies in place, the continued occupation of coastal areas is often preferred due to these considerations.

Understanding the full implications of the adaptation strategies, therefore, is very important for decision-making. The evaluation framework developed in this study provides a comprehensive, structured and straightforward method for understanding the broader implications of the adaptation strategies, using a resilience lens. It provides a high-level assessment of the strategies in a local context, combining the individual characteristics of communities and the site-specific attributes of strategies. Different than other assessment tools, the evaluation framework highlights impacts to whom, by separating local governments, and property owners. It incorporates social and institutional factors, which are often left out of or overlooked in such assessments due to the difficulties in measuring and quantifying them (Oulahen et al., 2017). The +1 to -1 scoring system, although coarse, allows the evaluation of strategies with minimal technical knowledge or reliance on technical studies, making it accessible to communities with varying levels of resources. Moreover, this scoring system and the comparison of the proposed strategies to existing baseline conditions help inclusion of social and institutional components. The weighting system of the evaluation framework provides flexibility for communities to adjust the assessment to address their priorities (equal weights were used in the application). Allocating 60 points to six modules (6 to 30 points per module) and 25 points to five components (2.5 to 12.5 points per component) requires communities to consider all of the evaluation framework modules and components. Besides providing a holistic and integrated approach, this weighting system prevents the dismissal of some modules and components that may not be considered otherwise.

The evaluation framework can help foster a transparent and integrated decision-making process for adaptation. Therefore, the public participation must be recognized as an integral part of the evaluation framework, and public events should be organized before or after the completion of the evaluation framework. In addition, to the integration of the public in the planning process, incorporation of the expert input while completing the evaluation framework can provide transparency to and justification of the decisions. Therefore, a team of local experts, which brings together diverse perspectives and expertise should complete the evaluation framework.

Although the evaluation framework is comprehensive and provides a straightforward structure, it has several limitations. Compromises have to be made so that the users can use this tool without the need for detailed economic or technical studies. Therefore, not all important resilience concepts of adaptation were included. For example, the magnitude of the economic implications of strategies can be a deal-breaker when considering adaptation options. However, this would require detailed site assessments and cost-benefit studies. Communities would have to complete such studies to be able to use the tool, which was not the intended purpose of the evaluation framework. Moreover, it was also challenging to format concepts into a +1 to -1 scale and identify the potential changes compared to the baseline conditions. This is because some concepts occur independently from the proposed strategies or the baseline conditions, thus predicting the implications of strategies would not be possible. For example, while building functional collaborations with other communities and jurisdictions is acknowledged to be a significant factor for resilience, it may exist (or not) independently from the strategies. In fact, they depend heavily on the leadership and local government will, and capacity to undertake appropriate public engagement events.

The scenarios developed in this study conceptually illustrate the adaptation strategies and their implications in a simple and visual way. The expert meetings and participatory workshop provided the background material and data for the scenarios. Four adaptation scenarios were developed to illustrate the future conditions of the study area when four different strategies were adopted. A baseline scenario was also developed to understand future conditions if no actions were taken. The evaluation framework was applied to the four scenarios using equal weights for each of the framework's modules and components. The results highlight the site-specific benefits and disadvantages of the adaptation strategies and the trade-offs between them.

First, the results supported the growing body of literature, indicating that overall the CGI is a valuable adaptation measure with various co-benefits. Indeed, the 'Protection with CGI' scenario performed the best amongst all scenarios. It scored the highest positive benefits for the coastal processes, natural and built environment, and economic and social factors modules. This confirms the findings of the previous studies citing the wide range of CGI benefits. Even though the score of the economic factors module was low compared to other modules, CGI performed relatively high. It should be noted that this score does not reflect the actual cost of implementing CGI, but indicates the increases and decreases in the costs that private owners and local governments have to cover. Here, the coastal jurisdiction and ownership play an important role. The economic costs on private owners will likely to increase with a 'Protection with CGI' scenario because the improvements in the riparian areas will fall under private property boundaries. On the other hand, the economic costs on local governments will likely decrease because the foreshore falls under provincial jurisdiction; thus the improvements in the foreshore area become a provincial responsibility. The results also indicate that there are institutional trade-offs of this scenario. The low institutional score can be explained by the lack of experience, expertise, and data on CGI in this region. The CGI is a relatively new field of practice in British Columbia, and the expertise and resources are limited at the moment. If the study area was in an area with more established CGI practices, for example in Washington State, then the results of the institutional factors module would likely be much higher.

The results indicated that the 'Built environment accommodation' scenario was the second best option for the study area. It performed average or above average in most modules. However, the results highlighted that there were significant trade-offs between the economic and institutional implications of this scenario. On the one hand, the score of the institutional factors module was the highest amongst all scenarios. This is due to the existing institutional capacity of the community to undertake measures for the accommodate strategy. This is because the structural changes to buildings and upgrades in roads and infrastructure are services that are readily provided by the local government. On the other hand, the score of the economic factors module was the worst because actions related to the built environment retrofitting, and the associated implementation and maintenance costs fall under both the private owners' and local governments' responsibility. Even though there were some benefits through sustained development and businesses in the coastal area, this scenario will likely to have significant economic implications for the community.

One of the most interesting results was the trade-offs of the 'Retreat from the coasts' scenario. The retreat strategy is known to be a long-term solution for dealing with the sea level rise impacts. Indeed, the benefits of this scenario on the coastal processes and natural environments were very high. Allowing rising water levels to reclaim flood-prone areas and preventing new development from taking place enhances the sediment and wave processes, and the health of natural environments. However, the results showed that besides these high positive benefits, this scenario may have significant negative implications on the economic, institutional, and social components. Even though the avoid and retreat strategies used in this scenario do not have maintenance costs, the discontinuation of the development and economic activities will likely to have significant implications on the revenue collected by the local government, as well as impacts on the community's livelihoods. Besides, the cost of land acquisition will create a significant economic burden, especially in British Columbia where the property prices are very high, and there are insufficient federal and provincial financial resources to cover this cost. Institutionally, the implementation of this scenario will likely be extremely challenging because there are hardly any local or regional precedence, guidance, or resources for local communities. Moreover, the existing examples are typically from small coastal areas with low populations and assets. This scenario will also be very complicated to implement. A number of jurisdictions have to be involved in the development, design and decision-making processes but the roles of these jurisdictions are often unclear. Socially, the relocation of the community will be very difficult to communicate and the social acceptability of it will be very low compared to other strategies because this scenario is initially based upon the displacement of communities. And not surprisingly people do not want to leave their homes and communities they have known for years and move somewhere else.

The 'Protection with THS' scenario, which extended the existing seawalls throughout the coastline, performed the worst overall. It has similar build environment, institutional and social component scores with the 'Built environment accommodation' scenario. However, the coastal processes and natural environment implications of this scenario were the worst amongst all. This result also supports the literature citing the false sense of security and significant degradation on coastal processes and natural environments caused by the THI. However, this scenario performed relatively high for the institutional factors module. This is mainly due to existing institutional capacity to implement such measures. As described in the previous sections, some parts of the study area are already protected using sea walls. Thus the expertise, data, and other resources to implement and monitor such measures already exist in the community's institutional capacity. This scenario had the same the economic factors module score as the CGI scenario. It had similar negative economic costs on the private property owners due to the responsibility to implement and maintain seawalls within their property boundaries. However, if an another THS measure were chosen rather than the sea walls, such as breakwaters, groins or jetties, the economic implications of this scenario would be very different as the responsibility of implementation and maintenance would be under another jurisdiction. Similar to the CGI scenario, the economic activities at the coasts were maintained, and there was no increase in the costs for local governments.

Each component and module were weighted equally in this study. However, the results showed that the place and community-appropriate weighting is critical to help decision-making, especially when the trade-offs of the strategies are extreme. This is seen with the institutional trade-offs of the 'Protection with CGI' scenario; the economic trade-offs of the 'Built environment accommodation' scenario; the economic, institutional and social trade-offs of the 'Retreat from the coasts' scenario; and the coastal processes and natural environment trade-offs of the 'Protection with THS' scenario.

Low overall economic scores of the scenarios suggested that any adaptation action will likely increase the economic burden on coastal communities as a whole. Economic considerations have been typically the most important factor while choosing an adaptation strategy, but they should not be the only ones. Other factors also can be barriers to or facilitators of successful implementation of actions and sustained improvements to them. By weighting the importance of the modules and components, communities can manage these trade-offs. In addition, the results also pointed out to the actionable modules that can weaken the differences in the trade-offs. For example, the trade-offs of the built environment module can be lessened by the changes in the building codes and zoning plans. Similarly, the differences between the institutional factors module scores can be reduced by the changes in the local and provincial institutional frameworks and arrangements. However, these changes have been proven to be very difficult to achieve.

The importance of the site-specific adaptation has already been recognized widely in the literature. The results of this study highlight that the place-appropriate adaptation options are not only essential to identify who and what needs to adapt, and the local capacity to undertake actions; but also to determine which levels of governments are responsible for implementation, and the roles of the private property owners in adaptation processes. As shown in Chapter 4, the beach and the foreshore are often owned by private owners in Washington State; therefore the economic and institutional implications of strategies would be different than in jurisdictions where the private ownership of coastal areas is not the case. In British Columbia, the jurisdictional boundaries of local and provincial governments played a significant role in determining the economic and institutional implications of strategies.

3.6 Conclusion

This study develops a comprehensive but straightforward tool to evaluate the sea level rise adaptation strategies. It does so by incorporating local perspectives and diverse technical expertise, and by operationalizing the resilience concept in adaptation. The methodological approach of this study, the tool developed for strategy evaluation, and the demonstration on four adaptation scenarios provide an in-depth understanding of (1) how the resilience framework can be incorporated in the adaptation planning, (2) the factors influencing adaptation and community resilience, and (3) the implications and trade-offs of adaptation strategies, particularly CGI's.

This study demonstrates that CGI can be a viable adaptation measure if communities choose to protect their coastlines. It highlights the positive trade-offs of CGI in the interaction with and protection from coastal processes, the conservation and enhancement of natural environments, and the protection of the assets in built environments. The study also shows that communities may not always have the capacity or the organization structure to undertake CGI actions. The improvements and changes have to be made to the institutional frameworks and arrangements so that the CGI's negative institutional implications can be weakened.

When dealing with the sea level rise impacts, it is likely that communities will choose a combination of different strategies, rather than a single one. This way they will be able to address various concerns and get the best out of each strategy. However, regardless of the type of strategy, communities' adaptation processes, the use of assessment tools, the successful implementation of strategies, and the continuous updating of the plans and policies will heavily rely on the active leadership of the knowledgeable and skilled practitioners and politicians in the community.

Disclaimer: This research is not commissioned by the District of North Saanich. The technical aspects of this work were not completed or supervised/reviewed by a professional engineer of the District. The work completed and any conclusion drawn as part of this academic research does not necessarily represent the position of the District. The analysis completed and information collected as part of this research is not intended to direct or influence future activities/initiatives/studies completed by the District vis-a-vis sea level rise.

Chapter 4

Institutional barriers to and facilitators of coastal green infrastructure implementation: A comparative study in British Columbia and Washington State

4.1 Introduction

Communities have long found ways to adapt to changing environmental conditions (Adger, 2003; Löf, 2013). They have done so by using different ways and capacities to adapt (Berrang-Ford et al., 2011; Smith et al., 2011). Institutions, from local to federal governments and organizations, and their arrangements have played important driver roles in adaptation (Bettini et al., 2015). They have paved the way for key changes in the way communities deal with adverse environmental events, such as implementing coastal green infrastructure (CGI) measures to protect coasts from rising sea levels. However, research on the institutional arrangements that impede CGI implementation or drives it has been very limited (Matthews et al., 2015).

CGI refers to the natural or nature-based (designed or engineered) systems that protect coasts from flood and erosion and provides numerous essential ecosystem services (Barbier et al., 2011; Bridges et al., 2015). CGI is often implemented in the form of coastal dunes, intertidal vegetations, barrier islands, sloped beaches (beach nourishment) with large woody debris, coastal and riparian habitats, and reef systems. Over the past few decades, CGI has gained increased attention (Sutton-Grier et al., 2018) because decision-makers have started to recognize the maladaptive nature of the traditional hard structures and their implications on coastal habitats (Hewitson et al., 2014). Decision makers also started to acknowledge the adaptive, multi-functional and low-cost and low-maintenance nature of CGI (USEPA, 2015).

Although CGI's recognition has increased around the world, its implementation has gained momentum at various levels in different places. The mainstreaming of CGI has been limited in some parts of the world due to the context-specific institutional barriers, amongst others (The Horinko Group, 2015; Sutton-Grier et al., 2018). For example, Washinton State has started to include CGI related coastal and environmental regulations, develop programs to fund CGI implementation, and increase education and knowledge on CGIs as early as 1975 (U.S, 1972; Houle and Macdonald, 2011). However, the progression of CGI during the same time has been relatively limited in British Columbia. British Columbia and the Washington States share a border, history, and culture, and have similar environmental and ecological characteristics and concerns (Simeon and Radin, 2010). Yet, the presence of two different countries (Canada and the United States), and corresponding institutional arrangements and regulatory frameworks have contributed to the differences in the implementation of CGI (Naumann et al., 2011; Carlsson-Kanyama et al., 2013).

The literature suggests that the institutional arrangements play a significant role in the slow progression of CGI implementation in some places, and the rapid diffusion in others. Specifically, constraints and opportunities related to the governance structure and corresponding authority distributions; financial resources dedicated for adaptation; leadership; regulations and mandate in place; senior government support; political will; organizational capacity; and communication have been reported to influence adaptation (Adger et al., 2007). However, there has been insufficient research looking into the CGI specific institutional barriers and facilitators. Identifying and understanding the institutional factors contributing to these barriers and strategies helping to these facilitators provide opportunities to increase the implementation of CGI.

Therefore, this study investigates the barriers to and facilitators of CGI implementation that are rooted in the institutional arrangements of British Columbia and Washington State. It aims to answer the following research question: what are the institutional barriers to and facilitators of CGI implementation? It operationalizes three methods, a review of the CGI projects, a review and synthesis of the institutional arrangements, and semi-structured interviews. Chapter 4 is organized as follows. Section 4.2 provides a background review of the relevant literature. Section 4.3 explains the methodological approach of this study, including the description of the study area and specific research activities. Section 4.4 provides and explains the results of the research activities. Section 4.5 discusses the findings, highlights the barriers and facilitators identified throughout this research, and identifies the limitations of the research methods and findings. Lastly, Section 4.6 provides concluding remarks.

4.2 Background

The rapid acceleration of climate change impacts such as sea level rise throughout the 21st century, driven both by natural and anthropogenic forces (IPCC, 2014), and increased complexity and diversity of communities (Bauer et al., 2012) have made adaptation no longer an option, but a requirement for most coastal communities. Owing to the mitigation efforts that were unable to sufficiently to cut global greenhouse gas emissions and the urgency of action, adaptation has gained significant academic and political interest (Bauer and Steurer, 2014; Berrang-Ford et al., 2011). One adaptation measure, coastal green infrastructure (CGI) has been praised not only for its ability to protect coasts from flooding and erosion but also to provide an adaptive and a relatively low cost and low maintenance alternative to traditional hard coastal protection structures (Barbier et al., 2011).

It has been long discussed that adaptation, and therefore CGI should be a local level responsibility (Nicholls, 2011) because the climate change impacts are observed, felt and dealt with at the local level (Adger et al., 2005). While this is often the case, the notion that adaptation has to be dealt with at the local level has led to the absence of the regional and national level coordination, authority distribution, regulations, partnerships, programs, and capacity and resources in Canada and the United States (Hassol and Udall, 2003; Lorenzoni and Pidgeon, 2006; Burch, 2010; Giest and Howlett, 2013). This absence is problematic because operationalizing adaptation actions, especially for emerging measures such as CGI, relies heavily on these institutional arrangements and the resulting social, cultural, political and regulatory environment (Löf, 2013; Mguni et al., 2015).

Institutional arrangements, therefore, are significant pieces of mechanisms fostering CGI implementation. Institutional arrangements in this context refer to the hierarchies, structures, organizational features and functioning of the formal governments and organizations (Glavovic and Smith, 2014; Oulahen et al., 2017). They define the roles of different levels of governments and their decision-making authorities. They influence regulations and policies, and impact adoption of one strategy or policy over another one (Murphy, 2014). They provide structure, financial assistance, technical guidance and expertise, tools and other essential resources to foster CGI policies and practices (Farber, 2009; Löf, 2013; Reckien et al., 2015). Therefore, institutional arrangements are recognized to be both barriers to and facilitators of CGI implementation (Mozumder et al., 2011; Uittenbroek et al., 2012; Reckien et al., 2015).

The institutional barriers to and facilitators of adaptation have been considered as context-dependent (Biesbroek, 2014). This is because they have displayed variation across different levels of governments (Reckien et al., 2015). Countries, regions, and communities reported that they experience different barriers to CGI implementation; so do local, regional and national governments. Barriers in this context refer to the obstacles (Moser and Ekstrom, 2010) and challenges resulting from our social, cultural, historical and intellectual constructs (Biesbroek, 2014). Therefore, they are not immutable (Hamin and Gurran, 2015); they can be changed and reorganized (Glavovic and Smith, 2014). Facilitators are opportunities and pathways to overcome barriers. They lead ideas to policies and policies to actions. Many barriers reported in the literature are also facilitators if the conditions creating these barriers can be overturned or eliminated (Uittenbroek et al., 2012).

The institutional barriers and facilitators of adaptation have only started to be recognized in the mid-2000s with Adger et al. (2007) (Barnett et al., 2013). Yet, the existing literature has primarily focused on the climate change and (sea level rise) adaptation (Biesbroek, 2014). There is a long list of institutional barriers to and facilitators of adaptation reported in the literature, covering a range of institutional factors (Biesbroek, 2014; Hamin et al., 2014). The most common barriers include the governance and decision-making authority; financial; leadership; regulations and mandate; senior government support; political will; organizational capacity; and communication.

Arguably, the most common and important reported barrier to and facilitator of adaptation is the governance structures and allocation of decision-making authorities (Moser and Ekstrom, 2010; Barnett et al., 2013). The ambiguity over which levels of governments and which departments are or should be responsible for implementing adaptation measures remain to be unclear in many places (Hansen et al., 2013; Ziervogel and Parnell, 2014; Mguni et al., 2015). In some cases, these responsibilities may be overlapping, leading to increased complexity and bureaucracy (Lemmen et al., 2008; Keeley et al., 2013). Moreover, even in places where the roles of local, regional and national governments' are clearly defined, problems related to the fragmentation of key decision-making authority, and regulatory roles of different levels of governments create another barrier (Keeley et al., 2013; Chaffin et al., 2016; Hopkins et al., 2018). In addition, the lack of communication and interaction between different institutions creates inefficient intergovernmental coordination and partnerships (Löf, 2013; O'Donnell et al., 2017).

Another common barrier and facilitator in the literature is financial (Adger et al., 2007; O'Donnell et al., 2017). The reported financial barriers of adaptation are as follows. One important issue is the lack of or insufficient budget within the organizations to understand risks, and develop, assess and implement solutions (Burch, 2010; Mozumder et al., 2011; Hansen et al., 2013). The next one is the limited high governmental level financial assistance, grants and programs to address adaptation adequately (Uittenbroek et al., 2012; Ziervogel and Parnell, 2014; Reckien et al., 2015). Another issue is the restrictions in financial resources to allocate spending to design, construction, or monitoring effectiveness (O'Donnell et al., 2017; Sutton-Grier et al., 2018). Without the financial mechanisms and resources in place, overcoming other barriers is less meaningful for CGI implementation (Keeley et al., 2013).

Leadership is also one of the most common barriers and facilitators cited in the literature (Moser and Ekstrom, 2010; Mozumder et al., 2011; Carlsson-Kanyama et al., 2013; Reckien et al., 2015). Leaders or champions with decision-making authorities can propose policies for adaptation and advocate for new approaches. Particularly in the absence of senior level guidance and regulatory support, adaptation depends on the characteristics of the local decision-makers (Ziervogel and Parnell, 2014). The lack of such leadership (Hamin et al., 2014; O'Donnell et al., 2017) or incompetent leadership (Uittenbroek et al., 2012) creates many barriers to adaptation, while the presence of it will increase the momentum to it (Ziervogel and Parnell, 2014).

The literature suggests that regulations and organizational mandates also hinder or drive progress on adaption (Moser and Ekstrom, 2010; Barnett et al., 2013; O'Donnell et al., 2017). Institutions that are keen to implement adaptation measures are often limited in their ability to do due to the lack of regulations and government programs that support adaptation (Houle and Macdonald, 2011; Löf, 2013; Hamin et al., 2014), and regulations that do not integrate climate change impacts and adaptation measures (Mozumder et al., 2011; Carlsson-Kanyama et al., 2013). The lack of space and flexibility in the current regulatory environment to accommodate adaptation measures are considered to be an important regulatory issue (Sutton-Grier et al., 2018). In addition, conflicting codes and rules within the existing regulations also hamper progress (US EPA, 2015; O'Donnell et al., 2017).

The senior government support, usually in the form of guidance, regulations, programs, partnerships, tools, and data is another critical barrier and facilitator noted in the literature (Moser and Ekstrom, 2010; Mozumder et al., 2011; Barnett et al., 2013; Reckien et al., 2015). The absence of the senior level support forces other levels of governments to rely solely on their organizational capacities. This absence leads to inequalities due to the institutions' ability to undertake adaptation actions by themselves (Dickinson and Burton, 2011). On the other hand, the presence of the senior level support can prevent disparate approaches to adaptation and promotes a harmonious regional adaptation response (Kittinger and Ayers, 2010).

Another frequently reported barrier and facilitator is political will. The political will barrier refers to the politicians' lack of motivation to consider long-term implications of adaptation measures due to the reelection concerns (Ziervogel and Parnell, 2014). It is considered to be a key barrier (Burch et al., 2010; Reckien et al., 2015), because the absence of political support leads to policies and actions focusing on short-term gains (Uittenbroek et al., 2012; Ziervogel and Parnell, 2014). It also prevents the long-term vision necessary for CGI implementation.

The organizational capacities of institutions, including having the right expertise in the organization (Moser and Ekstrom, 2010; Keeley et al., 2013), enough staff to work on variety of issues (Mozumder et al., 2011), and the availability and access to resources such as technologies and data (Uittenbroek et al., 2012; Barnett et al., 2013) is reported to be an important driver of adaptation (Ziervogel and Parnell, 2014; O'Donnell et al., 2017; Hopkins et al., 2018). The absence or limitations to these organizational capacities create significant constraints to the governments' ability to implement adaptation (Keeley et al., 2013; Hamin et al., 2014; Hamin and Gurran, 2015), even if the other institutional barriers are removed.

Lastly, communication is reported to be a significant barrier of adaptation. It is because communication issues influence perceived risks, public perceptions on the effectiveness of different measures, community buy-in, and advocacy (Moser and Ekstrom, 2010; Uittenbroek et al., 2012; Keeley et al., 2013; Ziervogel and Parnell, 2014; Reckien et al., 2015). Communicating the relevant, evidence-based, and up-to-date information with public increases awareness and reduces incorrect perceptions on effectiveness and cost of adaptation measures (Mozumder et al., 2011). The language used and the approach taken for the interactions with communities improves institution-to-institution and institution-to-community communication (Moser and Ekstrom, 2010). Communication fosters transparency and trust in relationships. Ensuring that the relevant information is available to and accessible by public fosters local advocacy for adaptation (Hamin et al., 2014; Measham et al., 2011).

Since 2013, the barriers to and facilitators of adaptation measures, particularly in the urban stormwater management context, has also started to gain attention. Studies of Keeley et al. (2013), Matthews et al. (2015), Mguni et al. (2015), Thorne et al. (2015), Chaffin et al. (2016), O'Donnell et al. (2017), and Hopkins et al. (2018) were the first attempts to characterize the factors impeding the use of urban green infrastructure for managing urban stormwater. Findings of these studies show that urban green infrastructure implementation is constrained by similar barriers to adaptation in general, but it also facing unique and specific challenges (Chaffin et al., 2016). Thorne et al. (2015) suggested that ensuring social equality, while delivering essential urban services is a barrier of urban green infrastructure implementation. Chaffin et al. (2016) added that functionality of land use changes due to green infrastructure implementation is another important barrier. O'Donnell et al. (2017) concluded that negative past experiences of municipal practitioners, low priority of urban stormwater issues compared to other essential services, and lack of available space act as barriers. Matthews et al. (2015); Hopkins et al. (2018) suggested that the path dependency such as long-term investments in grey infrastructure limits will to change. Lastly, Keeley et al. (2013); O'Donnell et al. (2017); Hopkins et al. (2018) concluded that the complexity and scale of the stormwater management systems and consequent management issues could prevent implementation of urban green infrastructure.

The barriers to and facilitators of adaptation described in this section are reported to be relatively common across different places. There are undoubtedly other factors that impact adaptation implementation, but not listed here. The barriers detailed here are typically challenging to overcome because institutional change is complicated and takes a long time to achieve; yet can be accomplished. Facilitators, often overshadowed by the barriers, can provide key opportunities and strategies to achieve institutional change and overcome related barriers (Glavovic and Smith, 2014).

This review showed that the investigation into the institutional barriers to and facilitators of different adaptation measures has finally started. The early studies indicated that besides the similarities, specific adaptation actions face unique challenges and influenced by different drivers. The review indicated that urban green infrastructure is influenced by specific barriers and facilitators due to the complexities of urban systems, competing interests and investments, and integration of new technologies into existing city plans and building codes. Similarly, CGI is likely to be influenced by CGI-specific barriers and facilitators due to its unique location at the interface between land and ocean (IPCC, 2014), the overlapping jurisdictions that regulate and manage the coastal areas, the lack of knowledge on its coastal protection role, and the unknowns surrounding its integration in the existing regulatory frameworks. This review highlighted that there are currently no studies investigating the specific institutional barriers to and facilitators of CGI. Therefore, this research aims to fill this gap using a comparative approach and three different and complementary methods.

4.3 Methods

This study operationalizes a mixed-method approach to identify the institutional barriers to and facilitators of CGI implementation. The study compares CGI projects, institutional arrangements and practitioner perspectives from British Columbia (BC), Canada and Washington State (WA), the United States. The main hypothesis of this research is that the implementation of CGI is influenced by common barriers to and facilitators of adaptation as well as CGI-specific disablers and enablers. The methodology of this study consists of the following three systematic steps, each aiming to contribute to the overall research question of what are the institutional barriers to and facilitators of CGI implementation, using three sub-research questions.

The first step is the review, analysis, and comparison of the CGI projects implemented in the study area, between 2008-2018. This step aims to answer the sub-research question what are the differences between the institutional roles in CGI implementation in BC and WA? It investigates the number, type, and area of the projects implemented in each region, as well as the roles and capacities of different levels of institutions in project implementation. By comparing the quantitative data in BC and WA, this step aims to provide an understanding of how often, in what capacity, and through what resources the CGI projects were implemented in the study area.

The second step is the review and synthesis of the institutional arrangements. It includes the literature and document review of the governance structures and consequent distribution of the decision-making-authorities, coastal jurisdiction, and coastal and environmental regulations and programs in BC and Canada, and in WA and the United States. This step poses the sub-question what are the differences between the institutional arrangements of different levels of governments in BC and WA? This step investigates the published academic and grey research as well as the official federal and provincial government websites for acts and programs. By comparing the qualitative data in BC and WA, this step aims to highlight the institutional barriers and facilitators through identifying relevant responsibilities of the different levels of governments, jurisdictional and ownership boundaries, and regulations and programs.

The last step is the semi-structured interviews with the practitioners from different governmental and non-governmental organizations (NGOs) in the study area. It poses the sub-research question what are the practitioners' perspectives on the institutional barriers to and facilitators of CGI implementation in BC and WA? Semi-structured interviews are conducted in this step to obtain qualitative (the types of barriers and facilitators) and quantitative data (i.e., the number of people that mentioned the same barriers and/or facilitators). The qualitative data is used to check whether the practitioners mentioned the barriers and facilitators similar to the findings of the CGI project review and the review and synthesis of the institutional arrangements steps. It is also used to identify the CGI specific institutional barriers and facilitators and to provide more nuanced and detailed factors to the common barriers and facilitators. The quantitative data is used to highlight the differences between BC and WA.

The comparative design of the research methods helps to understand the broad patterns, similarities and differences (Lachapelle et al., 2012) in the organizational, structural and functional aspects of institutions in these two regions. Using the comparative research approach, this study aims to provide insights into the barriers and facilitators that are experienced in each region due to the differences in their institutional arrangements. While an in-depth study focusing on one region may have yielded a more in-depth understanding of the institutional arrangements, and corresponding jurisdictional issues and regulatory frameworks, it would not have provided a way to understand how these arrangements act as barriers to and facilitators of CGI implementation.

4.3.1 Study Area

The coastal regions of British Columbia (BC) in the Pacific coast of Canada and Washington State (WA) in the Pacific Northwest of the United States were selected to for the study area of this research (Figure 4.1).

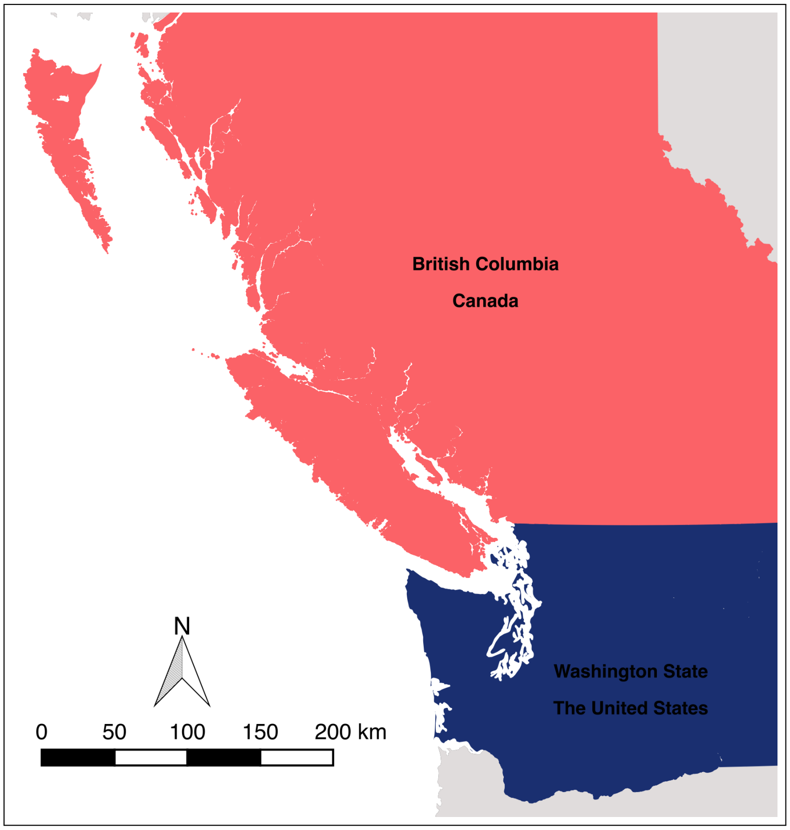

Figure 4.1: The map of the study area showing the coastal regions of British Columbia and Washington States

This study area provides unique opportunities to identify institutional barriers to and facilitators of CGI implementation in a comparative way because of the following reasons. The Canadian and American governments are both liberal democracies and federations (Lachapelle et al., 2012). They have relatively similar organizational structures: the federal government, First Nations and Tribal governments; provincial, territorial, and state governments; and local governments. Also, the study area includes an important body of water, the Salish Sea, which hosts most of the BC and WA populations and economic activities. In addition, the coastal population in both regions is very high compared to the rest of the regions. It is estimated that around 70% of Washington State's 7.2 million resident (2016 census), roughly 5 million people live in coastal counties (Adelsman et al., 2012), where in BC, around 78% of BC's of 4.6 million resident (2016 census), roughly 3.6 million people live in coastal municipalities (Statistics Canada, 2016). Moreover, both coastal regions have similar geomorphological, ecological and oceanic characteristics (Demarchi, 2011). These characteristics are not uniform but are similar in their diversity throughout the study area. Therefore, the adaptation measures implemented in one region can be considered in the other one. Lastly, Canada and the United States, and BC and WA often experience the flow of ideas, culture, and policies (Simeon and Radin, 2010), further advancing the knowledge sharing for adaptation in the region.

BC and WA also have several significant differences that should be mentioned here. For example, the length of the WA coastline (5,310 km) is about five times shorter than the BC coastline (25,725 km). Considering BC's population is smaller than WA's population, the BC coasts are not as densely developed and occupied as the WA coasts. Moreover, BC and WA face similar rates of projected sea level rise rates (1m) for 2100, but the coastal subsidence due to sediment compaction and groundwater extraction in parts of WA, and uplift due to geological and tectonic processes in parts of BC cause spatial variations of coastal flooding and erosion risks (Mazzotti et al., 2008). The variation in the risks they are exposed to may lead to differences in adaptation needs.

Despite their differences, BC and WA have been subject to numerous other comparative studies. These studies included investigating various issues such as coastal zone management (Day and Gamble, 1990), environmental management (Norman and Melious, 2004), adaptive management (Halbert, 2008) and governance models (Wolman, 2017). The similarities these two regions share, overtake the differences they have and provide a unique opportunity to investigate the institutional barriers to and facilitators of CGI implementation.

There has also been a growing interest in and expertise with CGI in the region. In Canada, CGI has started to be recognized as the part of the solution to deal with climate change. Restoring ecosystems, particularly coastal ecosystems that sequester 50 times more carbon than the same area in Canada's boreal and temperate forests has started to become a priority (CPAWS, 2016). There has been an increasing number of federal and provincial initiatives and grant programs for CGI projects in the last two years such as Natural Resources Canada's Green Infrastructure programs, Federation of Canadian Municipalities' Green Municipal Fund, and the Green Infrastructure Environmental Quality Program in BC. In the United States, EPA and NOAA have been providing guidance and programs for CGI projects over two decades. In WA, many municipal and county governments, state departments, multi-organizational partnerships, and environmental NGOs have been removing THSs and exploring CGI alternatives.

4.3.2 Research activities

Review and analysis of the CGI projects

This step aims to answer the sub-research question - what are the differences between the institutional roles in CGI implementation in BC and WA? To answer this question, the CGI projects that were implemented or are in the implementation process in the last ten years (2008-2008) were collected. These projects were reviewed and if the information was available, projects details, such as project objectives, types, area size, lead institutions, funding institutions, and funding amount were recorded. The recorded information was analyzed to understand how often, in what capacity, and through which resources the CGI projects were implemented, and to identify the differences between the institutional roles in CGI implementation in BC and WA.

The projects were gathered from various publicly available databases from federal, provincial, state, and NGOs' websites. The list of the data sources can be found in Appendix C.1. The project selection criteria included the following rules:

- Projects have to be (approximately) within 100m of the coastline. Projects on watersheds, streams, or urban parks were not included.
- Project implementation has to be completed or in the process of completion. Projects that are in the design and development stages were not included. If the permit applications were submitted for review, then the project was included. If this information was not available, then the project was not included.
- Projects have to include an on-site intervention. Land acquisition, design, feasibility, research, and mapping projects were not included.
- Projects have to be on public land (federal, First Nations, Tribal, provincial or state) due to data availability and access. Projects on private properties were not included.

Once the projects were located and the selection criteria were applied, information on the project name, type, objective, funding amount, lead institution, institutions where the funding was allocated from were systematically recorded. Information on the initial funding sources and the details of partnerships was not available in all cases; therefore they were not included. The past ten years (2008-2018) \$CAD to \$USD currency rates were gathered and averaged. The funding amount of the projects in BC were exchanged to USD. This exchange allowed for the comparison of the funding amount of the projects in BC and WA.

Review and synthesis of the institutional arrangements
This step aims to answer the sub-research question - what are the differences between the institutional arrangements of different levels of governments in BC and WA? To answer this question, the review and synthesis of the institutional arrangements in Canada, BC, the United States and WA were conducted to identify the institutional barriers and facilitators. Desk research was conducted to locate, review and synthesize the barriers and facilitators identified in the CGI project review step. These concepts included the governance systems and authority distribution, coastal jurisdiction and ownership, and the coastal and environmental regulations and programs.

In the first part, the governance systems of Canada and the United States were reviewed, and the responsibilities allocated to the provincial, state and local governments were identified. In the second part, coastal jurisdictions in the study area were identified using published government documents. In the third part, coastal and environmental regulations were researched on the federal, provincial and state governments' and departments' websites. The contents of these regulations were reviewed, and actions required for CGI implementation (such as permits, compliance, and approvals) were noted. Lastly, the federal, provincial, and state programs related to coastal and environmental issues were identified through a web search. If available, the start date, the specific time period of the programs, and the amount of financial assistance (such as grants, fundings, and others) were recorded.

The differences in the study area were identified and compared to highlight the barriers to and facilitators of CGI implementation.

Semi-structured interviews
This step aims to answer the sub-research question - what are the practitioners' perspectives on the institutional barriers to and facilitators of CGI implementation in their region? To assess what the practitioners involved in the CGI projects consider as institutional barriers to and facilitators of CGI implementation, interviews were held with the selected practitioners in the study area.

The criteria used to select the participants included:

- The participants should be representing the provincial/state, local and NGOs that are involved in the regulatory, implementation, guidance and coordination of the CGI projects;

- The participants should have been actively involved in the abovementioned roles in the last ten years and be aware of the concepts discussed; and
- The participants should be willing to be interviewed as part of the research.

After the participants were identified, they were contacted through their publicly available email addresses. After the initial contact and explanation of the research, the consent forms were sent if they agreed to participate in the study.

The semi-structured interview format was selected to allow for a range of responses, and to enable clarifying questions and additional discussions. The interviews were conducted either in person or on the phone, shortly after receiving the consent forms. The interviews were audio recorded for future analysis. The interview protocol included five parts. The first part was an initial introduction of the researcher, the research, and the format of the interview. After the introduction, in the second part, the participants were asked questions about their role of their organization and their role in the organization. In the third part, the participants were asked about jurisdiction, decision-making authority, and mandate of their organizations; regulations they are bounded by when dealing with the CGI projects; the funding sources for their organizations and the CGI projects; if applicable, how they use or distribute the funding; and other levels and types of organizations they commonly build partnerships with. In the fourth part, they were asked about what they would consider as the main barriers to and facilitators of CGI implementation. In the last part, they were presented with the prompted questions, which included a brief introduction of the results of the CGI project review, and the review and synthesis of the institutional arrangements. They were asked whether they agree with the findings of the previous research activities, and elaborate on their answers. The detailed interview protocol can be found in Appendix C.2.

After the semi-structured interviews were completed, the verbatim transcriptions of the audio files were created. These transcripts were coded using the NVIVO software. The initial coding procedure followed the themes discussed in the interviews. After the initial coding of the overarching themes, sub coding categories were created to get depth and context on the broader themes. The coded text was analyzed by the respondents' region (BC or WA) and level of governments or organizations they represent (provincial, state, local or NGO).

4.4 Results

4.4.1 CGI project review

A total of 235 CGI projects were gathered from the publicly available federal, provincial, state, and NGO sources listed in Appendix C.1. Out of the 235 CGI projects, 47 projects (20%) were from BC, and 188 projects (80%) were from WA (Figure 4.2).

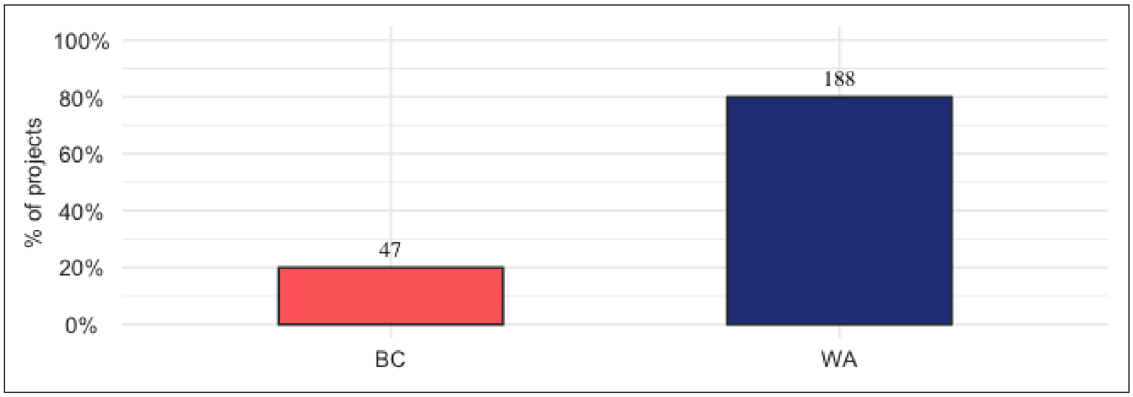

Figure 4.2: The number of CGI projects in BC and WA between 2008-2018

The significant majority of the projects did not have adaptation as their objective (Figure 4.3). Fish habitat restoration was the main driver of the projects in BC (79%) and in WA (47%). The CGI projects with adaptation objective made only about 8.5% of the total projects in BC and 20% of the total projects in WA. The projects with the indirect adaptation objective, such as projects restoring sediment flows and natural processes, made up about 12.5% of the BC projects and 33% of the WA projects.

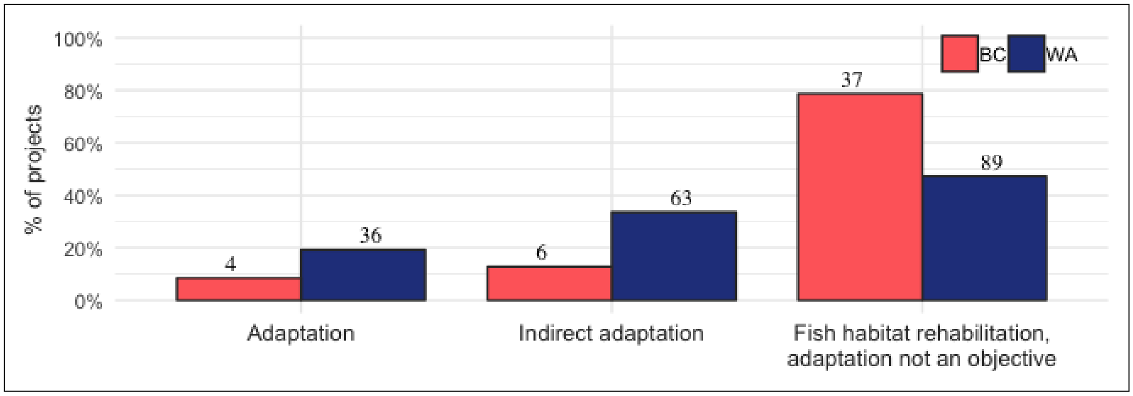

Figure 4.3: The objectives of the CGI projects

The projects did not show significant variety in types (Figure 4.4). Most of the projects were initiated to restore habitat and/or to remove human-made structures such as bulkheads and culverts. 83% of the CGI projects in BC were habitat restoration projects, where only 17% were both habitat restoration and human-made structure removal. In WA, 74% of the CGI projects were both habitat restoration and human-made structure removal projects, and only 21% of the projects were habitat restoration projects. Different than BC, 5% of the CGI projects were also hazard protection and climate change adaptation projects.

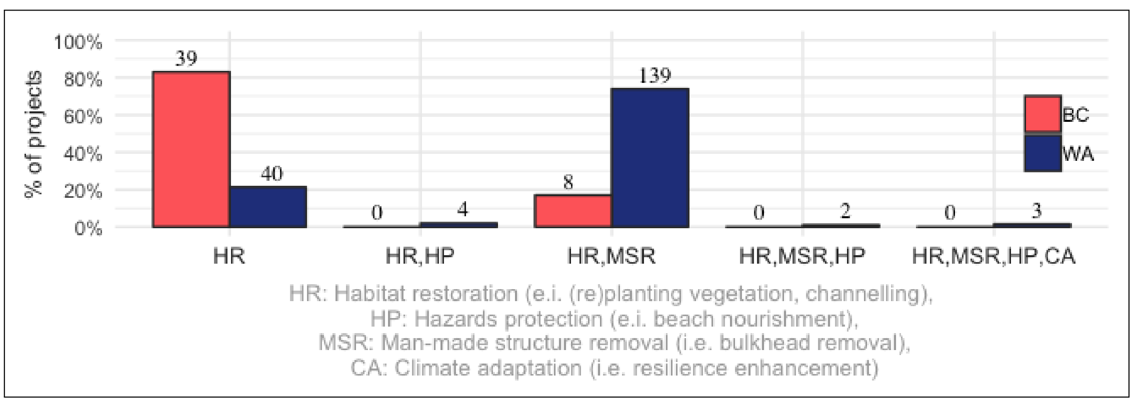

Figure 4.4: The CGI project types

The institutions where project funding was allocated from were very different. The state government in WA was the main institution where the CGI project funding was allocated. 79% of the projects received their funding from a state source (different state departments). It should be noted here that this does not mean that the funding was originated from a state department. The origins of the projects' funding were difficult to locate because the initial funding sources are typically nested in several layers of programs, and the funds often go through various channels of bureaucratic steps before being allocated. In BC, the federal government played an important role in funding allocation. 47% of the CGI projects in BC received their funding from a federal source (usually different ministers or directly from the government of Canada). In BC, local governments, NGOs, and partnerships also played roles in allocating funding for CGI projects.

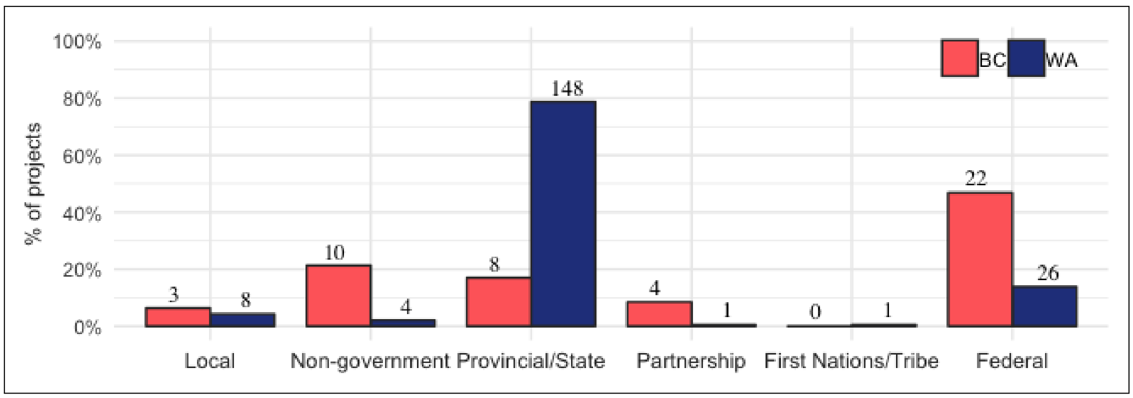

Figure 4.5: The institutions where the project funding was allocated from

Different institutions acted as the project leads (Figure 4.6). These organizations included the local governments, NGOs, provincial and state departments, partnerships, First Nations, Indian Tribes, and the federal governments. The project leads undertook various roles such as project initiation, coordination, and implementation. The NGOs played significant roles as the project leads in BC and WA, 51% and 42% respectively. In WA, the local, state and Tribal governments, and partnerships had more lead roles, compared to their counterparts in BC.

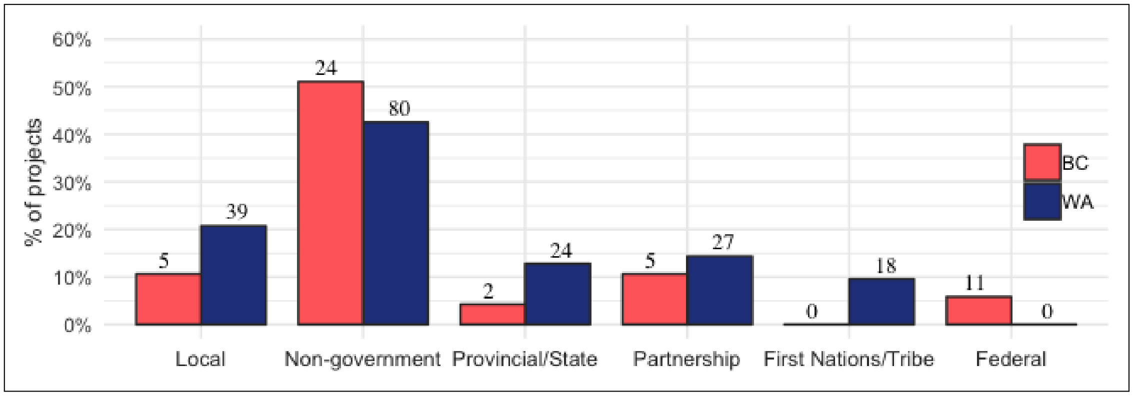

Figure 4.6: The CGI project leads

The minimum funding amount of the CGI projects was \$5,375 in BC and \$500 in WA, while the max funding amount was \$8,081,345 and \$64,707,676, respectively. The average funding of the CGI projects in BC was \$764,427, and \$1,802,752 in WA. The average funding amount allocated by different institutions was consistently and significantly higher in WA compared to BC, except for the local governments (Figure 4.7). The average funding allocated by the Federal government was the highest amongst all level of institutions in BC and WA.

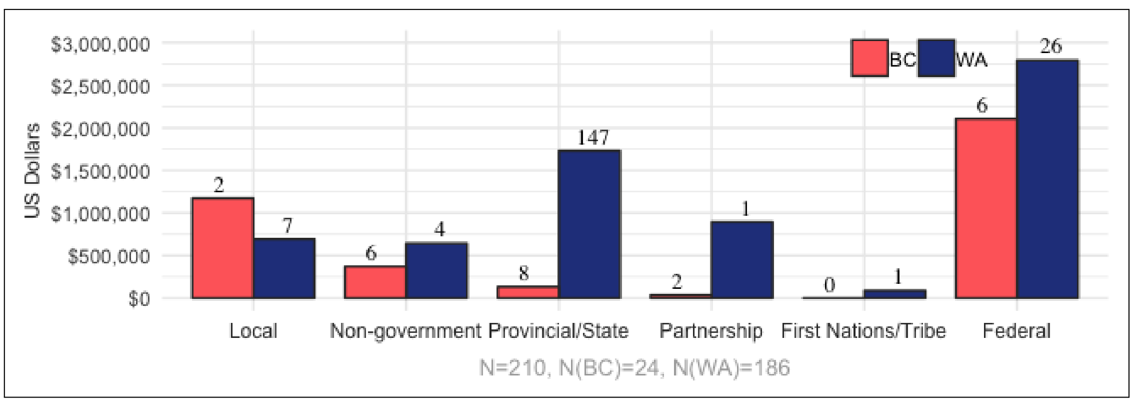

Figure 4.7: The average CGI project funding amount allocated by institutions

The minimum project area in BC and WA was 0.01 acres, while the max project area was 250 acres and 762 acres, respectively. The average project area in WA was 51.37 acres, about 20 acres larger than the average project area in BC (30.34 acres). The area size of the projects lead by the state government and partnerships in WA was significantly higher than those in BC, the size of the projects lead by the local governments and NGOs in BC was higher than those in WA. In WA, the project area size increased with the level of the lead institution (Figure 4.8). The CGI projects with the Tribal governments, state governments, and multi-institutional partnerships as the lead had larger average project areas than of the NGOs and local governments as the leads. In BC, the projects with the local governments and NGOs as the lead had larger average project areas than of the provincial governments, multi-institutional partnerships, and the federal government.

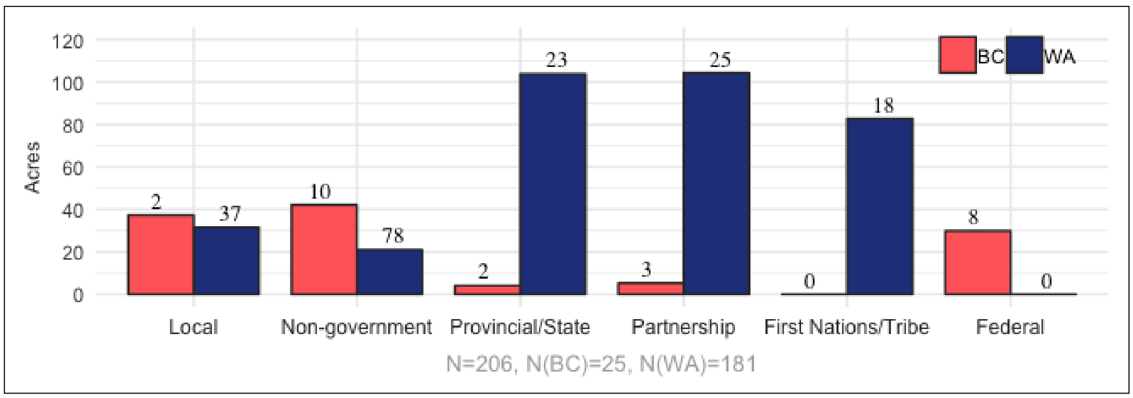

Figure 4.8: The average CGI project size in acres by the lead institution

4.4.1.1 Summary of the CGI project review results

The project review showed that there were notable differences in the CGI projects in BC and WA. These differences were in their project numbers, objectives, types, area size, leads, funding, and the institutions where the project funding was allocated. There were significantly more projects implemented or are in the implementation process in WA than in BC. In both regions, the project objectives were mainly fish habitat health, continuity, and access, rather than adaptation. The CGI project types were mainly habitat restoration projects in both places, but human-made structure removal projects were also a common type in WA. The funding for the CGI projects was allocated primarily from the state government in WA and the federal government in BC. The NGOs played significant roles as the project leads both in regions. In addition, the local, state and Tribe governments also took important lead roles in WA, compared to their counterparts in BC. The project areas varied in size but overall, the projects in WA were larger than those in BC. The CGI projects in WA received much more funding, compared to the projects in BC. In WA both the federal government and the state governments were the main institutions to allocate funding for the CGI projects, where in BC the funding was allocated mainly by the federal government and local governments.

The project review demonstrated that there were clear distinctions between the roles different governments in the study area played. The results show differences in the arrangements and functioning of the institutions in BC and WA, particularly for the institutions where the funding was allocated from, organizations with the lead roles, the funding availability, and the size of the projects. Based on the literature, these differences can be defined by the governance structure, and corresponding decision-making authority allocation, jurisdictional issues, and regulatory environment and programs that provide funding and other resources, and therefore were selected to be reviewed in the next section.

4.4.2 Review and synthesis of the institutional arrangements

4.4.2.1 Governance systems and the corresponding authority distribution

Governance systems influence the authority distribution in different levels of governments through the allocation of regulatory and financial responsibilities. These systems define the structure of the institutional arrangements, and institutions' decision-making authority to apply laws and implement programs. Therefore, understanding the governance systems and the corresponding decision-making authority distribution is significant when investigating the institutional barriers to and facilitators of CGI implementation.

Federal governments
Canada and the United States are both liberal democracies and federations (Bélanger, 2005; Simeon and Radin, 2010). However, Canada's governance system has started as a relatively centralized federation and has become decentralized over time, where the United State's governance system has started as a relatively decentralized, and has become relatively centralized over time (Bélanger, 2005; Thomas and Biette, 2014; Government of Alberta, 2015). These contrasting natures of the high-level governance systems and the differences in political traditions (Hamilton, 2013) have led to unique provincial and state, and local government structure,

coordination, and cooperation in Canada and the United States (Field, 1992; Simeon and Radin, 2010; Thomas and Biette, 2014).

Provincial and state governments

The influence of the different high-level governance systems in Canada and the United States can be seen in the decision-making authorities allocated to the Canadian provinces and the United States's states. For example, the United States constitution initially allocates the states all powers not explicitly assigned to the federal government (Bélanger, 2005; Taylor, 2005). These responsibilities are often characterized as imprecise and poorly defined but important nevertheless. They include justice, education, and environmental protection, amongst others (Patmore, 2009; Thomas and Biette, 2014). However, over time the federal government has used its authority to expand its jurisdiction and intervened with the broad responsibilities given to the states (Government of Alberta, 2015). As a result, there are only a few state-only responsibilities left, as most of them are now shared with the federal government. On the other hand, the provincial responsibilities are initially limited compared to the states, but they are carefully and clearly defined in the Canadian constitution. These responsibilities include taxation, natural resources, education, and health (Bélanger, 2005; Taylor, 2005). Yet, the division of these responsibilities is not always apparent in practice either. Similar to its neighbor in the South, the Canadian federal government has also used its authority to influence provincial policies and decisions (Government of Alberta, 2015).

Overall, the distinctions between provinces and states are not very clear. They depend predominantly on provinces' and states' financial autonomy and dependency on federal regulations for specific subject areas such as natural resources, marine habitat, and environment. For example, the provinces are larger and financially more independent than the states. They do not depend heavily on the federal transfers, as they raise large proportions of the provincial revenue, compared to the states (Simeon and Radin, 2010). On the other hand, states have their own constitutions, which do not conflict with but go beyond the federal constitution and allow states to shape their institutional structures (Arnold, 2004). In Canada, only BC has its own constitution, through the BC Constitution Act of 1996, which is not the equivalent of the state constitutions and can be easily amended (Morton, 2004). In general, there is a consensus in the literature that the provinces have more decision-making authority than their American counterparts, because they are financially more independent (Hamilton, 2013).

Local governments

Local governments are not recognized under the Canadian and American constitutions (Shah, 2006). Therefore, the decision-making authorities of the local governments are defined by the provincial and state governments (Dewing et al., 2006; Hamilton, 2013). However, there are major differences between the authorities allocated to the local governments in Canada and the United States. For example, the state governments have allocated greater authorities to their local governments compared to the provinces, leaving local governments in Canada with hardly any real power (Duffy et al., 2014). In fact, the Canadian local governments are restricted in their ability to raise revenue, and access and allocate financial resources as they are subject to a significant number of provincial rules and regulations (Dewing et al., 2006). On the contrary, the United States local governments have access to a broad range of financial resources. There is also a significant variation in municipalities' access to revenue tools (Kitchen, 2004). For example, the Canadian local governments have direct access to only property tax, which makes up more than 90% of all local government tax revenue (Kitchen, 2004). In the United States, however, local governments may have direct access to one or all of the income tax, sales tax, and property tax (Kitchen, 2004, 2002). As a result, the Canadian local governments rely more heavily on the federal and provincial funding sources for infrastructure projects and development and implementation of specific programs such as adaptation, compared to the American local governments.

The local governments in Canada and the United States have experienced a significant increase in their responsibilities, starting around the 1980s and 1990s (Berkes, 2010; Kousser, 2014). This increase was due to the transfer of the regulatory and financial responsibilities from senior levels of governments to local governments, which is called "the downloading (also known as offloading)" in Canada and "the devolution" in the United States (Hamilton, 2013; Duffy et al., 2014). In Canada, the downloading was carried first through the significant cuts in transfer payments from the federal government to provincial governments. Next, it was carried through the transfer of the essential responsibilities, such as flood protection, from provincial governments to local governments without providing sufficient funding or additional revenue sources (UBCM, 2011; Duffy et al., 2014). While resulting in significantly more autonomous provincial and local governments, the downloading created significant concerns over local governments' ability to carry out these responsibilities (UBCM, 2011). In the United States, the devolution aimed to reduce the size and role of the federal government and was carried through the provision of the block grants with overarching federal goals and guidelines to the states, which was then distributed to the local governments (Rodríguez-Pose and Gill, 2003; Hamilton, 2013). As a result, the states were allocated more responsibilities in developing and administering state-specific programs to achieve the federal goals (Hamilton, 2013).

In Canada, the downloading influenced the environment and the related infrastructure most (Duffy et al., 2014, p.6). In the United States, the devolution mainly impacted the welfare and healthcare areas, rather than the environment (Rodríguez-Pose and Gill, 2003; Kousser, 2014). Consequently, adaptation, and particularly flood management have become the main regulatory and financial responsibility of the local governments in Canada (UBCM, 2011; Duffy et al., 2014). The decentralization of some key services has essentially increased the local government expenditures in BC and WA (Hamilton, 2013; Duffy et al., 2014). However, the impact has been stronger in Canada, where the local governments have already had limited access to the revenue tools (UBCM, 2011). In a survey of the 133 municipalities, Duffy et al. (2014) found that 83.6% of the municipalities agreed that the downloading had been a major concern and challenge for their local government. The downloading of the senior government responsibilities to the local governments, without providing direct (through grants or programs) or indirect (through access to financial tools) have prevented local governments in BC to bridge the gap between what is needed to provide services and what is available (Duffy et al., 2014).

The decentralization of the senior level responsibilities has fundamentally transformed the authority distribution and roles of federal, provincial, state and local governments in Canada and the United States. Although the initial approach to bring regulatory responsibilities closer to the people affected is meaningful and breaks the one size fits all thinking (Hamilton, 2013); the lack of financial support and change in the existing financial mechanisms, and inequality over the ability of different local governments to handle these new responsibilities (Duffy et al., 2014) have led to the new debates on the roles of senior governments (Berkes, 2010).

4.4.2.2 Coastal jurisdiction and ownership

Besides the differences in their governance systems, Canada and the United States also have significant differences in their coastal jurisdiction and ownership (Figure 4.9). Jurisdiction here refers to the official decision-making authority to interpret and apply laws (Blair, 2009), and to regulate and manage issues through permits and programs in a specified spatial boundary. The jurisdictional boundaries, corresponding responsibilities, and conflicts due to ownership are not well-understood (Bauer et al., 2012). This misunderstanding is because the jurisdictional boundaries do not always reflect ownership, and ownership does not always translate into having jurisdiction. Therefore, understanding which aspects of the coastal areas falls under which level of governments' jurisdiction, and relates to which regulations (Becklumb, 2013) are significant when investigating the barriers to and facilitators of CGI implementation.

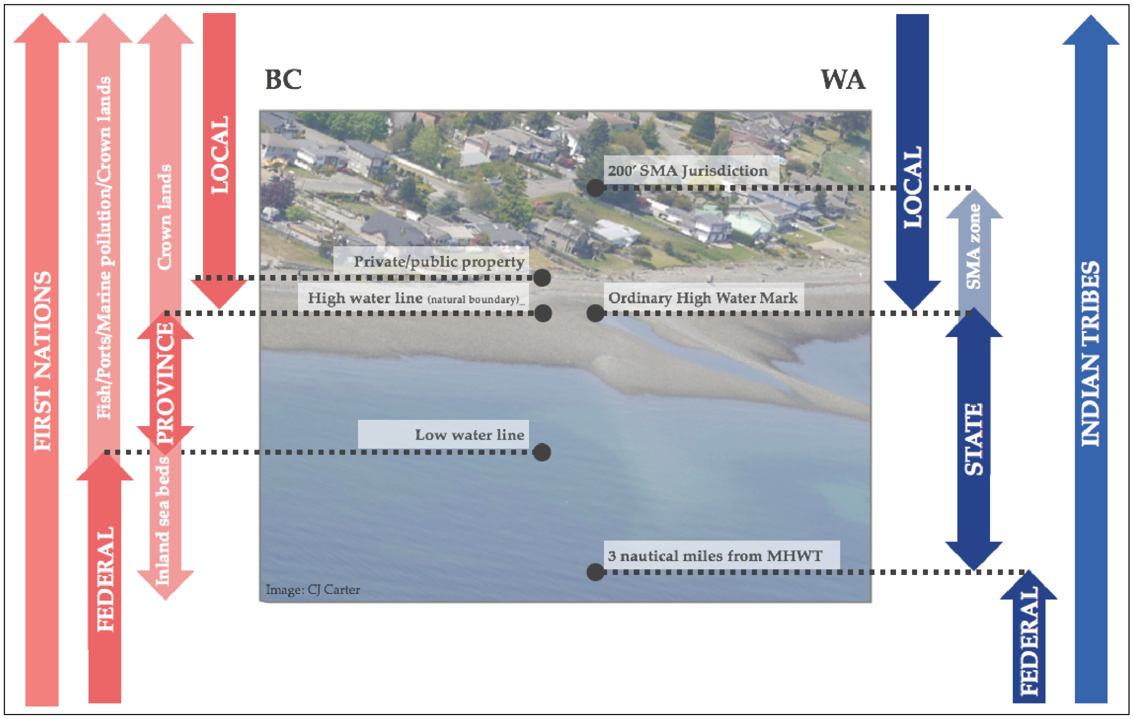

Figure 4.9: The graphic illustration of the coastal jurisdiction in BC and WA. Distances are not to scale.

Canada and BC

In Canada, the federal government and provincial governments have jurisdictions over lands, waters, and submerged waters they own. The local governments have jurisdiction over the land they own. However, there are several important overlaps (Giest and Howlett, 2013) as seen in Figure 4.9.

The federal government's jurisdiction and ownership extends from the low water mark (LWM) to 12 nautical miles in the Territorial Sea[1], to 200 nautical miles in the Exclusive Economic

[1]The Territorial Sea extends from the low water mark up to 12 nautical miles out to sea (Fisheries and Oceans

Zone[2] (Fisheries and Oceans Canada, 2011). This jurisdiction can also extend over the coastal riparian areas if the land is a federal Crown land (Blair, 2014). Within its jurisdiction, the federal government regulates environmental issues related to federally owned properties; coasts and fisheries; navigation and shipping; marine pollution and interprovincial water pollution; criminal law; boundary waters; migratory birds; and First Nations and First Nations lands (Becklumb, 2013, p.1-2).

The First Nations governments are sovereign nations and have jurisdiction to use and manage terrestrial and aquatic lands within their territories. This jurisdiction is subject to the nation to nation treaty negotiations between the First Nations governments and the federal government outside of their territories (Blair, 2014; McLeod et al., 2015). The federal and provincial governments have to consult with the First Nations governments on issues related to the "wildlife movement, supply and access; decisions with respect to pollution from construction or use that may affect flora or animal populations; change in regulation or policy that may restrict land use; federal life cycle of land management that may affect legal obligations and relationships with Aboriginal groups; or decisions with respect to use of natural resources that may limit supply and use by Aboriginal groups" (Minister of the Department of Aboriginal Affairs and Northern Development Canada, 2011, p.11).

The provincial jurisdiction and ownership at the coast extends throughout the foreshore (also known as the intertidal zone), which is the area between the low water mark[3] and the natural boundary[4] (Nature, 2002). This jurisdiction can extend over the coastal riparian areas if the land is a provincial Crown land (Blair, 2014). In BC, the provincial jurisdiction and ownership expand further from the low water mark towards inland seabeds such as the Strait of Georgia (Blair, 2014), and "submerged lands between major headlands such as bays, estuaries and fjords" (Fisheries and Oceans Canada, 2009, p.2). Within their jurisdiction, provincial governments regulate environmental issues related to the property and civil rights; regulation of most types of business, natural resource industries, and emissions; management of provincial Crown lands; and regulations related to municipal institutions (Becklumb, 2013, p.2). The provincial

Canada, 2011; USCOP, 2004a)

[2]The Exclusive Economic Zone (EEZ) refers to the zone between the Territorial Sea to a maximum of 200 nautical miles (Fisheries and Oceans Canada, 2011; USCOP, 2004a).

[3]The low water mark is the level reached by water at low tide (Fisheries and Oceans Canada, 2018).

[4]The natural boundary (high water mark) is the level reached by water at high tide (Fisheries and Oceans Canada, 2018).

governments do not regulate marine pollution as it is under the federal jurisdiction (Becklumb, 2013). In addition, the fish habitat in the coastal areas falls under the federal jurisdiction.

Local governments own and have jurisdictions over the land starting from the natural boundary and extending over their municipal boundaries (Blair, 2014). There are also exceptions if the land is federal and provincial Crown land. Within their jurisdiction, local governments regulate land use, building permits, development, waste management, and drinking and wastewater (Becklumb, 2013).

The United States and WA

In the United States, lands, waters and submerged waters can be privately owned or owned by a government institution, yet regulated by another.

Traditionally, the state governments had jurisdiction to govern coastal areas, but this responsibility had shifted to the federal government in the 1970s (Paddock, 1990). The federal jurisdiction at the coast extends from the mean lower low water line (MLLWL)[5] to 12 nautical miles in the Territorial Sea, and to 200 nautical miles in the EEZ (USCOP, 2004a). The federal government gives authority to the states to manage and regulate the zone known as the Shoreline Management Area (SMA)[6]. Within its jurisdiction, the federal government regulates environmental issues, which include coasts and fisheries; navigation and shipping; commerce; power generation; national defense; and international affairs (USCOP, 2004b).

The Indian Tribes are sovereign nations and assert their right to govern their members and lands, and control decision-making within their territories (Arnold, 2004; Kalt and Singer, 2004). This area also includes the intertidal lands if the land tenure is owned by the Tribes (NOAA, 2018a). Within their territories, the Tribal governments have rights to regulate matters such as economic development; natural resources; land use; religious and spiritual sites; wildlife habitat; and sensitive environmental areas, amongst others (Logsdon, 2001). Outside of their territories, the Tribal governments have special rights such as fishing, due to nation-to-nation treaty negotiations between the Tribal governments and the federal government (Miller, 2001). The Tribes governments co-manage the fishery resources with the states governments and the federal government (NOAA, 2018a).

[5]The mean lower low water line (MLLWL), refers to the line that represents the elevation of mean lower low water (NOAA, 2018b).

[6]The Shoreline Management Area in WA includes the area between the state waters (3 nautical miles in the territorial sea) and 200 feet inland.

The state governments have jurisdiction within the SMAs (State of Washington Department of Ecology, 2009). Although the federal government has jurisdiction over the states waters, the state governments were allocated the authority to govern individuals, property, and enterprises within the SMA boundaries (USCOP, 2004b) and "manage, develop, and lease resources throughout the water column and on and under the seafloor." (USCOP, 2004a, p.71).

The counties and municipalities have "regulatory, administrative, and taxing authorities" as determined by their state governments (Arnold, 2004, p.25). Within their jurisdiction, they are responsible for local recordkeeping and elections; creating and updating shoreline management plans, zoning, building codes; construction and maintenance of local and rural roads; and law enforcement (Arnold, 2004). Contrary to BC, beaches and tidelands can be privately owned by individuals in WA. The privately owned lands are still subject to local, state and federal regulations.

4.4.2.3 Coastal and environmental regulations and programs

Various coastal and environmental regulations are applied within the federal, provincial and state jurisdictions described above. The CGI projects in BC and WA may have to comply with various regulations and obtain permits from a number of different institutions. The complete list of the relevant CGI regulations, administering institutions, and the required actions can be found in Appendix C.3 and C.4. These regulations influence actions, policies, and programs related to CGI; therefore can be barriers to and facilitators of CGI implementation.

Regulating the coasts

- Canada

Fisheries and Oceans Canada (DFO), previously known as the Department of Fisheries and Oceans, is delegated as the main federal institution to govern oceans and marine habitats under the Department of Fisheries and Oceans Act (1985) and Oceans Act (1996). The DFO was also allocated jurisdiction to regulate and manage fisheries, the quality of fish-bearing waters and habitat, and marine plants and marine mammals under the Fisheries Act (1985); as well as the safety of coastal areas through the Canadian Coast Guard (Blair, 2014; Becklumb, 2013).

Transport Canada (TC) is another important federal institution involved in the management of coastal areas. Under the Canada Shipping Act (2001), the TC regulates emissions, sewage, oil discharges, as well as shipping routes and safety (Becklumb, 2013). Under the Navigation Protection Act (1985), the TC regulates in areas where there are navigable waters[7] (Blair, 2014) to reduce hazardous conditions to navigation (Sheffield, 2013). Under the Canada Marine Act (1998) TC regulates and manages harbor and shipping facilities that are in the federal Crown lands such as port authorities and major harbors (Becklumb, 2013).

Parks Canada regulates and protects marine areas through the Canada National Marine Conservation Areas Act (2002), and natural areas of national significance through the Canada National Parks Act (2000). Environment and Climate Change Canada (ECC) protects endangered or threatened species and their habitats through the Species at Risk Act (2002). The EEC creates, protects and regulates wildlife areas for research and conservation through Canada Wildlife Act (1985). It also regulates and protects migratory birds and their habitats through the Migratory Birds Convention Act (1994).

Under the Canadian Environmental Protection Act (1999), the ECC and Health Canada collaboratively assess the environmental and human health impacts of projects, particularly the risks from pollution (Becklumb, 2013). The Canadian Environmental Assessment Act, managed by the Canadian Environmental Assessment Agency, necessitates federal departments to assess the impacts of the federal projects on the environment and human health (2012).

- British Columbia
In BC, provincial laws are administered to activities on and related to natural resources, marine resources, and subsurface resources (Fisheries and Oceans Canada, 2009).

The Ministry of Environment and Climate Change Strategy (MoECCS) is the main provincial institution responsible for the "protection, management and conservation of" provincial resources such as land, water, air, and living resources under the Environmental Management Act, EMA (Ministry of Environment, 2016, pg.1). The EMA regulates environmental issues related to pollution, hazardous waste, waste discharges, and contaminated sites; and air quality (Sheffield, 2013; Ministry of Environment, 2016). The MoECCS also regulates all actions "constructed, assembled or installed to prevent the flooding of land" under the Drainage, Ditch and Dike Act (1996) or primarily by appointing an Inspector of Dikes under the Dike Maintenance Act (1996) (Fisheries and Oceans Canada, 2009). This responsibility includes approval of the construction, design, and changes to dikes; determining standards and design criteria for flood protection in-

[7]Navigable waters refer to the waters that can be passed even with a vessel

frastructures; working with the local diking authorities to monitor the management and assess the safety of flood protection infrastructure (The Arlington Group, 2010). The MoECCS also manages and administers all matters concerning parks, conservancies and recreation areas under the Park Act (1996) (BC Parks, 2018); designates Crown land for conservation under the Environment and Land Use Act (1996); and designates parks, recreation areas and conservancies under the Protected Areas of British Columbia Act (Fisheries and Oceans Canada, 2009).

The Ministry of Forests, Lands, Natural Resource Operations and Rural Development (FLNRRD) regulates seabed lands such as Strait of Georgia, and provincial Crown lands through the Land Tenure Branch under the Land Act (1996) (Becklumb, 2013). This responsibility includes allocation of land for industrial, private dock and commercial marina uses; permits; and land tenures (licenses or leases) to the federal government, First Nations, and local governments (Blair, 2014). The FLNRRD also protects riparian areas by requiring a Qualified Environmental Professional to assess proposed residential, commercial, and industrial development before local government approval under the Riparian Areas Protection Act (2016), formerly Fish Protection Act (The Ministry of Forests, Lands, Natural Resource Operations and Rural Development, 2016). In addition, the FLNRRD designates Wildlife Management Areas to manage and conserve fish, wildlife and their habitats under the Wildlife Act (1996) (Fisheries and Oceans Canada, 2009).

The BC Environmental Assessment Office regulates the Environmental Assessment Act (Environmental Assessment Office, 2018), except for the projects with implications on matters under the federal jurisdiction (Becklumb, 2013). The Land Title and Survey Authority of British Columbia manages "registration of land titles and the subdivision of lands." under the Land Title Act (Fisheries and Oceans Canada, 2009, p.13).

Under the Local Government Act (1996) and the Community Charter Act (2003) the local governments in BC govern and regulate, coastal riparian lands using bylaws, ordinances, zoning regulations, building permits, and specific plans such as Liquid Waste Management Plans.

- The United States
The National Oceanic and Atmospheric Administration (NOAA), under the Department of Commerce, was delegated as the main federal institution to manage coastal areas (Day and Gamble, 1990). Arguably, the most important regulation related to the management of the coastal areas in the United States is the Coastal Zone Management (CZM) Act (1972). This is because

through CZM, NOAA delegates state governments' responsibilities including the protection of natural resources (estuaries, beaches, dunes, barrier islands, and wetlands) and minimizing the loss of life and property from hazards, and evaluates state Coastal Zone Management programs' performance to approve or withhold federal funding and approval (USCOP, 2004b).

Under the Magnuson-Stevens Fishery Conservation and Management Act (1976), NOAA also regulates fishing activities in federal waters. The U.S. Army Corps of Engineers (USACE) regulates the nation-wide permit and development in the state waters (USCOP, 2004b) to prevent obstructions to navigation, under the Rivers and Harbors Act (1899).

NOAA and the U.S. Fish and Wildlife Service (FWS) regulate "the conservation of threatened and endangered plants and animals" and the habitats, under the Endangered Species Act (1973) and the Fish and Wildlife Act (1956). They also regulate the marine mammal species and population stocks under the Marine Mammal Protection Act (1972).

The Environmental Protection Agency (EPA) under the Clean Air Act (1970) regulates air emissions and protects public health (USCOP, 2004b). Under the Clean Water Act (1972), the EPA regulates activities affecting water quality, and pollutant discharges (USCOP, 2004b). EPA administers the National Environmental Policy Act (1969), which requires the assessment of the impacts of federal projects and decisions on the environment by the corresponding federal agencies. Under the Beaches Environmental Assessment and Coastal Health (BEACH) Act (2000), the EPA manages program developments for states, territories, and tribes to increase their water quality standards for public use. The EPA also develops ocean dumping criteria and evaluates permit applications under the Marine Protection, Research, and Sanctuaries Act (1988). EPA and the Coast Guard, "regulates the transportation of municipal and commercial wastes in coastal waters", under the Shore Protection Act (1988). Lastly, under the EPA, the Office of Pollution Prevention and Toxics manages programs aimed to reduce pollution and increase resource efficiency under the Pollution Prevention Act (1990).

- *Washington State*
WA has jurisdiction to regulate coastal issues in the state waters, but also has to comply with the abovementioned federal regulations (USCOP, 2004b).

The Department of Natural Resources manages the natural and living resources and human-made structures in and above of the state-owned aquatic lands under Title 332 of the State Legislature (1889). The Department of Ecology (DoE) regulates all private, local government, and state government actions on lands privately owned or owned by the local and state governments(State of Washington Department of Ecology, 2009) under the Shoreline Management Act (1971). The DoE also has regulatory control over the formation and co-management of the flood control districts (State of Washington Department of Ecology, 2004), under the Flood Control Act (1935) and the Diking and Drainage Act (1985. The DoE implements these acts in partnership with the local governments (Adelsman et al., 2012). In addition, under the Climate Leadership Act, the DoE oversees the integrated climate response strategy and the use of this strategy in the planning and designing policies and programs (Ziff, 2017)

The Department of Fish and Wildlife (WDFW) conducts a review process of permit applications, plans and policies to assess their environmental impacts under the State Environmental Policy Act, (1971). Under the State Hydraulic Code, the WDFW also regulates construction projects or activities such as works on bulkheads, culverts, bridges, and sediment dredging projects in or near state waters through the Hydraulic Project Approval. The Department of Archaeology and Historic Preservation regulates all alterations to an archaeological site under the Archaeological Resources Protection Act (1979).

The local governments in WA govern coastal riparian lands using by-laws, ordinances, zoning regulations, building permits under the Title 35 Cities and Towns (1969), and Title 36 Counties (1969). Under the state's Shoreline Management Act, local governments regulate and administer "the substantial development permits, conditional use permits, and variance permits".

Coastal and environmental programs

Coastal and environmental programs (i.e., grants, projects, or services) that are provided by different levels of governments to assist provincial, state and local governments, organizations, and individuals in matters related to coasts and environment. These programs provide incentives for actions such as habitat restoration, adaptation, and land conservation, amongst others. For example, the National Wetland Conservation Fund operated by the Environment and Climate Change Canada provides funding to projects that conserve and protect wetlands (Environment and Climate Change Canada , 2018). Similarly, the Estuary and Salmon Restoration program operated by NOAA provides funding and guidance to protect estuary habitats (National Oceanic and Atmospheric Administration, 2018).

Coastal and environmental programs in the study area were searched in the official government and NGO websites. The review identifies diverse federal, provincial and state level programs that are available for CGI implementation. This review shows that there have been significantly more programs in WA and the United States. The programs in the United States have started around three decades earlier than in Canada (Figure 4.10). In addition, the programs in WA have also started much earlier than the provincial programs in BC. Particularly since 2010, there has been a significant increase in the number of Canadian federal and BC provincial programs.

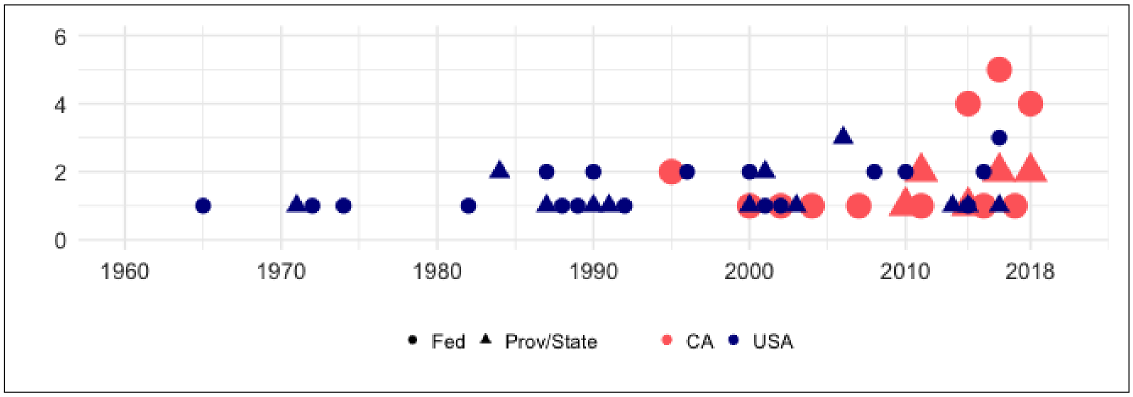

Figure 4.10: The timeframe of the coastal & environmental programs in Canada, BC, the USA, and WA

Besides the number of programs, a significant portion of the programs in the United States and WA have been continuous, where most of the programs in Canada and BC have been initiated for a limited period of time (Figure 4.11).

Unfortunately, the data on federal, provincial, and state grants and funding are not comparable because the information was not reported in a uniformed way across the study area. The funding information was sometimes available in the maximum amount available per project format, and other time in the total project funding per year format. However, the availability of the number of grants and funding in WA has been higher than in BC. The list of programs, lead institutions, time frames, and total or max. per project grant information can be found in Appendix C.5,C.6, C.7, and C.8.

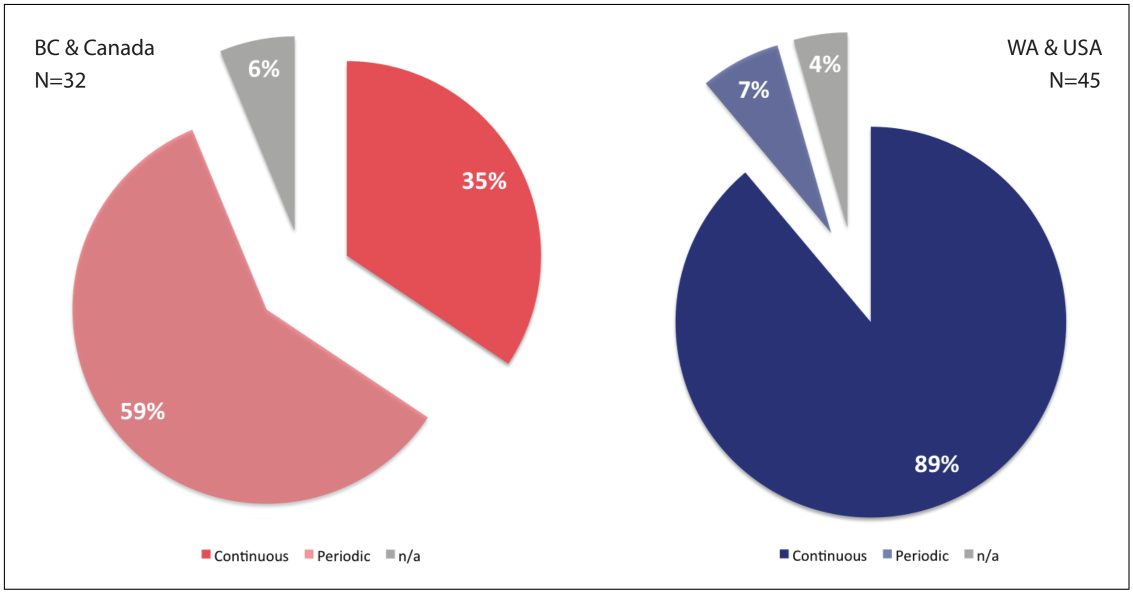

Figure 4.11: The continuity of the coastal and environmental programs available in WA and BC

4.4.2.4 Summary of the review and synthesis of the institutional arrangements results

The results of the review and synthesis of the institutional arrangements indicate that there are no clear authority distinctions in BC and WA. The BC provincial government is financially more independent than the WA government. The decentralization of the regulatory and financial responsibilities has altered the federal, provincial, state and local governments' roles in Canada and the United States. As a result, the local governments in BC has significantly less access to financial and other resources than the local governments in WA.

The results also show that the coastal jurisdiction in BC has multiple important overlaps. These overlaps are between the local, provincial, and federal jurisdictions. Overall, the provincial jurisdiction in BC is limited to a small strip at the coast. The BC provincial jurisdiction widens when there are inland seabeds such as Strait of Georgia. In WA, the state government was allocated the jurisdiction of the SMAs, which is the area between 200 feet inland to 3 nautical miles in the Territorial Sea.

A long list of coastal and environmental regulations are identified in this review. The results suggest that the CGI projects in BC and WA may have to deal with the similar number of regulations. In general, the contents of these regulations are similar across BC and WA. They deal with similar issues related to the air and water pollution, the safety of the navigable waters, marine and land habitats, fish populations, habitat, and passages, and other relevant issues. The most significant difference between BC and WA in coastal and environmental regulations is the CZM Act in the United States, which allocates states authority to regulate a large portion of the coastal zone that includes landward and seaward sides of the WA's coastline. In BC, the provincial government's role is limited to a narrow strip in the intertidal zone.

Lastly, there are numerous coastal and environmental programs in BC and WA. The results show that in the past 50 years there have been significantly more federal and state programs available for the CGI projects in WA than in BC. These programs have been predominantly continuous, and have been operating for longer than the programs in BC.

4.4.3 Semi-structured interviews

A total of 10 semi-structured interviews, five in each region, were conducted during April and May 2018. In each region, two participants were from the local governments, two participants were from the local NGOs, and one participant was from the provincial or state government. Table 4.1 shows the institutions of the interview participants.

	British Columbia	**Washington State**
Non-governmental organizations	1. Peninsula Streams Society 2. Fraser River Estuary Management Program	1. Northwest Straits Foundation 2. Puget Sound Partnership
Local governments	1. City of Surrey 2. Town of Qualicum Beach	1. Kitsap County 2. Skagit County
Provincial-State governments	1. Ministry of Environment and Climate Change	1. Department of Recreation and Conservation Office

Table 4.1: The institutions of the semi-structure interview participants

The interviews were conducted on the phone and in person. Interviews lasted between 40 minutes and 70 minutes. The interviews were audio recorded for analysis purposes. Each interview followed the protocol described in the Section 4.3.2 and can be found in Appendix C.2. After the interviews were completed, the verbatim transcriptions of the audio files were created. The transcripts were first coded to large themes such as "Barriers", second to sub-themes such as "Financial" and last to specific themes such as "Funding amount" using the NVIVO software.

The findings of the semi-structured interviews were organized into seven main themes to provide a structured way to explain the results and to compare BC and WA. These themes are not meant to be mutually exclusive. The barriers and facilitators under each theme can be relevant to some of the other themes. The seven themes are as follows:

- Financial,
- Jurisdiction and ownership,
- Regulations,
- Capacity and resources,
- Vision and leadership,
- Collaborations, and
- Community and knowledge.

The analysis of the semi-structured interviews has identified a number of institutional barriers to and facilitators of CGI implementation. The barriers that were most common both in BC and WA were financial, the funding amount and continuity, and timeline limitations of funding sources; and regulations, permitting processes and the wait time to obtain approvals. In BC, the regulations, financial, capacity and resources, and jurisdictional barriers were mentioned by most of the participants. In WA, the financial and regulations barriers were mentioned by most of the participants. In both BC and WA, the vision and leadership, financial, capacity and resources, collaborations, and community and knowledge facilitators were mentioned by most of the participants.

Each of the barrier and facilitator themes is described below. Each section also includes a graphic showing the different concepts of each theme. The scale bar from 0-5 indicates how many respondents mentioned the concept as a barrier and/or a facilitator. The pink and blue reflects the respondents from BC and WA, respectively.

Financial

As mentioned above, financial issues were recognized to be one of the most common barriers in BC and WA (Figure 4.12). Particularly, the funding amount and continuity, and the timeline limitations of funding sources were frequently mentioned by all of the participants.

Figure 4.12: The financial barriers and facilitators in BC and WA

The participants in BC suggested that the downloading of the senior level government responsibilities on the local governments, without providing means to finance them, have created even larger needs for funding. The participants acknowledged that the funding amount in WA has been significantly higher and has been available for a longer time than in BC. However, they still described a continuous need for more funding to achieve local, regional and national goals. One participant from a WA state department explained the funding need this way:

> "In the beginning projects tended to be somewhat opportunistic. They were kind of relatively easy to address and implement in a very short amount of time and didn't cost an incredibly large amount of money. And what we are finding now that the projects are more complex, they involve more partners, they are being implemented in phases, and the funding may be available only for certain phases."

The participants described that even they receive funding for a project, it is typically for a limited two-three year period, which is not long enough to cover all the project steps such as planning, design, consultation, permit applications, waiting for approvals, waiting for fish windows, construction and monitoring. They indicated that by the time they are ready for implementation, their funding cycle expires, creating a significant barrier for the CGI implementation. One participant from an NGO in BC described the time limitations of fundings as follows:

> “[The funding agency says] you have got 12 months to do it and you go. But our work window is between July 15th to September 15th. They do not understand that in Ottawa, right.”

The participants also described how the funding is used and on what, as a barrier. Notably, the availability of the funding only for the site assessment, planning, and design, or construction phases of the projects life cycle has frequently been reported. In addition, the lack of funding for specific actions such as land acquisition to create and rehabilitate CGI was noted as a barrier.

The participants also acknowledged funding as a key facilitator. From small seed funds to help with project applications or initial assessment of habitats, to large funds for complex and multi-objective projects, the funding amount and types create new opportunities for communities of all sizes and capacities to implement CGI projects. One participant from a WA NGO described how they use the small seed funds this way:

> “We are working right now to identify a stable funding source to provide loans to people to remove their shoreline armoring (...) a very successful program has been giving workshops and giving people a five thousand dollar grant to look into removing their shoreline armoring and to get the feasibility done on those. A high percentage of those small loans have resulted in the removal of armors.”

The variation in funding sources, particularly in politically challenging times, reduces dependencies on one funding source and ensures that there are continuous funding sources for the CGI projects. The cost-saving opportunities, such as bringing landowners together for one project application is also reported as a facilitator of CGI implementation. Lastly, the availability of the specific funding sources for land acquisition was defined as a driver of the CGI projects.

Jurisdiction and ownership

Jurisdiction and ownership is another major theme that has been described as a barrier and facilitator (Figure 4.13). The common concepts identified during the interviews include jurisdictional boundaries, organizational mandate/authority, organizational structure and involved parties, and private ownership of coastal areas.

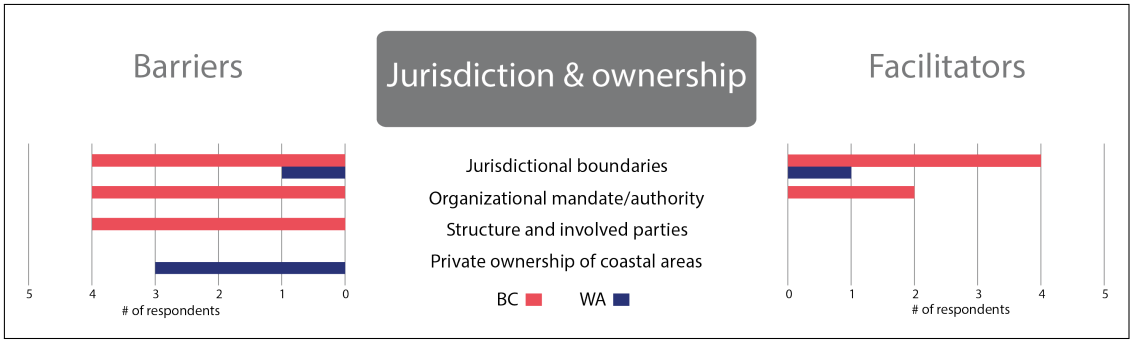

Figure 4.13: The jurisdiction and ownership barriers and facilitators in BC and WA

The participants in BC stated that the coastal jurisdiction is not always apparent, and often cited "the layers of overlapping jurisdictions" on the coastline. They also described the complexities that result from the way the jurisdictional boundaries are structured. As described in the previous section, the jurisdiction of coastal British Columbia has a number of overlaps below and above the natural boundary, which cause ambiguities regarding identifying institutions with decision making authority. They stated that operating within this jurisdictional context, and finding the right government departments or other involved parties pose significant challenges for the CGI projects. A participant from a local government in BC has explained the jurisdictional issue they experience this way:

> "The jurisdictional overlap on the foreshore, I would say is one of the biggest hurdles to effective decision making because our jurisdiction overlaps with the province's ownership of the land on the foreshore. (...) [The province] owns the Crown land but they do not always have the ability to bring things into too much detail as local governments do."

On the other hand, the participants in WA described challenges related to the private ownership of the coastal areas, particularly the tidelands, rather than the jurisdictional issues. They described that even though there are many jurisdictions involved in the coastal areas, the jurisdictional boundaries, and the roles of different institutions are relatively clear. However, they described the private ownership of the coastal areas as a significant challenge for CGI implementation. The participants cited that the private ownership of coastal areas in WA has resulted in the fragmented and uncontrolled development of different coastal protection measures. A participant from a WA state government described it this way:

> "In Washington State, almost 70 percent of the tidelands are not in government ownership and not in public ownership. So the land that private landowners may own are tidelands which has led to all the development going on along the shoreline kind of uncontrolled for a long time."

The participants from both sides, but mainly from BC, described the clarification of jurisdictional boundaries as a facilitator of the CGI implementation. One participant from an NGO in BC stated that "it is important to have those jurisdictions very clearly outlined and have all the players at the table when you are trying to make progress".

Most of the participants in BC suggested that the limitations in their decision-making authority or lack of mandate of their organization were significant barriers to the CGI projects. They often cited the bureaucracy they have to go through and the challenges related to "how different authorities might react to some of the bold approaches required" for adaptation (Participant from a local government in BC). Some of the participants recognized the decision-making authority and a structured organizational mandate as facilitators of the CGI projects. For example, one participant from an NGO in BC suggested that " governments need to be stronger in terms of preventing walls from being built unless there is absolutely no alternative".

Regulations

The participants in BC and WA described frustration over the regulations and regulatory processes related to CGI projects (Figure 4.14). Particularly issues related to the number of permit applications they have to go through, the review processes, and the time they have to wait to obtain approvals.

Figure 4.14: The regulations barriers and facilitators in BC and WA

Some of the participants in BC stated that they are not entirely sure what specific rules and permits they would need in certain areas. Most of the participants in BC perceived the challenges with the permitting processes as direct results of the jurisdictional ambiguity and the disconnection between departments and government levels. They described the existing regulations in BC that permits are set up to favor traditional hard solutions over CGI. One participant from a local government in BC stated:

> "The governance structure is actually set up to default to the worst solution [hard solutions]. And that is one of our biggest challenges right now. The approvals process, resulted from that jurisdictional gray area, (...) is cumbersome and doing it the right way is harder than doing it the wrong way."

This participant explained that it is easier to build a seawall within the municipal boundary, rather than to go through the lengthy process of permit applications with the provincial and federal governments within the current regulatory environment.

One participant from a local government in BC explained the permitting barriers as contradictions between different regulations, and disconnections between different departments and government levels:

> "A lot of times we find ourselves in the local government being sort of caught between two contradictory regulations. One says do X the other says Z, and they are not mutually exclusive. Then it makes it very difficult to control which one is before or how to work through that difference. (...) The contradictions often come within the province. Different departments or ministries I should say, and then between the different levels of government. There's very little coordination between the two. To the extent where it might take eight months to hear back from one group at the province for an application and from the federal government you may find out sooner, but the whole point is that it has been completely siloed."

Although the permitting processes were described as a significant barrier in WA, the participants also recognized the value of these regulations. They stated that the permits ensure the coastal areas are protected. The participants in WA viewed stated that the permitting processes as ”big hurdles”, yet they stated that they are used to them, and know what to do and whom to call. The main issue they experience was related to the burden of the permitting processes on individual homeowners, as the processes can be costly and confusing. A participant from an NGO in WA explained it this way:

> "We go to the full permitting process like any other project be required to do, and I would not say that I am bothered by any single regulation. I think I agree with the majority of the regulations that are out there. The challenge that we have and I think probably other organizations have, is really the amount of time that it takes to go through the permitting process here. (...) If there were fewer permits, then you would get more private property landowners that would be willing to engage in the [CGI] process."

On the other hand, the participants suggested that a streamlined permitting process would be a significant driver of the CGI projects. Both in Bc and WA, the participants agreed that the streamlined processes would reduce confusion, complexities and the wait time to receive approvals. A participant from a local government in WA described the way they try to reduce barriers related to permitting as follows:

> "For the permitting barrier, we put we put together permitting packages and then we also offer what we call "a restoration site consultations" where we kind of coordinate with local permit reviewers. So we will go up to the site with the homeowner, the engineers, or other involved parties. We talk about the site and the homeowners' objectives and then determine what permits would be needed in the case, what studies and plans that needs to be part of the permitting process. That really streamlined the process in the way that everybody involved knew from the very beginning what was required and what was not required so that they could save time and money in getting the permits through the process."

The wait time for the permit applications was characterized as a significant regulations barrier for the CGI projects. The participants from both side often cited " the workload" and "the lengthy review processes" as challenges. One participant from an NGO and then potentially lose your funding if your grant is only for a specific amount of time. So the permit process can be cumbersome."

The lack of proactive climate change and adaptation training for professional and building standards, such as engineering or planning certificates were also characterized as barriers in BC. Particularly one participant from the provincial government in BC described the professional reliance model used in BC and its short-comings this way:

> "It runs on the assumption that engineers will be prompted by their [engineering] association to acquire appropriate training to be capable of advising on decisions related to future climate. (...) But in reality, we are not there yet. We have many competent engineers who have all the necessary qualifications that engineers need to have. But they do not really understand yet how they should consider future climate information".

One participant from a local government in BC described these standards as an important potential driver of CGI projects. Lastly, the land use demands and regulations were considered to be both a barrier and a facilitator in BC. For example, balancing between the type of coastal access industries need and creating habitat was reported as a barrier.

Capacity and resources

Main barriers of the capacity and resources theme are senior level support, precedent, and staff expertise; while the main facilitators are senior level support, and processes regarding meetings, reviews and decision making (Figure 4.16).

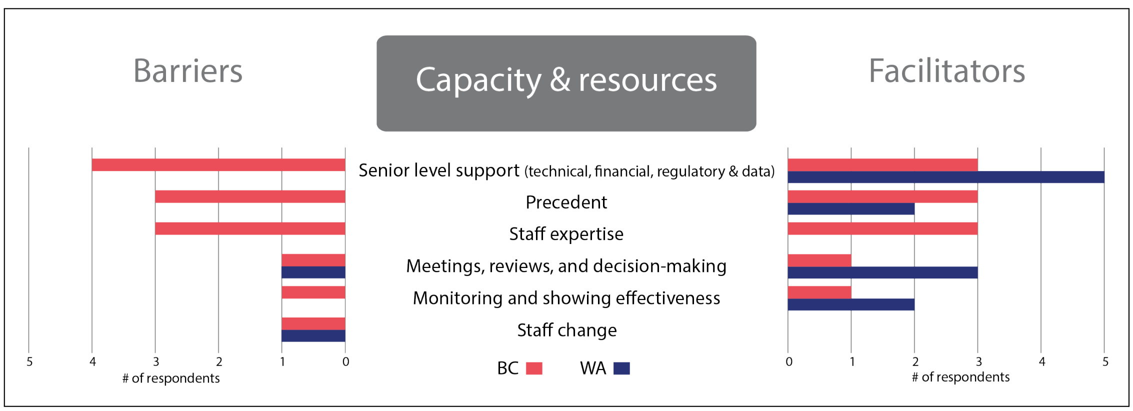

Figure 4.15: The capacity and resources barriers and facilitators in BC and WA

The participants in WA did not indicate significant capacity and resources related barriers, except for challenges related to ineffective meetings, project reviews and decision-making processes. They noted that these barriers influence the time it takes to get things done. Providing staff with training in facilitation and hosting efficient meetings were seen as facilitators that help overcome these barriers. The frequent staff change in key organizations and positions were also identified as a barrier. The participants described that where it was time-consuming to find the right person and build functioning relationships. These barriers were also reported in BC.

The constant struggle to show the value of partnerships and effectiveness of project implementation were described to be a barrier in BC, and a facilitator in both regions. A participant from an NGO in BC described the issue as follows:

> "You continually had to show, check in, and make sure you are showing value. Because the minute [partners] felt like they were not getting value, they would start to question their [monetary] contribution and not send staff to the meeting."

The lack of the necessary staff expertise was characterized as an important barrier in BC and the presence of it as an important facilitator. For example, the continuous empowerment and education of local planners and engineers were reported as important facilitators.

The lack of precedents such as case study examples and demonstration projects were cited as an important barrier to and facilitator of developing new CGI projects. A participant from a local government in BC stated "I do not think there are many examples or sort of a procedure for how to work through those issues, and it is a big problem". The presence of these examples, and learning from them were identified as an important facilitator. A participant from a local government in WA explained it this way:

> "We did a demonstration site on a public county park for people to see and kind of know that (...) [the shoreline] is supposed to be natural this way. So I think having these demonstration sites and having actual homeowners carry out projects and having their neighbors see these projects really be successful in building a lot of momentum."

The most important barrier and facilitator in this theme was the senior level technical, regulatory, and data support. In BC, the lack of the senior level government support was regularly cited by the participants. One participant from a local government in BC expressed their frustration with the lack of senior-level support this way:

> "When you think about where innovation is coming from, it is coming from local governments. It is coming from NGOs. It is not coming from the province. We are dragging them along with us."

However, besides being a significant barrier, the presence of the senior level support was also considered to be an important facilitator. In WA, the participants frequently voiced the importance of the senior level support they have received over the years. One participant from a local government in WA explained:

> "I think the amount of support that we have gotten from our local elected official from the first day and the federal government in providing monetary resources has really helped this program and move the ball. [The program] wouldn't exist otherwise."

Vision and leadership

The leadership, political will, vision and planning, and projects with multiple objectives were identified as the components of the vision and leadership theme (Figure 4.16).

Figure 4.16: The vision and leadership barriers and facilitators in CGI

The participants in BC characterized the lack of leadership as a significant barrier. Even in the local government level, the absence of a "keener" has been described as an important barrier to CGI implementation. The participants often cited "navigating the field" alone without guidance, due to the lack of leadership from the different levels of governments. A participant from an NGO In BC described the issue this way:

> "Here, there is not really any leadership. Leadership is not just throwing this voluntary stewardship program like they have. They have to say "OK this is the Green Shores program, we are going to educate people and then we are going to start regulating it." (...) The leadership has all the resources, and they do not want to get in a situation where they are pushing municipalities around and telling them what

> to do. Well yes, they should be told what to do because the shoreline of the ocean does not belong to the property and it certainly does not belong to the municipality, it belongs to all of us."

On the other hand, having the right leadership has also been seen as a significant facilitator. "The out of the box thinkers" and "innovators" in local, provincial, state and federal governments have frequently been noted by participants from both sides.

Political will, similar to leadership, has been characterized both as a barrier and a facilitator. The participants described the lack of political will as the result of the political cycle dependencies, and he concerns over the electorates' perceptions. The participants indicated that particularly in BC, the local governments are susceptible to what their electorate is concerned about. They suggested that the electorate is mostly concerned about the government spending, provision of services, real estate values, rather than the future changes in the climate. One participant from a provincial government in BC explained it this way:

> "When local governments feel that their electorate does not see the justification for them trying to implement CGI. I think that is a significant barrier."

When discussing the differences between the political will in BC and WA, one participant from an NGO in BC described the difference as follows:

> "There is something in the [WA] political process that seems to work better than ours. The issue is political; not so much the people are different. The people are very similar to the U.S., and the goals on the environment are the same. But when it comes down to getting things done on a political basis, they seem to have the ability to advocate and get stuff done where we do not."

Developing and adopting an institutional vision and plan were described as significant facilitators. In partnerships, having a shared vision, implementing practices that are developed using this vision, and sharing information across the partnership were noted to be successful approaches in WA. One participant from an NGO in WA described their vision, the collective impact model, as follows:

> "A model we use a lot is the collective impact model. The idea is that you have a backbone an organization that holds the shared vision, and together we can get ourselves organized with bringing in different groups. Collectively we will make a

bigger impact than if we all just keep doing our piecemeal."

Lastly, developing project proposals with multiple objectives and providing various ecosystem service benefits has been noted as a significant selling point of the CGI projects. In general, most of the participants indicated that the general understanding and knowledge on CGI have been increasing over time. Participants described that in most cases, the primary focus of CGI projects has still been on fish habitat rehabilitation or creation. However, there has been a shift from an opportunistic and single focus projects to complex and multi-objective projects, where the CGI benefits are highlighted as significant additional benefits. One participant from a state department in WA suggested that complex and competitive proposals with more ecological services in one project have a better chance of being funded. The participant suggested that in the cases where the primary objective is the restoration of fish habitat, including other objectives help diffuse the CGI projects.

Collaborations

Collaborations were mainly considered as important facilitators of CGI implementation in BC and WA. The concepts identified during the interviews include multiple partnerships, institutional relationships, NGOs, and private owner and community buy-in (Figure 4.17).

Figure 4.17: The collaborations barriers and facilitators in BC and WA

Ensuring respectful and fruitful relationships with all the parties involved were noted as facilitators. The participants from both sides described the diverse partnerships they have developed over the years involving various federal, provincial, state, and local departments; academic and scientific institutions; NGOs; politicians; businesses; consultant; land developers; private waterfront owners; and community residents and volunteers. Although the participants recognized the value of bringing all involved parties together and working collaboratively towards the same objective, they also identified working with multiple partners as a barrier. One participant from an NGO in WA described the challenge they face in this way:

> "The challenges are geographic. It is really hard to get people in the same room when they live everywhere. Getting to drive across the Puget Sound, getting them all in the same room, and asking them to volunteer their time (...) It is very challenging.".

Besides the geographic challenges, the participants also frequently noted that often partners might have different agendas or interests. Therefore, they described making everybody happy and meeting everyone's expectations as difficult tasks. Moreover, they explained that the workload of managing the partnerships and working with different governments was very time-consuming.

The most significant facilitator in the collaborations theme was the NGOs. The participants frequently reported the important roles NGOs play in the CGI projects. They described that NGOs often applies to the funding sources that are not typically available to governmental organizations, or they build partnerships with the private owners, they are more flexible as they are not bounded by governments' rules. A participant from an NGO in BC described their roles and opportunities provide as follows:

> "The NGOs can do can do things that government agencies cannot do. They build bridges to the property owners that the governments cannot do. They can be more flexible in terms of their interactions with the other partners that the governments cannot do. For example, let's say we want to do a stream restoration work on somebody's property. If we go and say "look we would like to do a little stream restoration on your property. What do you think?" and they ask "how much will it cost?". We say "it will not cost you anything because we already got funding for it". They will say "Well that sounds great!". Where if I was a government agency and I came to you and say " We have got a mandate to fix the creek on your property", they will ask you "Well, what do I get out of it?" (...) We found that people will not allow the municipality on their property. Never mind do any work on the property without getting paid for. They want something back from them. (...) We do not have that problem because when we go, they know that we cannot give them what

they want (a tax break or a better driveway). So the NGOs have a huge opportunity to bridge the gap between levels of governments and property owners and also the senior level of governments and local and local governments as well. So that is extremely important."

Lastly, the participants from both sides reported that for "a project to proceed, it is important to have buy-in from the landowners" and identify "the willing landowners". Therefore, the private owner and community buy-in are described as essential parts of facilitating the CGI projects.

Community and knowledge

Advocacy, knowledge on natural processes, CGI's functionality, and costs associated with CGI implementation are considered as important barriers to and facilitators of CGI implementation in BC and WA (Figure 4.18).

Figure 4.18: The community and knowledge barriers and facilitators in BC and WA

The advocacy of the local and environmental community was characterized as a barrier to and a facilitator of the CGI projects. The lack of advocacy for the CGI projects can influence the attention CGI receives, and reduce the resources being put towards. At the same time, the presence of coordinated advocacy can lead to the creation of new partnerships, and allocation of resources that can drive CGI implementation. A participant from an NGO described the role of the advocates as follows:

> "When we go back to when [the organization] was created, the drivers for it being created came a lot from the community."

The lack of or insufficient knowledge of natural processes, associated risks, the effectiveness of CGI and the perceptions of the implementation costs of CGI have been identified as key barriers. The presence of such knowledge, and science and evidence-based understanding of CGI were described as effective facilitators. The fears of flooding and the drive to protect people and assets have frequently been noted as significant drivers of adaptation. Increasing the understanding and the knowledge on the natural processes, the implications of climate change, and local risks associated with these events, therefore, has also been reported to be important. One participant from the provincial government in BC explained the role of the knowledge and public perception this way:

> "I think that is something that people do not necessarily understand. Sometimes people get really scared, and they end up reacting more on an emotional basis rather than actually having considered some evidence. They do not know what the evidence is. They do not know whom to talk to about and where they can get the kinds of figures. However, basically, there are things that have a lot to do with how people perceive [the implementation cost of CGI]."

Effective communication strategies, such as workshops for specific groups or topics; and providing easy access to resources have been reported as an essential part of increasing community knowledge and changing misperceptions. This includes developing different strategies, tools, and methods of communications and knowledge sharing. One participant from a state department in WA described the effect of knowledge sharing this way:

> "We need to be reaching out to other groups that maybe haven't been as supportive or even as knowledgeable of the issues as some people that are involved in. (...) It is information sharing, and it is engaging with folks and answering questions not in a paternalistic way or condescending way. Also working with kids and doing something that kids get excited about and (...) they can help bring that back home."

4.4.3.1 Summary of the semi-structured interview results

Besides the funding amount, the significant finding of the interviews included the roles of the funding continuity, funding timeline, and the timeline limitations of the funding sources as barriers. More flexible funding structures and diverse funding sources were suggested as facilitators. The results highlighted that the jurisdictional issues were mainly experienced in BC. The participants in BC described their frustrations and the challenges they experience related to the overlapping jurisdictional boundaries. In WA, the main issue was related to the private ownership of the tidelands, rather than the coastal jurisdiction.

The participants all agreed that the regulatory processes are work extensive and time-consuming. A significant finding of the interviews was the role of streamlined permitting processes can play in reducing some of the regulations barriers. The development of the regulations, and landscape, building and infrastructure designs that incorporate climate change and adaptation measures in the professional standards was another important finding. The capacity and resources theme was a major barrier in BC, rather than in WA. Notably, the lack of senior government support, case study examples, and staff expertise were frequently reported in BC. The capacity and resources were also seen as important facilitators of the CGI projects in BC and WA.

The participants in BC reported that they have suffered from the lack of leadership and political will. In WA, these were not reported as significant barriers. A significant finding was the role of having a formal organization vision as a facilitator. Participants in BC reported that the lack of this vision was an important barrier. The results show that the presence of the leadership, political will, vision, and developing projects with multiple objectives were facilitators in BC and WA. Except for the barriers related to the coordination and management of the partnerships, the participants identified the collaborations theme as another important facilitator of the CGI projects. An important finding here was the role of the NGOs in bridging people and institutions, and in accessing to the resources that are typically not available to governments.

Lastly, the main commonly reported barrier under the community and knowledge theme was the lack of knowledge and misperceptions on issues related to natural processes, risks, the effectiveness of CGI, and the implementation cost of CGI. In BC, the lack of local advocacy was also a significant barrier. All the factors related to the community and knowledge theme were also recognized as important facilitators.

4.5 Discussion

The literature on the barriers to and facilitators of adaptation recognizes the institutional arrangements as significant contributors. Several common and important barriers and facilitators were identified in the literature, focusing predominantly on adaptation as a general concept. Recently, studies have started to emerge, investigating the adaptation challenges and drivers of urban green infrastructure. These studies cited that the implementation of urban green infrastructure suffers from similar issues as the adaptation barriers, but identified several urban green infrastructure specific challenges. However, there remained a gap on the specific institutional challenges and drives of CGI implementation. This study provides the first attempt to identify the CGI specific institutional barriers and facilitators through a comparative study of the BC and WA institutional arrangements.

In the first step of this research, a review of the 235 CGI projects was carried out to understand the level of CGI implementation in BC and WA. This review showed that over the last ten years there were about four times more CGI projects implemented (or are in the process of implementation) in WA, compared to BC. A reason for this disparity may be due to the population and geographical differences between BC and WA. For example, WA's coasts have been more densely occupied and modified than the BC coasts, yet the length of the WA coastline is about five times shorter than the BC coastline. In addition, most parts of the BC coasts are not easily accessible, protecting coasts from human-made modifications, thus reducing habitat degradation. However, looking at the details of the projects yielded differences in the CGI project objectives, levels and types of institutions allocating funding, lead institutions, funding amount and project size in BC and WA.

The findings of the project review indicated that the geographical and population differences were not the only causes of the disparity between the CGI project implementation in BC and WA. Various institutional factors were influencing the mainstreaming of CGI projects, some of which were already frequently reported in the literature. These factors included the governance structure, and corresponding decision-making authority; jurisdictional issues; regulations; senior government support; and financial and other resources.

Therefore, the second step of this research included an extensive review and synthesis of the institutional arrangements to understand how these factors influence the CGI projects in BC and WA. The results indicated that there is more continuity in the federal goals, states' access to financial, regulatory and other resources, and allocation of these resources within the states' coastal zone. The Coastal Zone Management Act plays a significant role in the functioning of this chain. The management of the coastal zone as a whole empowered the WA government to oversee and work to ensure that the local needs are met, and regional and national goals are achieved. In addition, there have been numerous national programs and state programs available for the adaptation and CGI projects over the last 50 years. In BC, the provincial government is financially more independent than the WA state government. This independence has resulted in the expectation that provinces should start their own programs to address adaptation and CGI. This independence also means that the provincial government is less restricted to follow federal objectives. Even though the provincial government is relatively independent, its jurisdiction is very limited in the coastal zone. This limited jurisdiction and the absence of a formal provincial coastal zone management practice are preventing any holistic adaptation action from being implemented in BC.

In the third and last step, semi-structured interviews were conducted to get a deeper understanding of the barriers and facilitators reviewed in the CGI project reviews and the review and synthesis of the institutional arrangements steps. It also aimed to gain new insights into other less common but important factors and CGI specific barriers and facilitators. The results of the interviews confirm the barriers and facilitators identified in the previous steps and contribute new and important nuances to each. The results also show that there are new and specific barriers and facilitators influencing CGI implementation in BC and WA such as coastal jurisdiction and ownership; financial variation and flexibility; vision; organization efficiency and access to resources; partnerships and collaborations; NGOs; and community advocacy. In addition, they highlight that the CGI projects in BC are affected by different institutional barriers and facilitators than the CGI projects in WA.

4.5.1 Institutional barriers and facilitators

This research highlights 14 major institutional barriers to and facilitators of CGI implementation in BC and WA. Seven of them are commonly cited in the adaptation barriers and facilitators literature such as governance structure and authority distribution; regulations; financial assistance; senior level support; organizational capacity; leadership and political will; and public knowledge and communication. The other seven are CGI specific barriers and facilitators, and they include coastal jurisdiction and ownership; financial variation and flexibility; vision; organization efficiency and access to resources; partnerships and collaborations; NGOs; and community advocacy.

The governance structure is a crucial factor in determining the roles and responsibilities of different levels of governments. This research suggests that the main differences in BC and

WA can be seen in the decision-making authorities allocated to their local governments. In BC, after the transfer of several key provincial roles to the local governments, the planning and implementing of adaptation has become a local government responsibility. This downloading clarified the ambiguities related to who is responsible for adaptation. However, without any changes to the local governments' access to already limited financial means and resources, and in the absence of provincial and federal financial programs, local governments are restricted in their ability to address adaptation and implement measures like CGIs. In WA, although the local government responsibilities are similar to the BC local governments, they have access to significantly more financial sources, such as tax revenues, government programs, and other resources. For example, through the Flood Control Act and the Diking and Drainage Act, the state government can create special purpose governments, for flood management districts. These districts operate with a mandate and can allocate federal and state funding to flood protection projects within their boundaries, as well as provide policy oversight and other technical and capacity related resources.

Arguably, the main barrier impeding the CGI projects in BC is the coastal jurisdiction and ownership. The first issue is that the coastal jurisdiction in BC has several major overlaps between the local governments and the provincial and federal governments. Therefore, any holistic approach to adaptation requires multiple jurisdictions to work together and various regulations to adhere. The second issue is that the current coastal jurisdiction arrangement prevents any regional level management for adaptation. The provincial jurisdiction extends from the low water line until the natural boundary, limiting actions that can be implemented within its jurisdiction to the foreshore. And the third issue is that there is no regional oversight to local government actions above the natural boundary. The lack of regional oversight results in the lack of continuous and coherent adaptation actions and implementation of specific measures. The adaptation measures are implemented in fragmented pieces the absence of a coordinated management practice that sees the entirety of the coast as one connected system. On the contrary, the presence of the 1972 CZM Act in the United States and the corresponding SMA program in WA allocates regulatory authorities to the state government in the SMA zone. This mandate and the clear division of regulatory responsibilities enable a structured regional vision, objectives, programs, partnerships, and plans. While WA has clear coastal jurisdiction and associated institutional roles, it faces barriers related to the ownership of the coastal areas. The fact that beaches and tidelands are privately owned significantly impacts where the local governments and the state government can lead CGI projects. CGI implementation in these areas relies on the private owners' initiatives, leading to fragmented pieces of CGI implementation.

Regulations, resulting from the distribution of the decision-making authority and coastal jurisdiction is both a driver that facilitates CGI implementation and a barrier that is work intensive, complicated and time-consuming. This research suggests that there are many contributing factors to the regulations barriers and facilitators. In BC, the jurisdictional context and the following regulatory environment do not favor CGI implementation. Due to the overlapping jurisdictions and the lack of coordination between these jurisdictions, it is challenging to find the information on the regulations that the CGI projects need to comply with or obtain permits for. In addition, preparing and applying to various permits are time-consuming and work extensive processes. The wait time to receive approvals is different depending on the jurisdiction reviewing the applications and can take a very long time. The wait time to receive approvals can delay the CGI project implementation, especially if the project funding is for a short period of time. Moreover, CGI's regulatory framework is not established extensively, and its integration to the professional standards such as engineering and planning certificates have been limited. The regulatory gaps and the lack of integration to the professional standards make implementation of CGI much more difficult than the traditional measures. In addition, the existing land use designations that do not provide space or category for CGI. Consequently, the current regulatory environment has room for only small and simple CGI projects, as larger and more complex projects likely face conflicting regulations, and experience significant challenges obtaining necessary permits.

Financial assistance was an important barrier and facilitator of the CGI projects. The number and availability of financial resources have increased the number of the CGI projects implemented in WA. In addition, all of the interview participants recognized financial assistance as a key factor. They described that the absence of financial assistance is a crucial barrier and the presence of it is a significant driver.

Besides the amount of the financial assistance available for the CGI projects, this research suggests that the continuity and diversity of financial sources, the flexibility of funding conditions, opportunities for cost saving arrangements, and financial assistance for specific purposes are essential contributing factors to the financial barriers and facilitators. The continuity of financial resources ensures that there are long-term funding sources available for the CGI projects. In BC, the number of financial resources has increased over the two years, yet most of these resources are available only for a limited period of time. The diversity of the financial resources ensures availability of funding for the CGI implementation, even if one of the funding sources is cut. The funding amount for the CGI projects in WA was considerably higher in WA. The project review shows that funding from different state and federal institutions were allocated for the CGI projects, where the funding for the projects in BC was allocated main from the federal and local institutions, showing the absence of the provincial role in CGI implementation. The increase in the number of diverse funding sources in BC over the last two years is, therefore, an encouraging sign for fostering more CGI projects. The flexibility of funding conditions ensures that projects can use the funding in a way that is appropriate to complete their objectives, and over a period of time that takes the lengthy permit applications and fish windows into account. In addition, providing flexible funding structures that provide cost-saving opportunities through partnerships, collaborations and merging projects can make more people and institutions to consider CGI. Lastly, developing specific funding programs targetting specific adaptation actions can reduce competition in other funding sources, provide diversity in funding structure and increase CGI implementation. The projects in BC and WA can both benefit from the changes in the funding structures.

The findings of this research emphasize that the senior level government support is one of the key barriers to and facilitators of CGI implementation. The technological and policy innovation, programs, tools and data, and training provided by provincial governments facilitates CGI implementation and impedes it when absent. In WA, the senior level support through continuous programs, have helped the diffusion of the CGI projects. During the interviews participants in WA frequently praised the support they have received from their state and federal governments. On the contrary, there has been significantly less number of programs in BC. Some local governments and organizations feel as they have been left alone to tackle adaptation with limited guidance and support from their senior governments. The findings of this research also suggest that providing precedent, in the form of case studies and demonstration projects, illustrates the design, regulatory and construction processes. It sets an example and fosters the development of the CGI projects.

The organizational capacity of institutions has frequently been cited in the adaptation and urban green infrastructure literature. The CGI projects typically have to go through complicated and competitive grant applications, permit applications, and other work intensive and lengthy processes. Small organizations and local governments with limited resources usually do not have enough staff, staff time, or the right expertise to manage these processes. In addition, the frequent changes in staff in key positions and departments delay progress.

Besides the organizational capacity, CGI implementation also suffers from organizational inefficiency and lack of access to resources. An important barrier is the lack of access to data, tools, technologies, and dedicated room in the budget to monitor implemented projects. Especially when governments are trying to deliver other essential services, allocating resources from priority services to monitor the project effectiveness is challenging. The lack of efficiency in the meetings, project development, and review processes delay progress. In WA, the formal training of staff with facilitation techniques was reported to increase efficiency in the decision-making processes.

The research suggests that leadership and political will is an important barrier of and facilitator to CGI implementation. Having leadership and political will have repeatedly been reported in the adaptation literature. This is because leaders can influence CGI implementation by proposing and advocating for adaptation policies for the use of THSs or adaptive measures like CGI. The political will may be affected by reelection concerns or conflicting political interests, resulting in strategies with short-term gains to be preferred.

In addition to the leadership and political will, having a formal regional and an organizational vision was noted to be significant for CGI implementation. In WA, the use of a formal regional and an organizational vision, called the collective impact model, has helped to bring different levels of governments, organizations, and stakeholder groups together to develop procedures to work towards shared-objectives. Even though this partnership operates without a mandate, it is now considered to be one of the most successful partnerships in the region. On the other hand, the lack of a formal vision in a similar partnership operating without a mandate in BC was dissolved due to the lack of a formal vision leadership, and political will (semi-structured interview notes). Having a vision can also influence the type of CGI projects developed and approved. Preparing proposals that provide multiple benefits can help sell the CGI projects, or giving preference to projects with multiple objectives can lead the way for more CGI implementation. For example, a project that aims to improve fish passages by removing culverts and restoring fish habitat also stabilizes coastal edges and river mounts, thus unintentionally reduces erosion. The project reviews show that the fish habitat rehabilitation has been the primary objective of the projects in BC and WA. Therefore, demonstrating the CGI's role in fish habitat rehabilitation as well as restoring natural processes and flood and erosion protection can open more opportunities for its implementation.

Not commonly referenced in the literature, partnerships and collaborations are also important barriers to and facilitators of CGI. Most CGI projects involve multiple partners and collaborations with different jurisdictions. Bringing the right people in the project development, consultation, and implementation steps is not just important for CGI implementation but is also essential to obtain permits. Investing in the partnerships with community and private owners can increase the public interest and community in-in the CGI projects. In WA, most of the NGOs and local governments have developed protocols and programs to support public-private partnerships and collaborations (semi-structured interview notes). Yet, managing these partnerships is usually time-consuming and difficult. As mentioned above, partners or collaborators may have conflicting interests and agendas. There may also be issues related to the past and present relationships between different partners. Therefore, healthy and efficient partnerships would entail the development of common objectives and good relationships amongst partners.

A significant finding of this research is the roles NGOs play in facilitating CGI implementation. The results of the project review and the semi-structured interviews showed that the NGOs have an important lead role in initiating, developing and implementing CGI projects. Both in BC and WA, the NGOs were able to access financial resources that are typically not available to governments, build stronger relationships with their communities and private owners, and bride institutions. Empowerment of such organizations, and increasing funding sources they can apply to increases the implementation of CGI.

The local level advocacy for CGI is important for fostering political will and increasing the number of small-scale demonstration projects. The lack of local advocacy influences the attention CGI receives from politicians, while the presence of it can promote funding sources to be allocated to CGI implementation and creation of partnerships.

Lastly, the findings of this research emphasize the importance of public knowledge and communication as barriers and facilitators for CGI implementation. Improved local knowledge on the natural processes and associated risks, the effectiveness of CGI to reduce these risks, and the implementation costs of CGI are considered as important factors. This is because they contribute to the advocacy for CGI, and therefore increase the implementation of CGI. The community perceptions built over false information damages the mainstreaming of CGI. A way to eliminate these knowledge gaps and change the misperceptions is to develop robust, diverse and continuous communication strategies, and to make sure that the scientific information is available and accessible in a way that is understandable by the interested parties. For example, it has been reported that the waterfront property owners and community workshops on coastal protection hosted in various communities in WA have promoted small-scale CGI projects.

This research contributes to the literature on adaptation and CGI implementation. The barriers and facilitators highlighted above provide new insights into what factors impede CGI implementation and what strategies drive it. These institutional barriers make CGI implementation more time consuming to go through and challenging to accomplish, now and in the future. The facilitators help developing strategies to overcome these barriers.

The findings of this research suggest that adaptation and adaptation measures such as CGI need new approaches to governance rather than trying to squeeze them in the existing institutional roles and responsibilities. Due to its unique location at the interface between land and ocean (IPCC, 2014), CGI implementation requires a holistic approach to the jurisdictions and corresponding regulatory environment, rather than siloed actions and disconnected regulations. Institutions with clear mandates and support from senior levels of governments are needed to address adaptation adequately and holistically. Developing and implementing small to large scale CGI projects require financial assistance, diversity in financial sources, and flexibility in funding terms. Engineers, planners, emergency managers, and other key government staffs need to be trained in climate change adaptation and CGI's efficiency and cost, as well as other tasks such as funding application writing and meeting facilitation. Communities need to identify their data knowledge and technology needs and look for ways in which they can acquire or access the resources that are required to undertake adaptation actions.

Facilitating a holistic and resilient adaptation needs the development of a shared vision. Following that vision, new strategies for building horizontal (between communities) and vertical (between different levels of institutions, property owners, and residents) partnerships and collaborations need to be identified. To change public misperceptions over CGI's effectiveness and costs, innovative communications and knowledge transfer strategies need to be developed. Moreover, communities need to take advantage of the unique roles NGOs have been playing in facilitating partnerships and collaborations, as well as improving knowledge of CGI and local advocacy. It should be acknowledged that most of the changes listed above are difficult to achieve and time-consuming, but not impossible. Political will that is separated from short-term gains because of the re-election concerns and effective leadership that can put forward policies and regulations for a holistic and resilient adaptation can help drive the change step by step.

4.5.2 Limitations

This research has several limitations. The project reviews of the CGI projects may not show the complete picture of all the CGI projects in the study area. Access to data has been a challenge throughout the project review, particularly in BC. A thorough review of the publicly accessible project databases was conducted. However, access to the projects and relevant information on First Nations and Indian Tribes territories was limited. This limitation is because the reports of the projects on the First Nations and Indian Tribes territories were not always publicly accessible. Therefore, the CGI projects that were not reported in the public databases were not included. Even though the qualitative information obtained throughout the interviews supported the findings of the project CGI reviews, the 235 projects reviewed may not be complete. Therefore, they may not represent the complete picture of the CGI projects in BC and WA.

As discussed in the paper, the disparity of the number of projects in BC and WA may be the direct result of the more densely developed nature of WA's coastlines and untouched nature of the BC's coastlines. In WA, more people live at the coast and are exposed to flooding and erosion risks compared to BC. In addition, a higher portion of the coastline is hardened in WA than in BC. Historically, there have been many modifications to WA coastlines in the form of bulkheads, seawalls, culverts, dikes, and fillings (State of Washington Department of Ecology, 2010). This type of modification is less common in BC and exist mainly in the southern part of the province (Howes et al., 1994). Therefore the need for the CGI projects and the allocation of the state and federal resources are likely to be higher in WA. Although, the project review showed that there significant institutional factors influencing the CGI projects, the differences in the population density and naturalness of the coastal areas should be acknowledged as a limitation.

The document review and synthesis section of this research did not detail each regulation and program available in BC and WA. It did list the relevant regulations that have been adopted over time, and how they may relate to the CGI practices. However, merely the presence of a regulation may not always translate into a program that provides funding and other resources.

The objectives of the semi-structured interviews were to understand whether the practitioners were experiencing barriers and facilitators that were found during the previous steps and to identify if they have been experiencing different and CGI-specific barriers. Although the selected participants equally represented practitioners in BC and WA and different levels of institutions, the small sample size reduced the generability of the findings of the interviews. Moreover, the interview participants were selected from the practitioners who have been involved in the CGI project implementation in the last ten years. However, this selection excluded some of the other important actors that are involved in CGI implementation, such as First Nations and Indian Tribes communities, local politicians, lawmakers, and private owners. This exclusion further restricted the generability of the findings of the interviews.

It should also be noted that even though some of the findings of this research may be experienced in other parts of the world, such as constraints related to regulations, financial issues, organizational capacity and efficiency, leadership and political will, or public knowledge, the results should be considered within the context of the study area. The barriers and facilitators identified in this study are the results of the past and present social and institutional constructs of BC, WA, Canada and the United States. Therefore, some of the barriers and facilitators outlined here may not be present in other places.

4.6 Conclusion

This research investigates the institutional barriers to and facilitators of CGI implementation. It does so by using a comparative approach to the institutional arrangements in BC and WA. It operationalizes this approach using three different but complementary methods; CGI project reviews, document review and synthesis, and semi-structured interviews.

The findings of this research indicate that CGI implementation is constrained by the CGI-specific institutional barriers and facilitators, and shares some common ones with the adaptation literature. The results of this research show that the CGI implementation in BC has been limited compared to WA. Besides the geographical and density differences, this limitation is due to the specific barriers in the institutional arrangements. This research provides 14 major institutional barriers to and facilitator of CGI implementation: governance structure and authority distribution; regulations; financial assistance; senior level support; organizational capacity; leadership and political will; public knowledge and communication; coastal jurisdiction and ownership;

financial variation and flexibility; vision; organization efficiency and access to resources; partnerships and collaborations; NGOs; and community advocacy.

The findings of this research suggest many complementary future directions. The development of a provincial and state CGI project database that details relevant project information would be handy for future research. A more comprehensive qualitative work using participatory methods like focus groups and workshops with different actors (First Nations and Indian Tribes, elected local politicians, state lawmakers, local governments, and private owners) can yield more refined barriers and facilitators. It would also be helpful to consider a quantitative approach and investigate correlations between the CGI projects and the barriers and facilitators outlined in this research. A qualitative or quantitative measurement of the effectiveness of the some of the facilitators outlined in this research would help prioritization of the strategies. Studies investigating the influence of the recent financial incentives in Canada and BC on the progression of CGI implementation would be helpful. Lastly, future research can investigate what types of institutional barriers and facilitators are experienced in other parts of the world, and compare the results from different regions.

Chapter 5

Conclusion

This dissertation is comprised of three empirical studies aiming to understand the environmental, local and institutional contexts in which CGI can be used as a sea level rise adaptation measure within the coastal regions of British Columbia (BC) and the Washington State (WA). This chapter will provide the summary of findings, broad conclusions and policy implications, strengths and limitations, future research directions, and personal reflections.

5.1 Summary of findings

In this dissertation, I sought to contribute to the scholarship on coastal green infrastructure's context-dependency as a sea level rise adaptation measure. As I discussed at several points in this dissertation, the literature on CGI has frequently pointed to the context-dependency of CGI (i.e., Catenacci and Giupponi 2013; Langridge et al. 2014; Biesbroek 2014; Oddo et al. 2015). However, the influence of different contexts on the functionality, adaptability, and implementation of CGI has been greatly understudied. Therefore, this dissertation aimed to understand the contexts in which CGI can be used as a sea level rise adaptation measure within the coastal regions of BC and WA, and three empirical studies were designed to achieve the research goal.

Achieving this goal in *Chapter 2* involved the development and synthesis of CGI indices to identify CGI's potential coastal protection benefits in an environmental context. I hypothesized that CGI's vulnerability to changing environmental conditions influences its protection benefits. I argued that both CGI's protection benefits and vulnerability vary by the environmental contexts in which CGI is considered. I suggested that incorporating CGI's vulnerability and using spatially linked environmental indicators can provide a holistic approach to identifying CGI areas with high coastal protection potential. Therefore, I developed two indices: the CGI coastal protection index and the CGI vulnerability index. I organized and calculated the indices using Gornitz (1991)'s CVI methodology that has been used in Canada and the United States for coastal sensitivity assessments. I applied the indices to the Salish Sea region to demonstrate the methodology. Lastly, I synthesized the indices to achieve the goal of the chapter.

The results of Chapter 2 showed that the CGI's coastal protection potential varies by the environmental contexts. The results indicated that the big population centers in the Salish Sea region may not have the ideal environmental conditions for CGI to provide coastal protection benefits. On the contrast, the smaller communities in the study have higher potential to utilize CGI for coastal protection. Overall, the results showed that CGI in the north of the study area, which is the southwest of BC, have higher coastal protection potential than the CGI in the south of the study area (north of WA). This is mainly due to the high vulnerability of CGI in WA. This vulnerability is caused primarily by the low-lying slopes, sea level change trends that show subsidence, thus higher sea level rise, and denser developments at the WA's coasts. In addition, the differences in coastal types also contributed to these findings, where approximately 3% of the BC's coastline and 17% of the total WA's coastline is hardened with human-made structures. This is because human-made structures at the coast both reduces CGI's vulnerability by reducing habitat and increases the wave impacts by amplifying wave spray. The results of this chapter are informative for the environmental policy and management practices in the study region but not as informative for other regions. The results are relative to the study area and should be interpreted within the contexts of this study area as the CGI in the low potential zone in this study area may fall under a higher or lower zone in other regions.

In *Chapter 3*, accomplishing the research goal involved the development of the local sea level rise adaptation scenarios and an evaluation framework to highlight the trade-offs between CGI and other adaptation strategies in a local context. I hypothesized that the adaptation and resilience contributions of CGI vary by the characteristics and capacities of the local communities. I suggested that the coastal processes, natural and built environments, and economic, institutional and social implications of the adaptation strategies should be considered to understand the tradeoffs between CGI and other adaptation strategies in local contexts. I employed a case study with the District of North Saanich in BC to conceptually apply the research methods. I first developed four local sea level rise adaptation scenarios, using public perspectives on the preferred adaptation strategies and expert feedback. Second, I developed an evaluation framework that incorporates coastal processes, natural and built environments, and economic, institutional and social components of community adaptation and resilience. Finally, I applied the framework to the scenarios to achieve the goal of the chapter.

The conceptual application of the methods to the case study community showed that there are trade-offs between CGI and other adaptation strategies due to the local characteristics of the community. The results of Chapter 3 are consistent with the findings of other studies, suggesting that overall CGI is a valuable adaptation measure with co-benefits and that THSs have negative implications for coastal processes and natural environments. The "protection with coastal green infrastructure" scenario performed the best in the evaluation framework, followed by the "built environment accommodation", "retreat from the coast", and "protection with traditional hard structures" scenarios. The analysis demonstrated that CGI provides benefits for the coastal processes, natural and built environment, economic and social modules, but has important institutional trade-offs compared to other strategies. The institutional trade-offs were caused by the lack of integration of CGI into the existing environmental, urban planning and engineering regulations, as well as the lack of staff expertise and data, tools and other resources that could support CGI strategies. The results also highlighted the trade-offs between the economic and institutional implications of the "built environment accommodation" scenario; the economic, institutional and social implications of the "retreat from the coasts" scenario; and lastly, the coastal processes and natural environment implications of the "protection with traditional hard structure' scenario. The findings of this study need to be considered within the local the study is applied. Different sea level rise adaptation strategies may perform better than the CGI strategies, and the local trade-offs of strategies may vary in different local contexts.

Lastly, achieving the research goal in *Chapter 4* involved comparing the CGI project implementation, institutional arrangements and practitioners' perspectives in BC and WA to identify the institutional barriers to and facilitators of CGI implementation. I hypothesized that the implementation of CGI depends on the institutional contexts. I discussed that CGI implementation is influenced by the barriers to and facilitators of the general adaptation concept, but also by CGI-specific barriers and facilitators. I searched the publicly available databases to collect information on the CGI projects implemented between 2008-2018 in BC and WA. Next, I reviewed the governance structures, distribution of decision-making authorities, coastal jurisdiction and ownership boundaries, and regulations and programs in BC and WA. Lastly, I conducted semi-structured interviews with the practitioners in BC and WA to achieve the goal of the chapter.

The findings of Chapter 4 showed that the implementation of CGI is influenced by the differences in institutional arrangements in BC and WA. The results showed that there are significantly more CGI projects implemented in WA than in BC and that there are important differences in ways and capacities governments organizations have been involved in the CGI project implementation. The findings indicated that the coastal zone is managed and regulated in silos in BC and more holistically in WA. The downloading of senior-level responsibilities to local governments without providing adequate resources have had significant implications in BC than in WA. The results showed that different barriers and facilitators influenced the CGI project implementation in BC and WA, owing to the differences in their institutional arrangements. Overall, the general adaptation barriers and facilitators, as well as several key CGI-specific barriers and facilitators influence CGI implementation.

A total of 14 barriers and facilitators were identified and grouped under governance structure and authority distribution; regulations; financial assistance; senior level support; organizational capacity; leadership and political will; public knowledge and communication; coastal jurisdiction and ownership; financial variation and flexibility; vision; organization efficiency and access to resources; partnerships and collaborations; NGOs; and community advocacy. Most importantly, the amount, diversity, and continuity of federal and state programs in WA have provided the financial opportunities for the CGI projects. Moreover, the holistic management of WA coastlines through the clear distribution of responsibilities and regulations, as well as the federal and state level political, technical and guidance have empowered different levels of governments and organizations to undertake CGI projects. In addition, organizational capacity and access to resources have enabled action in WA. In BC, the overlapping coastal jurisdiction has created a restricted environment for CGI implementation. Financial, regulations and senior support barriers have limited CGI's progression in BC. The lack of vision, leadership and political will have further restricted action in BC. NGOs have been very effective in BC and WA to mobilize resources, create partnerships and reach out to residents because of their non-government status and ability to build relationships with residents. Similar to the other chapters of this dissertation, the findings of Chapter 4 need to be considered within the geographical region in which the research was conducted. The barriers and facilitators identified in Chapter 4 may not be present in other countries and geographical regions.

5.2 Broad conclusions and policy implications

By investigating CGI's environmental, local and institutional contexts, I have identified a number of broad conclusions and policy implications.

This dissertation shows that environmental, local and institutional contexts influence the ways CGI provides coastal protection benefits, contributes to the local adaptation and resilience, and is limited or driven by institutional arrangements. This finding highlights that communities need to undertake context-specific investigations prior to considering, deciding and implementing CGI as a sea level rise adaptation measure. Communities need to confirm if they have the appropriate environmental conditions to obtain coastal protection benefits from CGI. They need to verify if the local tradeoffs of CGI are more appropriate than some of the other adaptation strategies. They need to explore if any institutional barriers may prevent or discourage them from implementing CGI.

Each chapter of this dissertation provides important contributions to the management, regulation, prioritization, decision-making, and knowledge sharing practices in the study area. The use of CGI can help protect critical ecosystems, natural processes, habitats, and biodiversity, even in a case where the coastal protection benefits of CGI may not be high, or other strategies may have higher adaptation and resilience benefits. Therefore, hybrid or alternative ways of CGI implementation should be considered.

The findings of this dissertation do not only contribute to the CGI literature but also to the broader adaptation literature. Adaptation also depends on the contexts that it is considered and one size fits all adaptation approaches fail to deal with the local challenges communities face (Bierbaum et al., 2012). Adaptation is not, and should notbe just about protection from the physical impacts of sea level rise. Considering that the coastal communities are coupled social and ecological systems (Kittinger and Ayers, 2010), the local level economic, environmental, social, and institutional adaptation to sea level rise should also be regarded.

The economic module of the evaluation framework developed in Chapter 3 and the findings of other studies (i.e., Fankhauser 2009; Hinkel et al. 2014; Lu et al. 2018) remind that any actions for sea level rise adaptation will be costly. Some adaptation measures will likely be more costly than the others (Haer et al., 2017). Besides, the cost of adaptation will likely not be shared equally amongst levels of governments and within communities (Salzmann et al., 2016). Moreover, an increasing number of studies predict that the cost of adaptation will be higher in the future (i.e., Hallegatte et al. 2013; Nicholls 2015). The cost of adaptation was also a theme brought up multiple times by the interview participants in Chapter 4. The lack of financial assistance, and variations and flexibility of financial programs were frequently stated as important barriers to CGI implementation. In addition, the Canadian local governments' limited access to financial resources such as taxation is recognized as a key factor impeding the implementation of adaptation actions. Therefore, communities and all levels of governments need to determine who pays for adaptation, and how. Financial mechanisms and financing models need to be developed and studied to reduce the current and future costs of adaptation.

The inclusion of public perspectives in Chapter 3 was an essential part of the research design and provided valuable insights into the concerns and expectations of the residents in the study area. However, the participants responded differently to the questions on what strategies are effective to protect coasts from flooding and erosion, and what strategies they would like to see implemented in their community's coastline. This disparity showed that there might be different motivations behind public's adaptation strategy choices. The differences in public's and decision-makers' motivations were also highlighted in Chapter 4. Practitioners in BC and WA described challenges regarding collaborating with partners with different agendas or interests. Therefore, it is essential for the researchers, planning teams and decision-makers to recognize these differences and understand the underlying causes and rationales behind public and decision-maker opinions. Sea level rise impacts on local real estate prices and the fear of losing a portion of the private lands to strategy implementation are real concerns influencing public opinions over adaptation strategies.

The results of Chapter 4 showed a clear difference between the CGI projects implemented in BC and WA. WA had significantly more number of CGI projects implemented than BC. However, the results of Chapter 2 showed that CGI in WA had less coastal protection potential than CGI in BC. The differences in CGI's coastal protection potential and the implemented CGI projects in the study area emphasize two important points. First, CGI projects can be implemented even if the objective of the implementation is not flood and erosion protection. CGI's wide array of social, environmental, and economic benefits attract investments from all levels of governments. The CGI project review in Chapter 4 showed that most of the projects were implemented to restore habitats, rather than to provide flood and erosion protection. Second, the differences in Chapter 2 and 4 findings highlighted the importance of accounting for local variations. CGI can be implemented on small properties or large regional coastlines, and the local variations can play important roles in determining where CGI can be used.

Lastly, the scientific evidence shows that communities will experience more rapid changes in future due to accelerated impacts of climate change (Devoy, 2015; Nicholls, 2015; Nauels et al., 2017). However, our planning and engineering practices, as well as the national and regional policies and regulations are not yet well-equipped to deal with and respond to rapid changes. Therefore, institutional adaptability, flexibility, and creativity are needed for meaningful and sustainable sea level rise adaptation.

5.3 Strengths and limitations

A key strength of this dissertation is that it investigates three contexts that influence the use of CGI as a sea level rise adaptation measure: environmental, local and institutional. In addition, it employs multiple quantitative and qualitative methodologies, incorporates public perspectives and opinions, and advises with expert knowledge and feedback in various parts of the research. Moreover, the methods and tools developed in this dissertation can be used independently and applied to different community scales and regions. Besides the strengths, the dissertation has a number of limitations. Each chapter of the dissertation includes specific limitations of the methods, research activities, and analysis. Here, I provide an overview of the limitations identified.

I would argue that the greatest weakness of this dissertation is related to the data and sample size. As with many other research projects, this dissertation is constrained by the availability of and access to data, as well as the willingness of the public, experts, and practitioners to participate. In Chapter 2, this limitation inevitably affected the number of indicators used for the development of the CGI indices. Some of the key themes used to measure CGI coastal protection benefits and vulnerability (i.e., CGI cover, sedimentation, and soil properties) were excluded from the development of the CGI indices due to the lack of availability and access to the spatially-linked data. In addition, there were differences in the scale of the data collected for the study area. For example, the coastal morphology data were in fine resolution and were available for small coastal segments, where land use data were in much coarser resolution). Therefore, when indices were calculated, the finer resolution data were aggregated to larger segments to match the coarser resolution data. This approach was suitable to the regional scale and the unit of analysis of this study. However, the use of the finer resolution data would have been more beneficial to assess the implications of the biophysical and geomorphological characteristics and the built environment on CGI's coastal protection benefits and vulnerability. The approach used in Chapter 2 overlooked the local variations that could have been captured if the finer resolution data were to be used or the coarser resolution data were to be dissipated to the finer resolution.

In Chapter 3, the data and sample size limitation resulted in the low sample size for the expert elicitation survey and the lack of participation of the local community in the application of the evaluation framework to the adaptation scenarios. Even though an extensive literature review was conducted for the development of the evaluation framework and a considerable effort was put into recruiting experts, higher participation in the expert elicitation survey would have made the framework more robust. In addition, the local community's participation in the application of the framework would have been ideal. However, research depends on the mutual understanding, and functioning and healthy relationships between the researchers and the participants. It is important to understand communities' concerns and explore ways to work through the sensitivities and issues related to communities' objectives and fears over public perceptions. In cases where the research objectives can no longer be achieved within the existing relationship with the study area community, researchers would need to find alternate pathways. Therefore, alterations to the research activities were needed in Chapter 3 to accommodate for the changes regarding the community's participation in the project.

In Chapter 4, the data and sample size limitation led to the gaps in the project information and the number of recorded CGI projects in BC. I should note here that based on my conversations with the practitioners and knowledge of the region, I believe the number of CGI projects in BC would not go up by much if I would have had more access to data. The number of the CGI projects in BC would still be significantly lower than the ones in WA. Nevertheless, access to information on more CGI projects in BC would have helped to portray a more accurate picture in the study area.

There are also limitations related to the goal of the dissertation. First, even though it was not a research goal, it should be acknowledged that this dissertation did not explain the magnitude of influence the environmental, local, and institutional contexts have on the use of CGI. For example, the extent of protection benefits or vulnerability of CGI in Chapter 2, the extent of economic impacts of strategies on local communities in Chapter 3, and the extent of the barriers' or facilitators' impacts on CGI implementation in Chapter 4 were not explained.

Second, a number of different ways could have been used to develop the CGI indices in Chapter 2 and the evaluation framework in Chapter 3. For example, a combined CGI coastal protection and vulnerability index could have been developed, or different organizational and computational methods for the indices could have been used in Chapter 2. I decided to use two separate indices because they can be used independently. Practitioners and researchers might be interested in using only one of the indices rather than two together. For example, the CGI vulnerability index can be used as a stand-alone index to explore CGI's vulnerability to environmental change, independent from CGI's coastal protection benefits in that location. The results can inform priority locations for habitat restoration/rehabilitation actions. I also chose to employ Gornitz's CIVI methodology to organize and compute the indices because of its compatibility with the coastal sensitivity assessments in Canada and the United States. These deliberate decisions, therefore, eliminated the consideration of some other potential methods by default. In Chapter 3, in an attempt to develop a straightforward evaluation framework, I chose to use a +1 to -1 scoring system and a criteria format that compares the proposed strategies to baseline conditions. This decision excluded some important concepts (such as political leadership, collaborations with neighboring communities, and so on) from the framework because they occur independently from the strategies and therefore, could not be compared to the baseline conditions and could not be scored using the +1 to -1 scoring system.

Third, some other aspects of CGI's context dependency were left out of the scope of this dissertation. The temporal variability of CGI influences its coastal protection benefits and vulnerability to environmental change due to the changes in CGI density, plant thickness, and area throughout seasons (Koch et al., 2009). However, the temporal aspects of CGI's coastal protection benefits and vulnerability were not included in Chapter 2. In Chapter 3, each scenario included only one strategy. However, it is likely that communities will implement more than one strategy to tackle the multi-faceted challenges of sea level rise. In Chapter 4, I focused on the institutional arrangements to explain the differences in CGI implementation in BC and WA. Other important factors, such as the progression of climate change adaptation and the use of CGI terminology in policies and regulations in Canada and the United States, were left out of scope.

Lastly, the tools developed in each chapter and the results of the dissertation are to some extent limited to the geographical region where the research was conducted. For example in Chapter

2, CGI types such as mangroves and reefs were not included in the indices because the study region does not have such CGI types. The local trade-offs identified in Chapter 3 are specific to the study area community and may not be present in other places. Lastly, Canada and the United States are both developed western countries: therefore, the results of Chapter 4 may not represent the institutional barriers to and facilitators of CGI implementation in other parts of the world. However, the methodologies used in each chapter could be applied elsewhere, and tools/frameworks can be amended to be used in other studies.

5.4 Future research directions

Since the CGI research is relatively new, there are many fruitful research directions. The limitations discussed above suggest some general and priority areas for further research in order to advance understanding of the context-dependency of CGI and to support local and regional decision-making regarding the use of CGI as a sea level rise adaptation strategy. These research directions are grouped under the following categories: general directions, methodological approaches, expanding the concepts, application to different scales and places, and non-research directions that could help future research.

General directions

Other contexts that influence the use of CGI as a sea level rise adaptation measure can be investigated to improve understanding of CGI's context-dependency. These contexts may include the economic/financial context, where various mechanisms to pay for the CGI projects and the division of the costs amongst homeowners and taxpayers can be investigated. Alternatively, a coastal urban context can be explored, where hybrid THS/CGI measures are considered. Social contexts of CGI can also be investigated to better understand the public knowledge on and acceptability of CGI as an adaptation measure.

As I mentioned in the previous section, this dissertation did not explain the magnitude of the influences that the environmental, local, and institutional contexts have on the use of CGI. Therefore, future research can investigate the magnitude of influence different contexts have on CGI. This involves posing different research questions such as what are the impacts of CGI's vulnerability on its coastal protection potential; what are the coastal processes, natural and built environment, economic, institutional and social implications of different adaptation strategies; or, to what degree the institutional barriers and facilitators influence CGI implementation?

Methodological approaches
Future research can test the use of different methodological approaches. For example, alternative methods to incorporate CGI vulnerability to its coastal protection benefits can be explored. Different organizational and computational approaches can be tested for the CGI indices rather than Gornitz's CIVI approach. Rather than the indicator-based methods, different approaches can be employed to measure CGI coastal protection benefits and vulnerability.

In addition, quantitative approaches can be employed to measure the coastal processes, natural and built environment, economic, institutional and social impacts of different adaptation strategies. Similarly, quantitative and qualitative methods of evaluating the contributions of the evaluation framework to the local decision-making processes can be explored.

Furthermore, quantitative approaches can be considered to investigate correlations between the CGI projects and the institutional barriers and facilitators. Besides the semi-structured interviews, other participatory methods such as focus groups or workshops can be employed to obtain practitioners' perspectives. Lastly, qualitative or quantitative methods can be employed to measure the influence of the institutional barriers to and facilitators of the CGI implementation.

Expanding the research
Future research can also expand the context and design of the evaluation framework developed in Chapter 3. Workshops or focus groups with experts from different government levels and organizations can be organized to review and enrich the evaluation framework. This may include adding other modules or components or finding alternative scoring systems to account for variations in the implications of strategies. For example, an ecological/biodiversity component can be added, or a $\{1 \text{ to } 3\}$, $\{1 \text{ to } 5\}$ or an alternative point system can be considered. In addition, how multiple strategies can be evaluated under different future scenarios can be explored.

Similarly, future research can expand the semi-structured interview method in Chapter 4. A more comprehensive qualitative research that incorporates diverse perspectives on the institutional barriers to and facilitators of CGI implementation can be conducted. Practitioners from the federal government, First Nations and Indian Tribes, elected local politicians, state lawmakers, local governments, and private owners can be included. Future research can also track and document how the recent financial incentives in Canada drive (or not) the progression of CGI implementation.

Application to different scales and places
Future research can explore the application of the indices developed in Chapter 2 at a local scale to identify coastal segments where CGI yields higher coastal protection potential. In addition, the application of the evaluation framework developed in Chapter 3 to different communities can improve the understanding of the trade-offs between strategies. Similarly, the application of the methods in Chapter 4 to different regions around the world can bring more light into the institutional barriers to and facilitators of CGI implementation.

Non-research directions that can help future research
There are also some important non-research directions that can help future research. For example, the evaluation framework can be operationalized. It can be formatted as an online interactive document, where planning teams can customize, fill and download the document. This way, the framework can be easily implemented and tracked for future assessments.

Alternatively, a region-wide CGI project database can be established that systematically collects and details the information on the implemented CGI projects. Such a comprehensive database can reduce data gaps; track the progression of the projects; contribute to knowledge sharing and spread of best practices; and provide valuable data for various research projects looking into environmental, economic, institutional and social factors influencing CGI implementation.

5.5 Reflections

I discussed the significance and limitations of the research findings at length in the previous sections. Here, I want to conclude by noting some of my reflections on the research process and some of the findings.

To start with, I find some findings of this dissertation surprising. Based on my knowledge of the study area, I was aware of the numerous governmental and non-governmental initiatives in WA that have been investing in CGI projects. Therefore, the low CGI coastal protection potential in WA was an unexpected result of Chapter 2. But as I mentioned in the broad conclusions section, this finding highlights the regional scale of the study and its limitations in capturing local variations. Therefore, I believe the results be considered to provide guidance for further investigations into the specific coastal segments of communities' coastlines. These coastal segments can be identified through coastal types using the geomorphological or ecological features such as unvegetated mud flats can be separated from the sloped beaches and rocky coastlines.

I was also surprised by the built environment, economic, institutional and social trade-offs of the managed retreat strategy. I believe this surprise was due to the wide recognition of managed retreat as the most sustainable and long-term strategy for sea level rise adaptation in the literature (i.e., Pethick 2002; Abel et al. 2011; Alexander et al. 2012). However, the findings of Chapter 3 suggest similar trade-offs to Hino et al. (2017)'s findings, which suggested that the socio-policial implications of managed retreat strategy are important barriers for its implementation. These unexpected findings pushed me to use a more critical lens during the research activities and interpretation of the results.

On a different note, this research challenged me to think about the difficulties of conducting research with local communities and other participatory approaches. I have found that the challenges around research collaborations with local communities are often understated. I feel that there is a disconnection between the common academic research objectives and methods, and local governments' political and public-related concerns. In my observation, the political concerns are related to election cycles and re-election desires and maintaining key relationships with the prominent members of public or strong community groups. The public-related sensitivities are often around the (perhaps, premature) exposure of the public to information on sea level rise impacts, local risks, and adaptation options. Both of these concerns seemed to be fueled by the fears of potential implications of sea level rise adaptation on local property values. I think researchers should be aware of these concerns and understand that even academic research exploring adaptation options can contribute to such fears. In cases where the completion of research depends on the continuous participation of local communities, the prior understanding of these concerns and having backup plans can ensure researchers to achieve their research objectives.

This research also made me think about the role of the communities' demographics, economic wealth, and social status in their adaptation planning processes. I think the research on adaptation commonly focuses on high-risk communities (either due to high exposure and sensitivity, or low capacity) with low social and economic status. However, research on wealthy communities' adaptation planning processes seems to be very limited. I think that the existing economic wealth and social status of communities, and the age group of the residents play important roles in communities' attitudes towards adaptation needs. A wealthy community is likely to consider a wider variety of adaptation options, even the expensive ones because the local government and property owners can likely afford the implementation and maintenance costs. On the other hand, a community with low social and economic status may have to exclude some adaptation options from public debate. Therefore, the processes followed and conclusions driven from the adaptation research on high-risk communities with low social and economic status may not be observed in other types of communities.

As adaptation occurs in an extended period, communities with older populations may not be very concerned with the impacts of sea level rise. During the workshop in Chapter 3, some participants repeatedly stated that they are not concerned with sea level rise impacts because of their age (about 53% of the study community is 55 years and older (Statistics Canada, 2017), and 70% of the workshop participants were 55 years and older). They stated that they will not be around to experience the impacts of sea level rise and that they are mainly concerned with the effects of the local decisions on their property values. These statements were not reflected as strongly in the surveys they filled during the workshop. I found myself contemplating these concerns and the literature on sea level rise impacts and objectives adaptation for a long time. I have come to the conclusion that the full extent of the implications of sea level rise and adaptation actions are not entirely understood yet.

Lastly, adaptation is not an easy task and requires time for planning, implementation, and evaluation. Communities need to identify the data gaps and expertise needs for undertaking adaptation processes, and they need to work towards to fill those gaps and needs urgently. In addition, they need to start transparent and meaningful engagement processes with their residents to understand their concerns and desires, to increase public knowledge on adaptation strategies and their potential implications, and to reduce misperceptions over THSs and CGI.

CGI provides a critical resource for communities, not just for adaptation to sea level rise but also for the greater community resilience. It is my hope that this dissertation will contribute to the shift from using THSs to a more beneficial, adaptable, flexible and multifunctional way of protecting our coasts using CGI. I hope that this dissertation will improve the public, political and practitioner understanding of CGI and will lead to meaningful change in practices and policies.

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Appendices

Appendix A

Appendix to Chapter 2

A.1 CGI coastal protection index

CSDUID	Community	Relief	C.types	C.vege.	W.exp.	W.hgt.	W.fet.	H.zone	Land use	Index	Classes
5929005	Gibsons	5	1	3	3	3	4	3	3	24.65	low
5919049	Cowichan Valley C	3	1	5	3	3	n/a	3	4	15.21	v_low
5917042	Metchosin	5	5	4	2	3	4	3	4	60.00	high
5917029	Capital G	5	4	5	3	3	3	3	4	63.64	high
5921030	Nanaimo E	5	4	5	3	3	1	3	4	36.74	med.
5926021	Comox Valley A	5	1	5	4	3	3	3	5	41.08	med.
5921010	Nanaimo A	3	4	5	3	3	5	4	4	73.48	high
5926022	Comox Valley B	5	1	5	3	3	4	3	3	31.82	low
5921034	Nanaimo G	5	3	5	4	3	4	3	5	82.16	high
5919021	Ladysmith	5	1	4	4	3	5	4	1	24.49	low
5926024	Comox Valley C	5	1	4	3	3	n/a	3	4	17.57	v_low
5921023	Qualicum Beach	5	1	3	3	3	4	3	3	24.65	low
5929011	Sechelt	5	5	5	3	3	1	3	3	35.58	low
5917047	View Royal	5	4	4	4	3	5	3	3	73.48	high
5917027	Capital F	5	4	5	3	3	n/a	3	4	39.28	med.
5917005	North Saanich	3	4	5	4	3	4	3	3	56.92	high
5917010	Sidney	3	1	5	3	3	4	4	3	28.46	low
5917052	Sooke	5	1	4	4	1	1	3	5	12.25	v_low
5921018	Parksville	5	3	5	4	3	4	3	3	63.64	high

CSDUID	Community	Relief	C.types	C.vege.	W.exp.	W.hgt.	W.fet.	H.zone	Land use	Index	Classes
5915020	Greater Vancouver A	5	5	4	4	3	3	3	3	63.64	high
5927008	Powell River	5	1	3	3	3	5	3	3	27.56	low
5926005	Comox	5	3	5	3	3	n/a	3	3	29.46	low
5917015	Central Saanich	3	1	5	4	3	5	3	4	36.74	med.
5917041	Colwood	5	3	4	4	3	4	5	3	73.48	high
5917040	Esquimalt	5	2	4	4	3	5	5	1	38.73	med.
5931006	Squamish	5	2	4	4	1	2	3	3	18.97	v_low
5917030	Oak Bay	5	4	5	3	3	4	3	3	63.64	high
5915007	White Rock	5	1	4	3	1	5	4	3	21.21	v_low
5926010	Courtenay	5	3	4	4	3	4	3	3	56.92	high
5919008	North Cowichan	5	3	5	4	1	5	3	5	53.03	high
5917044	Langford	5	3	5	5	1	5	5	3	59.29	high
5924034	Campbell River	5	3	5	3	3	3	3	3	47.73	med.
5915043	Port Moody	5	1	5	4	1	5	3	3	23.72	v_low
5915055	West Vancouver	5	5	3	3	3	4	3	3	55.11	high
5915051	North Vancouver	5	2	3	4	3	5	5	2	47.43	med.
5917034	Victoria	5	2	4	2	3	4	5	1	24.49	low
5921007	Nanaimo	3	4	5	4	3	4	3	3	56.92	high
5915046	D. North Vancouver	5	2	3	4	3	4	3	3	40.25	med.
5915011	Delta	5	3	5	4	1	3	4	4	42.43	med.
5917021	Saanich	5	1	5	3	3	5	3	3	35.58	low
5915015	Richmond	5	2	5	4	1	3	4	2	24.49	low

CSDUID	Community	Relief	C.types	C.vege.	W.exp.	W.hgt.	W.fet.	H.zone	Land use	Index	Classes
5915025	Burnaby	5	1	5	4	3	4	3	3	36.74	med.
5915004	Surrey	5	3	5	4	1	5	4	4	54.77	high
5915022	Vancouver	5	2	5	2	3	4	3	1	21.21	v_low
5306505	Blaine	3	1	5	4	3	4	3	5	36.74	med.
5367770	Steilacoom	3	3	5	3	2	5	3	2	31.82	low
5367455	Stanwood	2	3	4	5	2	5	5	1	27.39	low
5349415	Normandy Park	3	1	3	3	2	5	3	3	17.43	v_low
5363385	Sequim	4	3	5	4	2	5	3	3	51.96	high
5326735	Gig Harbor	3	3	5	5	2	5	3	3	50.31	med.
5318965	DuPont	4	3	4	3	2	5	5	2	42.43	med.
5355855	Port Townsend	3	1	4	2	4	1	3	1	6.00	v_low
5355995	Poulsbo	3	1	5	5	1	5	3	3	20.54	v_low
5363735	Shelton	3	2	4	4	1	5	5	1	17.32	v_low
5355785	Port Orchard	3	1	1	4	1	5	3	1	4.74	v_low
5301990	Anacortes	5	2	5	4	5	4	3	2	54.77	high
5355365	Port Angeles	3	3	4	3	5	1	3	1	14.23	v_low
5347735	Mukilteo	4	3	4	3	3	5	3	3	49.30	med.
5350360	Oak Harbor	2	1	5	4	2	5	3	1	12.25	v_low
5303736	Bainbridge Island	5	1	5	4	2	5	3	3	33.54	low
5317635	Des Moines	4	1	3	3	2	5	3	3	20.12	v_low
5373465	University Place	4	3	4	3	2	5	3	1	23.24	v_low
5308850	Burien	4	1	3	3	3	5	3	3	24.65	low
5307695	Bremerton	5	3	5	4	1	5	3	1	23.72	v_low
5320750	Edmonds	4	3	3	3	3	5	3	3	42.69	med.
5336745	Lacey	2	3	5	3	2	5	3	3	31.82	low

CSDUID	Community	Relief	C.types	C.vege.	W.exp.	W.hgt.	W.fet.	H.zone	Land use	Index	Classes
5351300	Olympia	3	1	5	4	2	5	3	2	21.21	v_low
5363960	Shoreline	4	1	4	3	3	4	3	3	25.46	low
5343955	Marysville	3	3	5	5	3	5	5	2	64.95	high
5305280	Bellingham	5	2	5	4	3	5	3	2	47.43	med.
5323515	Federal Way	4	1	3	3	2	5	3	3	20.12	v_low
5322640	Everett	4	2	5	5	3	5	3	2	47.43	med.
5370000	Tacoma	4	2	4	5	2	5	3	2	34.64	low
5363000	Seattle	5	2	5	3	4	5	3	2	47.43	med.

Table A.1: CGI coastal protection index indicator values, scores and classes
Lowest score: 4.74, Highest score: 82.16
Very low: 4.74 - 23.91; low: 23.91- 36.16; medium: 36.16 - 51.55; high: 51.55 - 82.16

A.2 CGI vulnerability index

CSDUID	Community	Relief	Sea level	Tidal rng.	Slope stab.	W.exp.	H.zone	Land use	Index	Classes
5929005	Gibsons	1	3	4	3	3	3	3	11.78	med.
5919049	Cowichan Valley C	3	3	3	3	3	3	2	14.43	med.
5917042	Metchosin	1	1	4	3	4	3	2	6.41	v_low
5917029	Capital G	1	3	3	3	3	3	2	8.33	v_low
5921030	Nanaimo E	1	4	4	3	3	3	2	11.11	med.
5926021	Comox Valley A	1	3	4	3	2	3	1	5.55	v_low
5921010	Nanaimo A	3	3	4	3	3	2	2	13.61	med.
5926022	Comox Valley B	1	3	4	3	3	3	3	11.78	med.
5921034	Nanaimo G	1	4	4	3	2	3	1	6.41	v_low
5919021	Ladysmith	1	3	3	3	2	2	5	8.78	v_low
5926024	Comox Valley C	1	3	4	3	3	3	2	9.62	low
5921023	Qualicum Beach	1	4	4	3	3	3	3	13.61	med.
5929011	Sechelt	1	3	4	3	3	3	3	11.78	med.
5917047	View Royal	1	3	3	3	2	3	3	8.33	v_low
5917027	Capital F	1	3	3	3	3	3	2	8.33	v_low
5917005	North Saanich	3	3	3	3	2	3	3	14.43	med.
5917010	Sidney	3	3	3	3	3	2	3	14.43	med.
5917052	Sooke	1	1	4	3	2	3	1	3.21	v_low
5921018	Parksville	1	4	4	3	2	3	3	11.11	med.

CSDUID	Community	Relief	Sea level	Tidal rng.	Slope stab.	W.exp.	H.zone	Land use	Index	Classes
5915020	Greater Vancouver A	1	3	4	3	2	3	3	9.62	low
5927008	Powell River	1	3	4	3	3	3	3	11.78	med.
5926005	Comox	1	3	4	3	3	3	3	11.78	med.
5917015	Central Saanich	3	3	3	3	2	3	2	11.78	med.
5917041	Colwood	1	3	3	3	2	1	3	4.81	v_low
5917040	Esquimalt	1	3	3	3	2	1	5	6.21	v_low
5931006	Squamish	1	3	4	3	2	3	3	9.62	low
5917030	Oak Bay	1	3	3	3	3	3	3	10.21	low
5915007	White Rock	1	3	4	3	3	2	3	9.62	low
5926010	Courtenay	1	3	4	3	2	3	3	9.62	low
5919008	North Cowichan	1	3	3	3	2	3	1	4.81	v_low
5917044	Langford	1	3	4	3	1	1	3	3.93	v_low
5924034	Campbell River	1	3	4	3	3	3	3	11.78	med.
5915043	Port Moody	1	3	4	3	2	3	3	9.62	low
5915055	West Vancouver	1	3	4	3	3	3	3	11.78	med.
5915051	North Vancouver	1	3	4	3	2	1	4	6.41	v_low
5917034	Victoria	1	3	3	3	4	1	5	8.78	v_low
5921007	Nanaimo	3	3	4	3	2	3	3	16.66	high
5915046	d. North Vancouver	1	3	4	3	2	3	3	9.62	low
5915011	Delta	1	3	4	3	2	2	2	6.41	v_low
5917021	Saanich	1	3	3	3	3	3	3	10.21	low
5915015	Richmond	1	3	4	3	2	2	4	9.07	low

CSDUID	Community	Relief	Sea level	Tidal rng.	Slope stab.	W.exp.	H.zone	Land use	Index	Classes
5915025	Burnaby	1	3	4	3	2	3	3	9.62	low
5915004	Surrey	1	3	4	3	2	2	2	6.41	v_low
5915022	Vancouver	1	3	4	3	4	3	5	17.57	high
5306505	Blaine	3	4	2	3	2	3	1	7.86	v_low
5367770	Steilacoom	3	3	3	3	3	3	4	20.41	high
5367455	Stanwood	4	4	3	3	1	1	5	10.14	low
5349415	Normandy Park	3	4	3	3	3	3	3	20.41	high
5363385	Sequim	2	3	2	4.5	2	3	3	11.78	med.
5326735	Gig Harbor	3	3	3	3	1	3	3	10.21	low
5318965	DuPont	2	3	3	3	3	1	4	9.62	low
5355855	Port Townsend	3	3	2	4.5	4	3	5	26.35	high
5355995	Poulsbo	3	3	3	3	1	3	3	10.21	low
5363735	Shelton	3	3	3	3	2	1	5	10.76	med.
5355785	Port Orchard	3	3	3	3	2	3	5	18.63	high
5301990	Anacortes	1	4	2	3	2	3	4	9.07	low
5355365	Port Angeles	3	3	2	3	3	3	5	18.63	high
5347735	Mukilteo	2	4	3	3	3	3	3	16.66	high
5350360	Oak Harbor	4	4	3	3	2	3	5	24.84	high
5303736	Bainbridge Island	1	3	3	3	2	3	3	8.33	v_low
5317635	Des Moines	2	4	3	3	3	3	3	16.66	high
5373465	University Place	2	3	3	3	3	3	5	18.63	high
5308850	Burien	2	4	3	3	3	3	3	16.66	high
5307695	Bremerton	1	3	3	3	2	3	5	10.76	med.
5320750	Edmonds	2	4	3	3	3	3	3	16.66	high
5336745	Lacey	4	3	3	3	3	3	3	20.41	high

CSDUID	Community	Relief	Sea level	Tidal rng.	Slope stab.	W.exp.	H.zone	Land use	Index	Classes
5351300	Olympia	3	3	3	3	2	3	4	16.66	high
5363960	Shoreline	2	4	3	3	3	3	3	16.66	high
5343955	Marysville	3	4	3	3	1	1	4	7.86	v_low
5305280	Bellingham	1	4	2	3	2	3	4	9.07	low
5323515	Federal Way	2	4	3	3	3	3	3	16.66	high
5322640	Everett	2	4	3	3	1	3	4	11.11	med.
5370000	Tacoma	2	3	3	3	1	3	4	9.62	low
5363000	Seattle	1	4	3	3	3	3	4	13.61	med.

Table A.2: CGI vulnerability index indicator values, scores and classes
Lowest score: 3.21, highest score: 26.35
Very low: 3.21 - 8.85; low: 8.85- 10.48; medium: 10.48 - 14.43; high: 14.43 - 26.35

Appendix B

Appendix to Chapter 3

B.1 First expert meeting feedback form

FEEDBACK FORM

Print your name: ____

SECTION I - SEA LEVEL RISE PROJECTIONS TIME FRAME

Provincial (BC)		Regional		D. North Saanich		Case Studies	
2008 - Projected Sea Level Changes in BC	2100	2015 - CRD Coastal SLR Risk Assessment	2050 2100 2200	2014- SLR Mapping	2050 2100 2200	Burch et al., 2010 Delta, BC	2020 2050 2100
2011 - Coastal Floodplain Mapping	2100 2200	2015 - CRD SLR Planning Approaches	2050 2100 2200	2016- FCL Study	2100	Richards et al., 2011 Halifax, NS	2025 2050 2085 2100
2011 - Guidelines for Sea Dikes & Coastal Flood Hazard Land Use	2050 2100 2200	Plan2Adapt	2020 2050 2100			DCLG, 2006; DEFRA, 2006 England and Wales	+50 years

Figure B.1: Summary of the sea level rise projection timelines

1. Scenario time frames in different studies vary widely. Scenario modelling time frame for some sea level rise (SLR) adaptation studies starts as early as 2020. However, the CRD reports suggest that local impacts of SLR will not be felt until 2050 or beyond...

1.1. Do you agree with starting the project scenario modelling time frame at 2050?

Yes No

1.2. If you do not agree, when do you think the scenario modelling time frame should start?

Reason/Rationale: ____

____

____

2. Provincial and regional projections of sea level rise are – in many cases – until 2200. On the other hand, most case studies have expended their scenario time frames until 2100. Long-term strategies are useful to define community goals and development trajectories. However at the local scale, which is considered as the primary unit of action, planning for 2200 may be considered as vague and/or ambiguous.

2.1. Do you agree with ending the project scenario modelling time frame by 2200?

Yes No

2.2. If you do not agree, when do you think the scenario modelling time frame should end?

____

Reason/Rationale: ______________________________

3. Considering your previous answers, please list the time intervals you think would suit best for the project scenario modelling time frame. (E.g. 2050-2100, or 2025-2050-2075-2100, etc.)

____

4. Please use the space below if you have additional comments.

SECTION II - BASELINE DATA FOR WATER LEVELS

	Provincial (BC)			Regional (CRD)			D. North Saanich		
YEAR	2050	2100	2200	2050	2100	2200	2050	2100	2200
NET SLR	0.5 m m	**1 m**	2 m	0.5 m	**1 m**	2 m		**1 m**	
Tidal Water L.	1.6 m			1.6 m			1.5 m		
1:500 Storm	1.3 m			1.3 m			1.3 m to 4.9 m		
Wave Effects	0.65 m			0.65 m					
Free board	0.6 m			0.6 m			0.6 m		
Earthquake	0.5 to 2 m (not included)			(not included)			(not included)		
Tsunami	(not included)			max. 0.4 m (not included)			(not included)		

Figure B.2: Summary of the baseline data for water levels

5. The provincial and regional estimates of sea level rise suggest a 1 m increase by 2100[1,2,3]. On the other hand, the 2016 D. of North Saanich Flood Construction Levels Study suggests that 1 m of SLR may occur as early as 2065, based on recent data and science, and therefore suggests using a net local SLR of 1 m for 2100[4].

5.1. Do you agree with using the 2016 D. of North Saanich Flood Construction Levels Study net relative SLR of 1 m, for this project?

Yes No

[1] BCMoFLNRO (2011). “Coastal Floodplain Mapping – Guidelines and Specifications”. June 2011

[2] BCMoE (2011). “Climate Change Adaptation Guidelines for Sea Dikes and Coastal Flood Hazard Land Use: Draft Policy Discussion Paper”. January 2011.

[3] AECOM (2015). “Capital Regional District – Coastal Sea Level Rise Risk Assessment”. January 2015.

[4] SNC-LAVALIN (2016). “Flood Construction Level Study”. May 2016.

5.2. If you do not agree, what net sea level rise projections do you propose for this project?

____

Reason/Rationale: ____

____

____

6. The provincial and regional guidelines suggest using 1.6 m maximum high tide level for the east coast of Vancouver Island[1,2,3]. The 2016 D. of North Saanich Flood Construction Levels Study states that the maximum high tide levels for the District of North Saanich range from 1.4 m – 1.6 m, and suggests using 1.5 m for local high tide level[4].

6.1. Do you agree with using 1.5 m for maximum high tide level?

Yes No

6.2. If you do not agree, what maximum high tide value do you propose for this project?

____

Reason/Rationale: ____

____

____

7. The provincial and regional guidelines suggest using 1.3 m for storm surge and 0.65 m for wave effects for the east coast of Vancouver Island[1,2,3]. The 2016 D. of North Saanich Flood Construction Levels Study investigated six main typical storm scenarios for the area (NE, NW, SW1, SW2, SE1, SE2) and their wave effects[4]. This study concluded that the combined local impacts of storm surge and wave effects for the District of North Saanich coast would range from 1.3 m to 4.9 m depending on the shoreline exposure and characteristics.

7.1. Do you agree with using the 2016 D. of North Saanich Flood Construction Levels Study combined storm surge and wave effects values of 1.3 m to 4.9 m?

Yes No

7.2. If you do not agree, what storm surge value(s) do you propose for this project?

____

Reason/Rationale: ____

____

____

8. Provincial guidelines suggest that an extreme earthquake along the Cascadia subduction zone can result in a sudden decrease of the land, thus increase of water levels by 0.5 m to 2 m[5]. In addition, CRD tsunami model suggests that max. 0.4 m of increase in water levels can be observed in the District of North Saanich area due to a tsunami event[6]. However, these water level estimates have not been included in provincial, regional and local studies.

8.1. Do you agree with including the earthquake related water level estimates for this project?

Yes No

8.2. Do you agree with using 2 m for the earthquake related water level estimate?

Yes No

8.3. If you do not agree, what earthquake related water level estimate do you propose?

____

Reason/Rationale: ____

____

____

8.4. Do you agree with including the tsunami related water level estimates for this project?

Yes No

8.5. Do you agree with using 0.4 m for the tsunami related water level estimate?

Yes No

8.6. If you do not agree, what tsunami related water level estimate do you propose?

____

Reason/Rationale: ____

____

____

9. Are there any additional estimates/projections you think this project should include? If yes, please explain in detail:

____

____

10. Please use the space below if you have additional comments.

[5]BCMoE (2008). "Projected Sea Level Changes for British Columbia in the 21st Century". December 2008.
[6]AECOM (2013). "Modelling of Potential Tsunami Inundation Limits and Run-Up". April 2013.

SECTION III - STAKEHOLDER WORKSHOP

11. Please list the additional people and organizations you think should be invited to the stakeholder workshop.

12. Please list the additional recruitment techniques you think should be used to invite participants for the stakeholder workshop.

13. Please use the space below to add your comments on the workshop format.

B.2 Pre-workshop survey

PARTICIPANT SURVEY – PART A

1. Personal information

1.1 Age: Under 19 years old ☐ 35-44 years old ☐ 65-74 years old ☐
19-24 years old ☐ 45-54 years old ☐ 75 years or older ☐
25-34 years old ☐ 55-64 years old ☐

1.2 Education: Less than High School ☐ 4-year College Degree ☐
High School ☐ Masters Degree ☐
Some College ☐ Doctoral Degree ☐

1.3 Do you live in the District of North Saanich (DNS)? Yes ☐ No ☐

1.4 How long have you been living in the District North Saanich? ____________________________

1.5 How long have you been working in the District North Saanich? __________________________

1.6 What is the closest intersection to your house? ______________________________________

1.7 What is the closest intersection to your work? _______________________________________

1.8 Which of the following represents your role in this meeting? (Please select all that apply)

Homeowner in DNS ☐ Renter in DNS ☐ Business owner in DNS ☐ Politician ☐ Waterfront homeowner in DNS ☐ Community groups and organizations in DNS ☐ Boat owner ☐ School board ☐ DNS municipal staff ☐ First Nations municipal government ☐ Environmental initiatives and organizations outside DNS ☐ Capital Regional District ☐ Adjacent municipality ☐ Provincial government ☐ Transportation industry ☐ Other (please specify ___________________)

1.9 What are your favourite activities at the coast of the District of North Saanich? (Select all that apply)

Boating ☐ Hiking/walking ☐ Fishing ☐ Wildlife watching ☐ Swimming ☐
Storm watching ☐ Kayaking, paddle boarding ☐ Horseback riding ☐ Photography ☐
Scenic enjoyment ☐ Tide pooling ☐ Harvesting ☐ Other ☐ _________________

1.10 Please state the reason(s) you wanted to attend this meeting

PARTICIPANT SURVEY – PART A

2. Climate Change Impacts

2.1 How familiar are you with potential impacts of a changing climate in the following areas?

	1-Not Familiar	2-Somewhat Familiar	3-Moderately Familiar	4-Very Familiar
Global context	☐	☐	☐	☐
Regional context	☐	☐	☐	☐
District of North Saanich coastlines	☐	☐	☐	☐

2.2 What is the main source of your knowledge on impacts of climate change (Select all that apply)

Media (newspaper, TV, radio)	☐	Social media (Facebook, blogs, etc.)	☐
Printed sources (books, magazines)	☐	Academic journals (Science, Nature, etc.)	☐
Friends and family networks	☐	Community events (such as this workshop)	☐
Traditional knowledge	☐	Other ☐ ______________________________	

2.3 From your conversations with the people around you (family, friends, coworkers, etc.), how would you rate your level of awareness of climate change and its impacts?

1-Worse than people around me	2-Same level of awareness as people around me	3-Better than people around me	4-Much better than people around me
☐	☐	☐	☐

2.4 In your opinion, what is the risk of experiencing extreme coastal flooding events (due to combination of high tides and heavy storms) in the District of North Saanich due to sea level rise over the next 15, 50, and 100 years?

	0-20%	21-40%	41-60%	61-80%	81-100%
15 years	☐	☐	☐	☐	☐
50 years	☐	☐	☐	☐	☐
100 years	☐	☐	☐	☐	☐

PARTICIPANT SURVEY – PART A

2.5 How significant do you think each of the following potential impacts of climate change could be along the District of North Saanich coastlines?

	Don't Know	1-Not Significant	2-Somewhat Significant	3-Moderately Significant	4-Very Significant
Sea Level Rise	☐	☐	☐	☐	☐
Storm/Wave Impacts	☐	☐	☐	☐	☐
Erosion	☐	☐	☐	☐	☐
Habitat/wildlife loss	☐	☐	☐	☐	☐
Changes in fisheries	☐	☐	☐	☐	☐
Real estate values	☐	☐	☐	☐	☐
Damage to property	☐	☐	☐	☐	☐
Damage to infrastructure and local services	☐	☐	☐	☐	☐
Recreation opportunities	☐	☐	☐	☐	☐

2.6 Over time, have you noticed/observed changes in the following areas in the District of North Saanich?

	Don't Know	1-Decreased Significantly	2-Decreased Moderately	3-Not Changed	4-Increased Significantly	5-Increased Moderately
Tidal range	☐	☐	☐	☐	☐	☐
Storm frequency	☐	☐	☐	☐	☐	☐
Storm intensity	☐	☐	☐	☐	☐	☐
Wave height and strength	☐	☐	☐	☐	☐	☐
Coastal habitat	☐	☐	☐	☐	☐	☐
Wildlife sightings	☐	☐	☐	☐	☐	☐
Fish/shellfish numbers	☐	☐	☐	☐	☐	☐

PARTICIPANT SURVEY – PART A

2.7 In your opinion, how effective do you think are the following measures to protect the District of North Saanich coastlines?

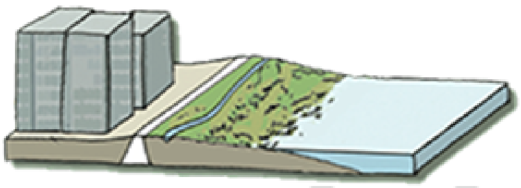
	Don't Know	1-Not Effective	2-Somewhat Effective	3-Moderately Effective	4-Very Effective
Seawalls and dikes	☐	☐	☐	☐	☐
 (NOT TO SCALE)					
Groynes, headlands, and breakwaters	☐	☐	☐	☐	☐
 (NOT TO SCALE)					
Revetments (stone, natural wood, etc.)	☐	☐	☐	☐	☐
 (NOT TO SCALE)					
Soft structures (dunes and barrier islands	☐	☐	☐	☐	☐
 (NOT TO SCALE)					
Coastal vegetation (dune vegetation, salt marshes and sea grasses)	☐	☐	☐	☐	☐
 (NOT TO SCALE)					

PARTICIPANT SURVEY – PART A

2.8 In your opinion, how effective do you think are the following sea level rise adaptation strategies?

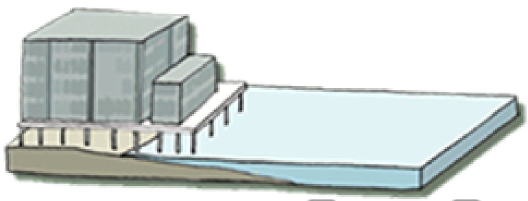
	0-Don't Know	1-Not Effective	2-Somewhat Effective	3-Moderately Effective	4-Very Effective
Protect strategy	☐	☐	☐	☐	☐

Protecting coasts from flooding using structural and/or non-structural approaches.



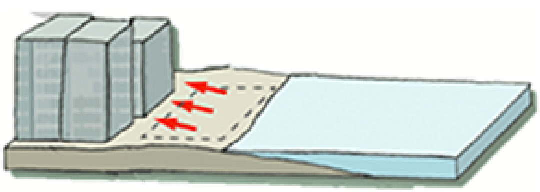
Accommodate	☐	☐	☐	☐	☐

Adjustments in the existing infrastructure and retrofitting structures to adapt to changes.



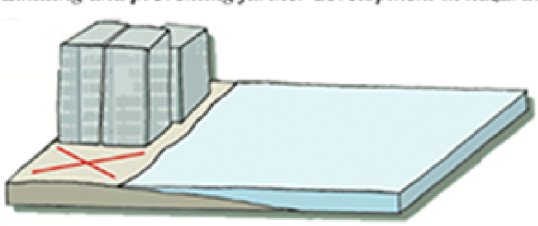
Managed retreat	☐	☐	☐	☐	☐

Withdrawing from hazardous areas and relocating development to a different location.



Avoid	☐	☐	☐	☐	☐

Limiting and preventing further development in hazardous areas.



PARTICIPANT SURVEY – PART A

2.9 At your residence/business, have you taken actions in the past to minimize the risk of damage to your home during storms? If so, please describe.

Yes ☐ No ☐

____

____

2.10 In your opinion, how important is community participation to climate change adaptation planning and policies?

0-Don't Know	1-Not Important	2-Somewhat Important	3-Moderately Important	4-Very Important
☐	☐	☐	☐	☐

2.11 To what extent do you agree or disagree with the following statements?

	Strongly disagree	Somewhat disagree	Neutral	Somewhat agree	Strongly agree
The District of North Saanich is working to plan for climate change impacts and adaption.	☐	☐	☐	☐	☐
The District of North Saanich values community input into matters concerning climate change impacts and adaption.	☐	☐	☐	☐	☐
The District of North Saanich is preparing technical and non-technical studies for climate change impacts and adaption.	☐	☐	☐	☐	☐
The District of North Saanich is addressing my personal concerns over climate change impacts and adaption.	☐	☐	☐	☐	☐

B.3 Post-workshop survey

PARTICIPANT SURVEY – PART B

3. Post Workshop Information

3.1 After attending this meeting, how did your knowledge on potential impacts of a changing climate in the following areas change?

	0-Don't know	1-Not increased	2-Somewhat increased	3-Moderately increased	4-Significantly increased
Global context	☐	☐	☐	☐	☐
Regional context	☐	☐	☐	☐	☐
District of North Saanich	☐	☐	☐	☐	☐

3.2 How effective were each of the following in terms of communicating the impacts of climate change?

	0-Don't know	1-Not effective	2-Somewhat effective	3-Moderately effective	4-Very effective
Oral presentation	☐	☐	☐	☐	☐
Maps	☐	☐	☐	☐	☐
3D visuals	☐	☐	☐	☐	☐
Other ______________	☐	☐	☐	☐	☐

3.3 How effective were each of the following in terms of envisioning potential adaptation strategies?

	0-Don't know	1-Not effective	2-Somewhat effective	3-Moderately effective	4-Very effective
Group conversations	☐	☐	☐	☐	☐
Strategy summaries	☐	☐	☐	☐	☐
Movable parts on the map	☐	☐	☐	☐	☐
Drawing on a map	☐	☐	☐	☐	☐
Play dough	☐	☐	☐	☐	☐
Other ______________	☐	☐	☐	☐	☐

PARTICIPANT SURVEY – PART B

3.4 How did this meeting change your opinions about each of the following potential impacts of climate change along the District of North Saanich coastlines?

	0-Don't know	1-Not increased	2-Somewhat increased	3-Moderately increased	4-Significantly increased
Sea Level Rise	☐	☐	☐	☐	☐
Storm/Wave Impacts	☐	☐	☐	☐	☐
Erosion	☐	☐	☐	☐	☐
Habitat/wildlife loss	☐	☐	☐	☐	☐
Changes in fisheries	☐	☐	☐	☐	☐
Real estate values	☐	☐	☐	☐	☐
Damage to property	☐	☐	☐	☐	☐
Damage to infrastructure and local services	☐	☐	☐	☐	☐
Recreation opportunities	☐	☐	☐	☐	☐

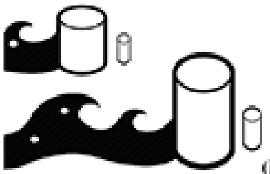
3.5 After attending this meeting, how effective do you think are the following measures to protect the District of North Saanich coastlines?

	Don't Know	1-Not Effective	2-Somewhat Effective	3-Moderately Effective	4-Very Effective
Seawalls and dikes	☐	☐	☐	☐	☐

(NOT TO SCALE)

PARTICIPANT SURVEY – PART B

Groynes, headlands, and breakwaters	☐	☐	☐	☐	☐



(NOT TO SCALE)

Revetments (stone, natural wood, etc.)	☐	☐	☐	☐	☐

(NOT TO SCALE)

Soft structures (dunes and barrier islands	☐	☐	☐	☐	☐

(NOT TO SCALE)

Coastal vegetation (dune vegetation, salt marshes and sea grasses)	☐	☐	☐	☐	☐

(NOT TO SCALE)

3.6 Regarding your previous answer, which are your preferred protection measures for the two focus areas in the District of North Saanich. (Please select all that apply)

	Seawalls and dikes	Groynes headlands breakwaters	Revetments	Soft structures	Coastal vegetation
Focus Area 1	☐	☐	☐	☐	☐
Focus Area 2	☐	☐	☐	☐	☐

PARTICIPANT SURVEY – PART B

3.7 After attending this meeting, which are your preferred adaptation strategies for the District of North Saanich sea level rise adaptation. (Please select all that apply)

	Protect	Accommodate	Managed Retreat	Avoid	Do Nothing
Focus Area 1	☐	☐	☐	☐	☐
Focus Area 2	☐	☐	☐	☐	☐

3.8 After attending this meeting, in your opinion, how important is the community participation to climate change adaptation planning and policies?

0-Don't know	1-Not Important	2-Somewhat Important	3-Moderately Important	4-Very Important
☐	☐	☐	☐	☐

3.9 Did you build new networks and meet new people in this meeting? Yes ☐ No ☐

3.10 Overall, how useful was this stakeholder meeting?

	0-Don't know	1-Not useful	2-Somewhat useful	3-Moderately useful	4-Very useful
Learning about the impacts of climate change on DNS	☐	☐	☐	☐	☐
Informing the decision makers about my concerns	☐	☐	☐	☐	☐
Giving my opinion about climate change adaptation strategies	☐	☐	☐	☐	☐
Working together with other stakeholders and community members	☐	☐	☐	☐	☐
Working together with the District of North Saanich municipal staff and city council	☐	☐	☐	☐	☐
Building trust within the community members	☐	☐	☐	☐	☐

PARTICIPANT SURVEY – PART B

3.11 To what extent do you agree or disagree with the following statements?

	Strongly disagree	Somewhat disagree	Neutral	Somewhat agree	Strongly agree
I now appreciate working together with my community members and other stakeholder to plan for climate change impacts and adaption.	☐	☐	☐	☐	☐
I will share my insights and knowledge from this meeting with my family, friends and coworkers.	☐	☐	☐	☐	☐
Today's workshop increased my confidence that municipal staff in the District of North Saanich are working hard to plan for climate change impacts and adaption.	☐	☐	☐	☐	☐
The District of North Saanich is committed to public participation and community inputs in planning and policies regarding climate change impacts and adaption.	☐	☐	☐	☐	☐
The District of North Saanich is addressing my personal concerns over climate change impacts and adaptation.	☐	☐	☐	☐	☐

3.12 Please use the space below for any further comments regarding the meeting format and content

____
____
____
____
____
____
____
____
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____
____
____

B.4 Sea level rise adaptation strategies evaluation framework

SEA LEVEL RISE ADAPTATION STRATEGIES EVALUATION FRAMEWORK

The Evaluation Framework:
The evaluation framework has been developed based on a review of the published literature and discussions/feedback from experts. It has six modules, reflecting varying themes of the resilience concept. These modules are Coastal Processes, Natural Environment, Built Environment, Economic, Institutional, and Social. There are a total of 30 components (5 in each module), aiming to identify the resilience specific elements of the modules.

Objective:
The main objective of this evaluation framework is to provide a structured method that practitioners and policy makers can use to rate different sea level rise adaptation strategies, and identify trade-offs between their contributions to the local resilience, compared to the current (baseline) conditions.

Implementation:
The evaluation framework is designed to be implemented by a planning and/or project team. This team should include municipal planners, engineers, emergency managers, sustainability coordinators, utility managers and other relevant municipal departments, as well as relevant regional/provincial/federal experts from Regional Districts; Transportation and Infrastructure, Environment and Climate Change, Agriculture Forests Lands Natural Resource Operations and Rural Development, Indigenous Relations and Reconciliation, Public Safety and Emergency ministries; and the Fisheries and Oceans Canada.

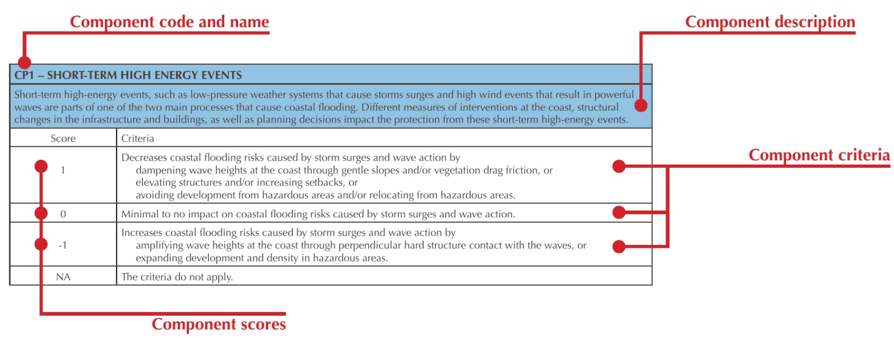
The evaluation framework can be implemented either prior to or after a public stakeholder workshop.

(1) Implementation prior to a public stakeholder workshop. This tool can be used as an initial screening tool to review various sea level rise adaptation options. The planning/project team can use this tool to help identify few strategies that can be brought up in a public stakeholder meeting to discuss with the participants in greater detail.

(2) Implementation after a public stakeholder workshop. The implementation of the tool follows a public stakeholder workshop, where the public preferences on adaptation strategies are obtained. The planning/project team then can use this tool to review the benefits, challenges, and overall trade-offs each options and to help decision-making process.

Disclaimer:
The results of this evaluation framework do not represent the intentions or opinions of the developers.

Parts of the Evaluation Framework components:



Overview of the Evaluation Framework:
Below is the summary of the modules and components of the SLR Adaptation Strategies Evaluation Framework.

Coastal Processes

CP1 – SHORT-TERM HIGH ENERGY EVENTS

Score
1
0
-1
NA

CP2 – LONG-TERM LOW ENERGY EVENTS

Score
1
0
-1
NA

CP3 – COASTAL EROSION CAUSED BY DRAG FRICTION

Score
1
0
-1

CP4 – COASTAL EROSION CAUSED BY DISRUPTION TO SEDIMENT PROCESSES

Score
1

CP5 – SECONDARY THREATS FROM LOOSE MATERIALS

Score	Criteria

Natural Environment

NE1 – HABITAT MIGRATION ALONG THE COASTAL PROFILE

Score
1
0
-1
NA

NE2 – COASTAL HABITAT AND BIODIVERSITY

Score
1
0
-1
NA

NE3 – RIPARIAN AND INLAND HABITAT AND BIODIVERSITY

Score
1
0
-1

NE4 – MOVEMENT OF SEDIMENTS THROUGHOUT COASTAL PROFILE

Score
1

NE5 – REGIONALLY IMPORTANT & SENSITIVE COASTAL HABITATS

Score	Criteria

Built Environment

BE1 – SPECIFIC LAND USE LOSS DUE TO STRATEGY IMPLEMENTATION

Score
1
0
-1
NA

BE2 – FLOODING RISKS ON PRIVATE PROPERTIES

Score
1
0
-1
NA

BE3 – FLOODING RISKS ON BUSINESSES AND OTHER COMMERCIAL/INDUSTRIAL STRUCTURES

Score
1
0
-1

BE4 – FLOODING RISKS ON ROADS AND INFRASTRUCTURE

Score
1

BE5 – VISUAL AESTHETICS OF THE STRATEGY

Score	Criteria

Economic

E1 – ECONOMIC BENEFITS TO COMMUNITIES

Score
1
0
-1
NA

E2 – IMPLEMENTATION COSTS TO LOCAL GOVERNMENTS

Score
1
0
-1
NA

E3 – IMPLEMENTATION COSTS TO WATERFRONT PROPERTY OWNERS

Score
1
0
-1

E4 – MAINTENANCE COST TO LOCAL GOVERNMENTS

Score
1

E5 – MAINTENANCE COST TO WATERFRONT PROPERTY OWNERS

Score	Criteria

Institutional

I1 – SUPPORT IN PLANNING DOCUMENTS

Score
1
0
-1
NA

I2 - MUNICIPAL AUTHORITY

Score
1
0
-1
NA

I3 – AVAILABILITY OF INFORMATION, DATA AND TOOLS

Score
1
0
-1

I4 – AVAILABILITY OF TECHNICAL EXPERTISE

Score
1

I5 – ADAPTABILITY TO CHANGING ENVIRONMENTAL CONDITIONS

Score	Criteria

Social

S1 – ACCEPTABILITY OF THE STRATEGY

Score
1
0
-1
NA

S2 – OPPORTUNITIES FOR COMMUNITY BENEFITS

Score
1
0
-1
NA

S3 – ACCESS TO COASTAL AREAS

Score
1
0
-1
NA

S4 – PRESERVING ECOLOGICAL AND CULTURAL VALUES

Score
1
0
-1
NA

S5 – DISPLACEMENT OF POPULATIONS

Score	Criteria
1	Decreases the displacement of populations.
0	Minimal to no impact on the displacement of populations.
-1	Increases the displacement of populations.
NA	The criteria do not apply.

CP1 – SHORT-TERM HIGH ENERGY EVENTS	
Short-term high-energy events, such as low-pressure weather systems that cause storms surges and high wind events that result in powerful waves are parts of one of the two main processes that cause coastal flooding. Different measures of interventions at the coast, structural changes in the infrastructure and buildings, as well as planning decisions impact the protection from these short-term high-energy events.	
Score	Criteria
1	Decreases coastal flooding risks caused by storm surges and wave action by dampening wave heights at the coast through gentle slopes and/or vegetation drag friction, or elevating structures and/or increasing setbacks, or avoiding development from hazardous areas and/or relocating from hazardous areas.
0	Minimal to no impact on coastal flooding risks caused by storm surges and wave action.
-1	Increases coastal flooding risks caused by storm surges and wave action by amplifying wave heights at the coast through perpendicular hard structure contact with the waves, or expanding development and density in hazardous areas.
NA	The criteria do not apply.

CP2 – LONG-TERM LOW ENERGY EVENTS	
Long-term low energy events, such as rising water levels and corresponding changes in tidal range that alters the mean water levels, are the other processes that cause coastal flooding. Different measures of interventions at the coast, structural changes in the infrastructure and buildings, as well as planning decisions impact the protection from these long-term low energy events.	
Score	Criteria
1	Decreases coastal flooding risks caused by rising water levels and altered tidal range through hard structures (i.e. dikes, seawalls, groins) or coastal green infrastructure (i.e. eel grasses, salt marshes, dunes), or elevating structures and/or increasing setbacks, or avoiding development from hazardous areas and/or relocating from hazardous areas.
0	Minimal to no impact on coastal flooding risks caused by rising water levels and altered tidal range.
-1	Increases coastal flooding risks caused by rising water levels and altered tidal range through expanding development and density in hazardous areas.
NA	The criteria do not apply.

CP3 – COASTAL EROSION CAUSED BY DRAG FRICTION	
Waves, currents and tidal oscillations are the main drivers of coastal erosion, as the drag friction stress caused by the backwash of water transports loose sediment, soil, rock and vegetation patches away from coasts. Measures that increase the sediment trapping at the ground surface, and/or decrease the sediment, soil, rock and vegetation loss help tackling coastal erosion.	
Score	Criteria
1	Decreases soil erosion risks caused by loose sediment, soil, rock and vegetation patches by enhancing sediment trapping at the coast (i.e. groins, headlands, barrier islands, wetlands), or enhancing binding of soil particles at the ground surface through vegetation root systems.
0	Minimal to no impact on coastal erosion risks caused by loose sediment, soil, rock and vegetation patches.
-1	Increases soil erosion risks caused by loose sediment, soil, rock and vegetation patches by disabling mechanisms for sediment trapping (i.e. removal of groins, wetlands), or reducing soil binding opportunities (i.e. removal of coastal vegetation).
NA	The criteria do not apply.

CP4 – COASTAL EROSION CAUSED BY DISRUPTION TO SEDIMENT PROCESSES	
Coastal erosion is also caused by changes in the mean water levels at the coast, such as rapid rates of sea level rise. Measures allowing for soil accretion, a natural process of gradual increase in surface elevation through organic and inorganic sediment trapping, root accumulation, primary production and plant decay, help maintaining or increasing coastal elevation.	
Score	Criteria
1	Decreases coastal erosion risks caused by changes in the mean water levels by enhancing mechanisms for accretion (i.e. vegetation, wetlands, barrier islands, groins).
0	Minimal to no impact on the coastal erosion risks caused by changes in the mean water levels.
-1	Increases coastal erosion risks caused by changes in the mean water levels by eliminating mechanisms for accretion (i.e. removal or limiting areas of vegetation, wetlands, barrier islands, groins; and building structures that don't allow accretion).
NA	The criteria do not apply.

CP5 – SECONDARY THREATS FROM LOOSE MATERIALS	
Besides the flooding and erosion damages, storm surges and wave action can also result in unintended secondary threats (additional damages) caused by loose parts of the protection structures. Measures with less hard materials reduces the risk of the secondary threats.	
Score	Criteria
1	Decreases the unintended damage risks caused by loose parts of the structures at the coast through the use of soft materials, such as vegetation and sand dunes.
0	Minimal to no impact on the unintended damage risks caused by loose parts of the structures at the coast.
-1	Increases the unintended damage risks caused by loose parts of the structures at the coast through the use of hard materials, such as concrete barriers or seawall rocks.
NA	The criteria do not apply.

Notes for the Module 1 - Coastal Processes

NE1 – HABITAT MIGRATION ALONG THE COASTAL PROFILE	
Migration of the habitat along the coastal profile is a natural coastal process that enables habitats to survive changes in the mean water levels. Human intervention such as structures and development along the coastline or naturally high elevation land behind the existing habitat limit the space available for habitats to migrate landwards, creating a "coastal squeeze" between rising water levels and developed coastline.	
Score	Criteria
1	Enables habitat migration up the coastal profile by protecting and/or enhancing the area of natural buffers, and removing structural barriers at the coast.
0	Minimal to no impact on habitat migration.
-1	Disables habitat migration up the coastal profile by eliminating and/or reducing the area of natural buffers, and placing structural barriers at the coast.
NA	The criteria do not apply.

NE2 – COASTAL HABITAT AND BIODIVERSITY	
Coastal ecosystems are amongst the most valuable and productive ecosystems in the world. They provide coastal flooding and erosion protection, raw material and food, and biodiversity; they sequester carbon from the atmosphere, and they are crucial assets for tourism, recreation, education and research assets. Measures that increase foreshore areas (between low and high water marks) for coastal ecosystems contribute to enhancing habitat and biodiversity.	
Score	Criteria
1	Increases coastal habitat and biodiversity by creating or enhancing new areas for coastal (foreshore) ecosystems.
0	Minimal to no impact on coastal habitat and biodiversity.
-1	Decreases coastal habitat and biodiversity by reducing the existing areas of coastal (foreshore) ecosystems.
NA	The criteria do not apply.

NE3 – RIPARIAN AND INLAND HABITAT AND BIODIVERSITY	
Inland green spaces are essential for sustainable communities as they provide various environmental, social, health and economic services. Preserved and enhanced inland open spaces can help promote habitat and biodiversity while serving as a buffer during inundation events and absorbing flood water.	
Score	Criteria
1	Increases riparian and inland habitat and biodiversity by creating or enhancing new green spaces.
0	Minimal to no impact on riparian and inland habitat and biodiversity.
-1	Decreases riparian and inland habitat and biodiversity by reducing existing green spaces.
NA	The criteria do not apply.

NE4 – MOVEMENT OF SEDIMENTS THROUGHOUT COASTAL PROFILE	
Sediment movement throughout coastal profile is defined and altered by various factors such as geology, geomorphology, currents, winds, water levels, as well as human interventions. Measures that introduce barriers to this movement affect both the location, amount, and rate of sediment deposited, and cause coastal and inland erosion.	
Score	Criteria
1	Increases the natural movement of organic and inorganic sediments throughout the coastal profile (from inter-tidal zone to inland) through natural buffers.
0	Minimal to no impact on the natural movement of organic and inorganic sediments throughout the coastal profile.
-1	Decreases the natural movement of organic and inorganic sediments throughout the coastal profile (from inter-tidal zone to inland) through structural barriers.
NA	The criteria do not apply.

NE5 – REGIONALLY IMPORTANT & SENSITIVE COASTAL HABITATS	
Some coastal ecosystems provide ecosystems benefits not only to the adjacent local communities but also to a greater regional area. Measures protecting these significant coastal ecosystems, such as estuaries and bird sanctuaries, promote mutual benefits to communities who enjoy and depend on them.	
Score	Criteria
1	Protects the locally and regionally important and sensitive coastal habitats.
0	Minimal to no impact on the locally and regionally important and sensitive coastal habitats.
-1	Threatens the locally and regionally important and sensitive coastal habitats.
NA	The criteria do not apply.

Notes for the Module 2 - Natural Environment

BE1 – SPECIFIC LAND USE LOSS DUE TO STRATEGY IMPLEMENTATION	
Implementation of some strategies may lead to loss of specific land uses in the community, such as the area dedicated for food production, rental housing units or industrial areas, and can alter the built environment fabric of the community. If a community is concerned with losing specific land uses, strategies that would decrease the loss of these land uses to strategy implementation should be considered.	
Score	Criteria
1	Decreases the loss of specific land use to strategy implementation.
0	Minimal to no impact on the existing land use due to strategy implementation.
-1	Increases the loss of existing specific land use to strategy implementation.
NA	The criteria do not apply.

BE2 – FLOODING RISKS ON PRIVATE PROPERTIES	
Functioning of daily life during and after flooding events contribute to the overall community resilience. Measures reducing coastal flooding risks to private property, compared to the current baseline conditions, not only improve personal safety and functioning of daily life but also reduce rescue, cleanup and rebuilding efforts.	
Score	Criteria
1	Decreases the flooding risks of the existing private property.
0	Minimal to no impact on the flooding risks of the existing private property.
-1	Increases the flooding risks of the existing private property.
NA	The criteria do not apply.

BE3 – FLOODING RISKS ON BUSINESSES AND OTHER COMMERCIAL/INDUSTRIAL STRUCTURES	
Functioning of businesses during and after flooding events contribute to the overall community resilience. Measures reducing coastal flooding risks to businesses and other commercial/industrial structures, compared to the current baseline conditions, not only improve the safety of employees and functioning of businesses but also reduce rescue, cleanup and rebuilding efforts.	
Score	Criteria
1	Decreases the flooding risks of the existing businesses and other commercial/industrial structures.
0	Minimal to no impact on the flooding risks of the existing businesses and other commercial/industrial structures.
-1	Increases the flooding risks of the existing businesses and other commercial/industrial structures.
NA	The criteria do not apply.

BE4 – FLOODING RISKS ON ROADS AND INFRASTRUCTURE	
Safety of residents and access to evacuation routes and services during and after flooding events contribute to overall community resilience. Measures reducing coastal flooding risks to roads and infrastructure, compared to the current baseline conditions, not only improve the safety of residents and functioning of roads and infrastructure but also reduce rescue, cleanup and rebuilding efforts.	
Score	Criteria
1	Decreases the flooding risks of the existing roads and infrastructure.
0	Minimal to no impact on the flooding risks of the existing roads and infrastructure.
-1	Increases the flooding risks of the the of the existing roads and infrastructure.
NA	The criteria do not apply.

BE5 – VISUAL AESTHETICS OF THE STRATEGY	
Some strategies may involve measures that changes the visual aesthetics of the coastal areas. For example, seawalls or dikes may have to built at heights that exceed the building heights eliminating the vista points or some buildings have to be elevated to heights that blocks pleasant views of the coasts.	
Score	Criteria
1	Improves coastal views.
0	Minimal to no impact on coastal views.
-1	Degrading coastal views.
NA	The criteria do not apply.

Notes for the Module 3 - Built Environment

E1 – ECONOMIC BENEFITS TO COMMUNITIES	
Coastal areas contribute to local economy through commerce, tourism, fisheries and other related industries. Tax revenues from properties and businesses are the main contributors for local governments' budgets, which are in turn used to provide services to communities. Sustaining and improving the economic benefits of coastal areas can be achieved through increasing safety, protection and usability of coastal areas.	
Score	Criteria
1	Increases the economic activities and opportunities in the coastal areas.
0	Minimal to no impact on the economic activities and opportunities in the coastal areas.
-1	Decreases the economic activities and opportunities in the coastal areas.
NA	The criteria do not apply.

E2 – IMPLEMENTATION COSTS TO LOCAL GOVERNMENTS	
Strategy implementation costs to local governments depend on the measures selected and should be considered compared to the current strategies in place, if there are any. Some strategies may have minimal to no implementation cost to the local governments, such as flood proofing private structures, while others may have high implementation costs such as coastal buyouts or building hard coastal protection structures. In addition, there may be cost-sharing programs available for local governments that may reduce the initial implementation burden. If there are not any strategies in effect for coastal flooding, any new strategy will increase the implementation cost.	
Score	Criteria
1	Decreases the implementation cost to local governments.
0	Minimal to no change on the implementation cost to local governments.
-1	Increases the implementation cost to local governments.
NA	The criteria do not apply.

E3 – IMPLEMENTATION COSTS TO WATERFRONT PROPERTY OWNERS	
Strategy implementation costs to waterfront property owners depend on the measures selected and should be considered compared to the current strategies in place, if there are any. Some strategies may have minimal to no implementation cost to the waterfront property owners, such as soft/green structures, while other may have high implementation costs such as elevating or flood proofing structures or losing land to strategy implementation. If there are not any strategies in effect for coastal flooding, any new strategy will increase the implementation cost.	
Score	Criteria
1	Decreases the implementation cost to waterfront property owners.
0	Minimal to no change on the implementation cost to waterfront property owners.
-1	Increases the implementation cost to waterfront property owners.
NA	The criteria do not apply.

E4 – MAINTENANCE COST TO LOCAL GOVERNMENTS	
Maintenance costs to local governments depend on the measures selected and should be considered compared to the current strategies in place, if there are any. Some strategies may have minimal to no maintenance cost to local governments, such as dry/wet flood proofing private structures, while others may have high maintenance costs, such as elevating and flood proofing roads and infrastructure.	
Score	Criteria
1	Decreases the maintenance cost to local governments.
0	Minimal to no impact on the maintenance cost to local governments.
-1	Increases the maintenance coast to local governments.
NA	The criteria do not apply.

E5 – MAINTENANCE COST TO WATERFRONT PROPERTY OWNERS	
Maintenance costs to waterfront property owners depend on the measures selected and should be considered compared to the current strategies in place, if there are any. Some strategies may have minimal to no maintenance cost to waterfront property owners, such as soft/green structures in the inter-tidal zone, while others may have high maintenance costs, such as maintaining seawalls or flood proofing structures.	
Score	Criteria
1	Decreases the maintenance cost to waterfront property owners.
0	Minimal to no impact on the maintenance cost to waterfront property owners.
-1	Increases the maintenance cost to waterfront property owners.
NA	The criteria do not apply.

Notes for the Module 4 - Economic

I1 – SUPPORT IN PLANNING DOCUMENTS	
Local governments use various planning documents such as official community plans, zoning bylaws, and development, subdivision and building permits, to plan and regulate within their boundaries. Regional districts provide various services and supports to local governments and can also have a region-wide planning role by developing a regional growth strategy. Strategic integration of new and ongoing adaptation efforts are essential for sustained resilience. Strategies that align with local and regional goals and integrate with other planning efforts can be better supported throughout their development, implementation and maintenance.	
Score	Criteria
1	Proposed measures are supported in the existing planning documents, such as the objectives of the strategy align with the local and regional goals outlined in these documents.
0	There are currently no existing local and regional goals in place to deal with coastal flooding.
-1	Proposed measures are poorly aligned with the existing planning documents, such as the objectives of the strategy do not align with the local and regional goals outlined in these documents.
NA	The criteria do not apply.

I2 - MUNICIPAL AUTHORITY	
The responsibilities and authorities of the local governments are defined by the provinces. Local governments in BC have direct access to only property tax and are restricted in their ability to raise revenue, and access and allocate financial resources. Implementation of the sea level rise strategies is more challenging, if the measures proposed are outside of the local government's authority, such as managed retreat. The process would involve forming partnerships with higher levels of governments, application to various permits, and potential conflicts between the different levels of governments. Measures that are within the limits of municipal authority can be implemented faster.	
Score	Criteria
1	Proposed measures are within the limits of municipal authority (such as diking or flood proofing structures), no further authorization is needed from higher government levels. (Does not include permit applications).
0	Proposed measures are partially aligned within the limits of municipal authority (such as diking, habitat restoration or flood proofing structures), no further authorization is needed from higher government levels. (Does not include permit applications).
-1	Proposed measures are not within the limits of municipal authority (such as habitat restoration or managed retreat), therefore authorization has be to obtained from higher government levels. (Does not include permit applications).
NA	The criteria do not apply.

I3 – AVAILABILITY OF INFORMATION, DATA AND TOOLS	
Strategy development, implementation, and monitoring rely on reliable and continuous information, data and tools. Access and availability of information, data and tools within the municipal capacity, as well as through regional, provincial and federal sources can effectively support decision-making.	
Score	Criteria
1	Decreases the dependency on external information, data and tools because the proposed measures can be planned, implemented, and maintained with the information, data and tools that exist in the municipal capacity.
0	Minimal to no impact on the dependency on external information, data and tools.
-1	Increases the dependency on external information, data and tools because the proposed measures cannot be planned, implemented, and maintained with the information, data and tools that exist in the municipal capacity.
NA	The criteria do not apply.

I4 – AVAILABILITY OF TECHNICAL EXPERTISE	
Reliable and continuous technical expertise (knowledgeable and skilled practitioners, and leaders) is also crucial for strategy development, implementation, and monitoring as well as to foster long-term change. Access and availability of the necessary technical expertise within the municipal capacity as well as through regional, provincial and federal sources can effectively support decision-making.	
Score	Criteria
1	Decreases the dependency on external technical expertise because the proposed measures can be planned, implemented, and maintained with the technical and professional expertise that exist in the municipal capacity.
0	Minimal to no impact on the dependency on external technical expertise.
-1	Increases the dependency on external technical expertise because the proposed measures cannot be planned, implemented, and maintained with the technical and professional expertise that exist in the municipal capacity.
NA	The criteria do not apply.

I5 – ADAPTABILITY TO CHANGING ENVIRONMENTAL CONDITIONS	
Change and uncertainty are expected and parts of coastal ecosystems as they are complex and dynamic systems. Strategies that are dynamic and adaptable to changing and/or unexpected environmental conditions improve foster community resilience, rather than static structures such as dikes and seawalls.	
Score	Criteria
1	Increases the adaptability of the community to changing environmental and climatic conditions and can be amended/modified easily.
0	Minimal to no impact on the adaptability of the community to changing environmental and climatic conditions.
-1	Decreases the adaptability of the community to changing environmental and climatic conditions and cannot be amended/modified easily.
NA	The criteria do not apply.

Notes for the Module 5 - Institutional

S1 – ACCEPTABILITY OF THE STRATEGY	
Impacts of sea level rise and the costs of implementing and maintaining strategies is often unevenly distributed within communities, making social acceptability of strategies challenging. Adding this the emotional toll of potentially losing one's home and livelihood makes it difficult for local governments to communicate the benefits of unconventional strategies. The acceptability of the strategies should be considered compared to the current strategies in place, if there are any.	
Score	Criteria
1	Higher acceptability of the strategy by the local community.
0	Minimal to no impact on the acceptability of the strategy by the local community.
-1	Lower acceptability of the strategy by the local community.
NA	The criteria do not apply.

S2 – OPPORTUNITIES FOR COMMUNITY BENEFITS	
Adaptation to sea level rise provides opportunities for community development through bringing community members to promote frequent and meaningful public participation in the implementation and maintenance of the strategies, and increasing transparency in planning and decision making processes. Increased public involvement in these processes can contribute to sense of belonging, taking ownership of actions and decision, as well as overall community resilience.	
Score	Criteria
1	Increases the opportunities for community involvement in the implementation and maintenance processes and interactions amongst stakeholders, decision-makers and municipal staff.
0	Minimal to no impact on the opportunities for community involvement in the implementation and maintenance processes and interactions amongst stakeholders, decision-makers and municipal staff.
-1	Decreases the opportunities for community involvement in the implementation and maintenance processes and interactions amongst stakeholders, decision-makers and municipal staff.
NA	The criteria do not apply.

S3 – ACCESS TO COASTAL AREAS	
Public access to coastal areas promotes tourism and recreational opportunities, and contributes to individual and community health. Measures protecting and/or promoting access to coastal areas contributes to the overall community resilience.	
Score	Criteria
1	Increases public access to coastal areas.
0	Minimal to no impact on public access to coastal areas.
-1	Decreases public access to coastal areas.
NA	The criteria do not apply.

S4 – PRESERVING ECOLOGICAL AND CULTURAL VALUES	
Ecological and cultural values are important to consider when deciding on sea level rise adaptation strategies because they can act as barriers or facilitators of adaptation. Measures protecting these values not only helps with the adaptation process but also contributes to community resilience.	
Score	Criteria
1	Protects communities' ecological and cultural values and sites.
0	Minimal to no impact on communities' ecological and cultural values and sites.
-1	Degrades communities' ecological and cultural values and sites.
NA	The criteria do not apply.

S5 – DISPLACEMENT OF POPULATIONS	
Sea level rise can force people to be displaced. Often the socio-economically disadvantaged populations are unevenly impacted by this displacement, when investment and projects to protect coastal areas are allocated to areas with higher socio-economic status, or low-income residents cannot afford to implement the measures selected and as a result are indirectly forced to move. Measures reducing the displacement of populations and addressing unequal displacement in the community can foster overall community resilience.	
Score	Criteria
1	Decreases the displacement of populations.
0	Minimal to no impact on the displacement of populations.
-1	Increases the displacement of populations.
NA	The criteria do not apply.

Notes for the Module 6 - Social

B.5 Sea level rise adaptation strategies evaluation framework spreadsheet

WEIGHTING MODULES Allocate a total of 60 points min.= 6, max.= 30	COMPONENTS	SCORE	WEIGHTING COMPONENTS Allocate a total of 25 points min.= 2, max.= 12	WEIGHTS	TOTAL WEIGHTED SCORE OF THE COMPONENTS	TOTAL WEIGHTED SCORE OF THE MODULES
	COASTAL PROTECTION		Allocate 25 points			
	CP1 PROTECTION FROM SHORT-TERM HIGH ENERGY EVENTS			0	0	
	CP2 PROTECTION FROM LONG-TERM LOW ENERGY EVENTS			0	0	
	CP3 PROTECTION FROM COASTAL EROSION CAUSED BY DRAG FRICTION			0	0	
	CP4 PROTECTION FROM COASTAL EROSION CAUSED BY DISRUPTION TO SEDIMENT PROCESSES			0	0	
	CP5 PROTECTION FROM SECONDARY THREATS			0	0	
			0		0	0.00
	NATURAL ENVIRONMENT		Allocate 25 points			
	NE1 HABITAT MIGRATION ALONG THE COASTAL PROFILE			0	0	
	NE2 COASTAL HABITAT AND BIODIVERSITY			0	0	
	NE3 INLAND HABITAT AND BIODIVERSITY			0	0	
	NE4 NATURAL MOVEMENT OF ORGANIC AND INORGANIC SEDIMENTS			0	0	
	NE5 REGIONALLY IMPORTANT AND SENSITIVE COASTAL HABITATS			0	0	
			0		0	0
	BUILT ENVIRONMENT		Allocate 25 points			
	BE1 SPECIFIC LAND USE LOSS DUE TO STRATEGY IMPLEMENTATION			0	0	
	BE2 FLOODING RISKS ON PRIVATE PROPERTY			0	0	
	BE3 FLOODING RISKS ON BUSINESSES AND OTHER COMMERCIAL/INDUSTRIAL STRUCTURES			0	0	
	BE4 FLOODING RISKS ON ROADS AND INFRASTRUCTURE			0	0	
	BE5 VISUAL AESTHETICS OF THE STRATEGY			0	0	
			0		0	0
	ECONOMIC		Allocate 25 points			
	E1 ECONOMIC BENEFITS TO COMMUNITIES			0	0	
	E2 IMPLEMENTATION COSTS TO LOCAL GOVERNMENTS			0	0	
	E3 IMPLEMENTATION COSTS TO WATERFRONT PROPERTY OWNERS			0	0	
	E4 MAINTENANCE COST TO LOCAL GOVERNMENTS			0	0	
	E5 MAINTENANCE COST TO WATERFRONT PROPERTY OWNERS			0	0	
			0		0	0
	INSTITUTIONAL		Allocate 25 points			
	I1 SUPPORT IN PLANNING DOCUMENTS			0	0	
	I2 MUNICIPAL AUTHORITY			0	0	
	I3 AVAILABILITY OF INFORMATION, DATA AND TOOLS			0	0	
	I4 AVAILABILITY OF TECHNICAL EXPERTISE			0	0	
	I5 ADAPTABILITY TO CHANGING ENVIRONMENTAL CONDITIONS			0	0	
			0		0	0
	SOCIAL		Allocate 25 points			
	S1 ACCEPTABILITY OF THE STRATEGY			0	0	
	S2 OPPORTUNITIES FOR COMMUNITY INVOLVEMENT			0	0	
	S3 ACCESS TO COASTAL AREAS			0	0	
	S4 PRESERVING ECOLOGICAL AND CULTURAL VALUES			0	0	
	S5 DISPLACEMENT OF POPULATIONS			0	0	
0			0		0	0

B.6 The evaluation framework application to four sea level rise adaptation scenarios

		Protect. with THI			Protect. with CGI			Built Env. Accomm.			Retreat from coasts		
Modules	Comp	Score	Weight	Weighted. score	Score	Weight	Weighted. scorer	Score	Weight	Weighted. score	Score	Weight	Weighted. score
Coastal Processes	CP1	-1	0.2	-0.2	1	0.2	0.2	1	0.2	0.2	1	0.2	0.2
	CP2	1	0.2	0.2	1	0.2	0.2	1	0.2	0.2	1	0.2	0.2
	CP3	-1	0.2	-0.2	1	0.2	0.2	0	0.2	0	0	0.2	0
	CP4	-1	0.2	-0.2	1	0.2	0.2	0	0.2	0	1	0.2	0.2
	CP5	-1	0.2	-0.2	1	0.2	0.2	0	0.2	0	0	0.2	0
	Total			**-0.6**			**1**			0.4			0.6
Natural Environment	NE1	-1	0.25	-0.25	1	0.25	0.25	0	0.25	0	1	0.25	0.25
	NE2	-1	0.25	-0.25	1	0.25	0.25	0	0.25	0	1	0.25	0.25
	NE3	-1	0.25	-0.25	1	0.25	0.25	0	0.25	0	1	0.25	0.25
	NE4	-1	0.25	-0.25	1	0.25	0.25	0	0.25	0	1	0.25	0.25
	NE5	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Total			**-1**			**1**			0			**1**
Built Environment	BE1	0	0.2	0	1	0.2	0.2	0	0.2	0	-1	0.2	-0.2
	BE2	1	0.2	0.2	1	0.2	0.2	1	0.2	0.2	1	0.2	0.2
	BE3	1	0.2	0.2	1	0.2	0.2	1	0.2	0.2	1	0.2	0.2
	BE4	1	0.2	0.2	1	0.2	0.2	1	0.2	0.2	1	0.2	0.2
	BE5	-1	0.2	-0.2	1	0.2	0.2	-1	0.2	-0.2	-1	0.2	-0.2
	Total			0.4			**1**			0.4			**0.2**
Economic	E1	1	0.2	0.2	1	0.2	0.2	1	0.2	0.2	-1	0.2	-0.2
	E2	0	0.2	0	0	0.2	0	-1	0.2	-0.2	-1	0.2	-0.2
	E3	-1	0.2	-0.2	-1	0.2	-0.2	-1	0.2	-0.2	1	0.2	0.2
	E4	0	0.2	0	0	0.2	0	-1	0.2	-0.2	-1	0.2	-0.2
	E5	-1	0.2	-0.2	-1	0.2	-0.2	-1	0.2	-0.2	0	0.2	0
	Total			**-0.2**			**-0.2**			**-0.6**			-0.4

		Protect. with THI			Protect. with CGI			Built Env. Accomm.			Retreat from coasts		
Modules	Comp	Score	Weight	Weighted. score	Score	Weight	Weighted. scorer	Score	Weight	Weighted. score	Score	Weight	Weighted. score
Institutional	I1	1	0.2	0.2	1	0.2	0.2	1	0.2	0.2	-1	0.2	-0.2
	I2	1	0.2	0.2	-1	0.2	-0.2	1	0.2	0.2	-1	0.2	-0.2
	I3	1	0.2	0.2	-1	0.2	-0.2	1	0.2	0.2	-1	0.2	-0.2
	I4	1	0.2	0.2	-1	0.2	-0.2	1	0.2	0.2	-1	0.2	-0.2
	I5	-1	0.2	-0.2	1	0.2	0.2	1	0.2	0.2	1	0.2	0.2
	Total			0.6			-0.2			**1**			**-0.6**
Social	S1	1	0.25	0.25	1	0.25	0.25	1	0.25	0.25	-1	0.25	-0.25
	S2	0	0.25	0	1	0.25	0.25	0	0.25	0	-1	0.25	-0.25
	S3	-1	0.25	-0.25	1	0.25	0.25	0	0.25	0	1	0.25	0.25
	S4	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	S5	0	0.25	0	0	0.25	0	0	0.25	0	-1	0.25	-0.25
	Total			0			**0.75**			0.25			**-0.5**
All modules	Total			**-1.2**			**3.35**			1.45			0.3

Appendix C

Appendix to Chapter 4

C.1 The data sources for the CGI project reviews

Institutions	Sources in BC	Sources in WA
Federal	- Fisheries and Oceans Canada, - Federation of Canadian Municipalities, - Parks Canada, - Natural Resources Canada, - Environmental and Climate Change Canada, - Port of Vancouver, and - Habitat Stewardship Program	- Environmental Protection Agency, - National Oceanic and Atmospheric Administration, - US Army Corps of Engineers.
Provincial and State	- Government of British Columbia, - Ministry of Forests, Lands and Natural Resource Operations, - Ministry of Transportation and Infrastructure, - Ministry of Environment, and - British Columbia Hydro	- Department of Fish and Wildlife, - Department of Recreation and Conservation, - Department Ecology, - Department of Natural Resources, - Department of Transportation, - Flood Plains by Design.
Non-governmental	- Green Shores, - Habitat Conservation Trust Foundation, - British Columbia Wildlife Federation, - Nature Trust, - National Wetland Conservation Fund, - World Wildlife Foundation Canada, - Sea Change Marine Conservation, - Burrard Inlet Environmental Action Program, - Fraser River Estuary Management Program, - Ducks Unlimited, - Pacific Salmon Recovery Program	- Puget Sound Partnership, - Nature Conservancy, - Ducks Unlimited, - World Wildlife Foundation USA, -Wildlife and Recreation Coalition.

Table C.1: The CGI project data sources

C.2 The protocole for the semi-structured interviews

[Consent form]

[Start recording]

If consent is granted.

[Introduce yourself]

My name is Tugce Conger. I am a PhD candidate at the University of British Columbia, in the Resource Management and Environmental Studies program. In the last 5 years, I have studied various different concepts in regards to the use of coastal green infrastructure (CGI), soft/natural/green coastal protection measures for coastal flood and erosion protection, and sea level rise adaptation more broadly.

[Introduce research purpose]

Briefly, the objective of this part of my research and this interview is to gain an in-depth understanding of the barriers and facilitators of coastal green infrastructure implementation in BC and WA. Primarily, to understand why there are more CGI projects implemented in WA then in BC? What drives action in WA and what are the barriers in BC? I am interested in the perspectives of the practitioners in the field as they have been involved in the design, development, project review, granting, partnership development and coordination, permitting and implementation parts of the GCI projects. These projects are often in the shape of habitat restoration man-made structure (such as bulkheads) removal, hazards protection, and climate change adaptation projects.

[Procedure]

The interview will take no more than 60 minutes. I have a list of questions about different types of barriers and facilitators, including regulation, funding, jurisdiction, authority, and partnerships. These questions will guide this interview but I may ask some additional follow-up or clarifying questions.

[Interview Questions]

Q1: What is/was your position and how have you been involved in CGI projects? How many projects they've been involved in approximately? Can you name one or two projects you were involved in?

Q2: What is/was the general opinion about CGI as a coastal flood and erosion protection measure in your organization? Was/Is the role of CGI has been known/acknowledged?

Q3: What is/was the jurisdiction of your organization? What decision-making and implementation authority does/did it has in regards to CGI project development/funding/implementation? Would you consider the jurisdiction of your organization a barrier for CGI projects?

Q4: What are the main regulations your organization was bounded by? (FOR BC such as 1970's Oceans Act that was renewed in 1996, 1980's Marine Environmental Quality initiative, Integrated Coastal and Ocean Management (ICOM), Oceans Action Plan in 2005), (FOR WA such as Coastal Zone Management program, Shoreline Management Act (SMA), Clean Water Act, Clean Air Act, State Environmental Policy Act, Energy Facility Site Evaluation Council Law, and Ocean Resources Management Act)

Q5: What is the main source of funding for your organization? What are the other funding sources? How is the funding distributed? Are there barriers and facilitators of access to and distribution of funding? (Such as project timelines, amount requested, type of project, project lead, etc.)

Q6: In a typical CGI project in (WA/BC), what other organizations are commonly involved? What roles these organizations take in the project timeline? For example, are there any organizations that solely provide funding, or technical expertise? Are all partners involved in the decision-making processes? Is there a procedure that you follow for these types of collaborations? What are/were the barriers and facilitators the partnerships and associated role distribution create for CGI implementation?

Q7: Considering regulation, funding, partnerships, and any other issues, what would you say are the most common barriers that impede CGI projects? Can you give an example?

Q8: And what would you say are the most common facilitators that enable CGI projects? Can you give an example?

Q9: What are the gaps and opportunities you can identify that would help increase coastal green infrastructure implementation?

Q10: How do you view the status of CGI projects in BC, as compared with WA?

*Prompted questions:

Q11: In my research so far, I have found that the provincial level financial, technical and regulatory support in BC differs from WA. Do you think the provincial level financial, technical and regulatory support has a significant impact on CGI implementation? If so, how?

Q12: I have also found that the government level of distribution/allocation of funding in BC differs from WA. Do you think the government level of distribution/allocation of funding has a significant impact on CGI implementation? If so, how?

Q13: I also found that the non-profits play significant roles in CGI projects. Do you think the presence of the non-profits and the support they receive from regional, local, provincial and federal governments have a significant impact on CGI implementation? If so, how?

Q14: Another finding of my research so far is the differences in the coastal jurisdiction in BC and WA. Do you think the coastal jurisdiction (how clear the boundaries are defined, etc.) has a significant impact on CGI implementation? If so, how?

Q15: Related to the previous question, I also found that the number of permits that projects may have to apply in BC is also different than in WA. Do you think the number or permits or the permitting process has a significant impact on CGI implementation? If so, how?

Q16: Are there other important factors that affect differences between BC and WA?

Q17: Lastly, do you know, and recommend, anyone else that may be a good person for me to talk to for my research?

This is the end of my questions. Please feel free to contact me if you have further comments and need to clarify any points you made during this interview. I am leaving you a copy of the consent form for you records, where you can find the information about this research and my contact information. I appreciate your time and insights. Have a great day.

C.3 The coastal and environmental regulations in Canada and BC

	Relevant regulations	Action(s)	Lead department(s)
Federal	- Oceans Act	Compliance	Fisheries & Oceans Canada
	- Species at Risk Act	Approval	Fisheries & Oceans Canada
	- Fisheries Act	Approval	Fisheries & Oceans Canada
	- Canadian Env. Protection Act	Permit	Env. & Climate Ch. Canada
	- Migratory Birds Convension Act	Compliance	Env. & Climate Ch. Canada
	- Canada Wildlife Act	Permits	Env. & Climate Ch. Canada
	- Navigation Protection Act	Approval	Transport Canada
	- Canada Shipping Act	Permits	Transport Canada
	- Canada Nat. Marine Conservation Areas Act	Permits	Parks Canada
	- Canada National Parks Act	Permits & licenses	Parks Canada
	- Environment Assessment Act	Approval	Env. Assessment Agency
	- Canada Marine Act	Permits	Port Authorities
Prov.	- Environmental Management Act	Approval & permits	Env. Prot. & Sustainability
	- Dike Maintenance Act	Approval	Env. Prot. & Sustainability
	- Drainage, Ditch and Dike Act	Approval	Env. Prot. & Sustainability
	- Park Act	Permits	Env. Prot. & Sustainability
	- Fish Protection Act	Compliance	Env. Prot. & Sustainability
	- Riparian Areas Protection Act	Compliance	Env. Prot. & Sustainability
	- Environmental Assessment Act	Approval	Env. Prot. & Sustainability
	- Land Act	Land tenure & lease	FLNRRD
	- Wildlife Act	Permits	FLNRRD
Local	- Local Government Act	Permits & bylaws	Local governments
	- Community Charter	Permits & bylaws	Local governments

Table C.2: The regulatory actions that may be required for CGI projects in BC

C.4 The coastal and environmental regulations in the United States and WA

	Relevant regulations	Action(s)	Lead department(s)
Federal	- Magnuson-Stevens Fishery Cons. and Management Act	Permits	NOAA
	- Estuary Restoration Act	Compliance	NOAA
	- Endangered Species Act	Permits	NOAA & Fish Wild. Ser.
	- Fish and Wildlife Act	Permits	NOAA & Fish Wild. Ser.
	- Marine Mammal Protection Act	Permits	NOAA & Fish Wild. Ser.
	- Clean Air Act	Permits	Env. Protection Agency
	- Clean Water Act	Permits	Env. Protection Agency
	- National Environmental Policy Act	Compliance	Env. Protection Agency
	- Beaches Env. Assess. & Coastal Health Act	Compliance	Env. Protection Agency
	- Marine Prot., Research, Sanct. Act	Permits	Env. Protection Agency
	- Pollution Prevention Act	Compliance	Env. Protection Agency
	- Shore Protection Act	Permits	Env. Protection Agency & Coast Guard
	- Rivers and Harbors Act	Permits	Army Corps of Engineers
	- Floodplain Management	Permits & Compliance	Federal Emergency Management Agency
State	- State Legislature Title 332	Authorization	Natural Resources
	- Shoreline Management Act	Permits & Compliance	Ecology
	- Flood Control Act	Permits	Ecology & Local governments
	- Diking and Drainage Act	Permits	Ecology & Local governments
	- Climate Leadership Act	Compliance	Ecology
	- State Environmental Policy Act	Permits	Fish and Wildlife Office
	- State Hydraulic Code	Permits	Fish and Wildlife Office
	- Archaeol. Resources Prot. Act	Permits	Archeol. Hist. Preserv.
Local	- State Legislature Title 35 & 36	Permits & bylaws	Local governments

Relevant regulations	Action(s)	Lead department(s)
- Community Charter	Permits & bylaws	Local governments

Table C.3: The regulatory actions that may be required for CGI projects in WA

C.5 The coastal and environmental programs in Canada

Timeline	Federal programs	Lead Insitution	Grant/funding
S. 1995	EcoAction Community Funding	Environ. & Climate Change Canada	Max $100K per project
S. 1995	Environmental Damages Fund	Environ. & Climate Change Canada	varies
2000-2016	Habitat Stewardship Program for Species at Risk	Environ. & Climate Change Canada	$163.7M+
S.2002	Interdepartmental Recovery Fund	Canadian Wildlife Service	$1.5M per year
S. 2004	Aboriginal Fund for Species at Risk	Environ. & Climate Change Canada Fish. & Oceans Canada	$4.5M per year
S. 2007	Regional Adaptation Collab.	Natural Resources Canada	varies
2011-2016	Clean Air Agenda	Environ. & Climate Change Canada	1.5BN
S. 2014	First Nation Infrastructure Fund	Indigenous & Northern Affairs Canada	Max. $9M per project
2014-2018	New Building Canada Fund	& Infrastructure Canada	$10BN per project
2014-2019	Low Carbon Economy Fund	Environ. & Climate Change Canada	$2BN, $30M per project
2014-2019	National Wetland Conservation Fund	Environ. & Climate Change Canada	Max. $500K per project
2015-2020	National Disaster Mitigation	Public Safety Canada	$200M
2016-2022	First Nation Adapt	Indigenous & Northern Affairs Canada	Max. $51.7M
2016-2028	Investing in Canada Plan	Transport Canada	$180BN
2016-2021	Oceans Protection Plan	Infrastructure Canada Fish. & Oceans Canada Environ. & Climate Change Canada	$1.5BN
2016-2021	Partnership Funds	Fish. & Oceans Canada	$5M per year
2016-2021	Coastal Restoration Fund	Fish. & Oceans Canada	$75M
2017-2019	Recreational Fisheries Conservation Partnerships	Fish. & Oceans Canada	$8.6M
2018-2028	Disaster Mitigation and Adaptation Fund	Infrastructure Canada	$2BN
2018-2023	Green Municipal Fund	Fed. of Canadian Municipalities	$550M

Timeline	Federal programs	Lead Insitution	Grant/funding
2018-2023	Municipal Asset Management	Fed. of Canadian Municipalities	$50M
2018-2023	Municip. for Climate Innovation	Fed. of Canadian Municipalities	$75M

Table C.4: The federal coastal and environmental programs in Canada.

C.6 The coastal and environmental programs in BC

Timeline	Federal programs	Lead Insitution	Grant/funding
n/a	Integrated Flood Hazard Management	Environment Protect. & Sustainability	n/a
n/a	Flood Protection Program	Emergency Management BC	n/a
S. 2010	Climate Action Revenue Incent.	Municipal Affairs & Housing	Tax refund
2011-2012	Community Recreation	Municipal Affairs & Housing	$30M
S. 2011	Fish & Wildlife Compensation	BC Hydro	$10M per year
2014-2024	Small Communities Fund	Transportation & Infrastructure	$310M
S. 2016	Infrastructure Planning Grant	Community, Sport and Cultural Development	$10K per project
S. 2016	Clean Water & Wastewater Fund	Community, Sport and Cultural Development	$373.6M, up to %83 cost
S. 2018	Comm. Emerg. Prepared. Fund	Union of BC Municipalities	$33.5M
2018-2019	Oyster Recovery Fund	Farming, Natural Resources and Industry	Max. $10K per project

Table C.5: The provincial coastal and environemtal programs in BC.

C.7 The coastal and environmental programs in the United States

Timeline	Federal programs	Lead Insitution	Grant/funding
n/a	Region 10 Grants	Environmental Protection Agency	$4BN
S. 1965	Land $ Water Conservation Fund	Forest Service	$900M per year
S. 1972	National Estuarine Research Reserves	Nat. Oceanic & Atmospheric Admin.	&20M per year
S. 1974	Community Development Block	Housing & Urban Development	varies
S. 1982	Superfund	Environmental Protection Agency Army Corps of Engineering	n/a
S. 1987	National Estuary Program	Environmental Protection Agency	$4BN since 2003
S. 1987	Partners for Fish & Wildlife	Fish & Wildlife Service	n/a
S. 1988	Clean Water State Revolving Fund	Environmental Protection Agency	$126BN
S. 1989	Hazard Mitigation Grant	Federal Emergency Manag. Agency	$13.8M
S. 1990	Wetland Program Development Grants	Environmental Protection Agency	$10K-2.6M
S. 1990	319 Grant Program	Env. Protection Agency	%175M
S. 1992	Wetlands Conservation	Fish & Wildlife Service	$20M per year
S. 1996	Coastal & Marine Habitat Restoration	Nat. Oceanic & Atmospheric Admin.	$8.2M per year
S. 1996	Community-Based Restoration	Nat. Oceanic & Atmospheric Admin.	$20M per year
2000-2013	Estuary and Salmon Restoration	Nat. Oceanic & Atmospheric Admin. & multiple other federal departments	Max $1.4M per year
S. 2000	Estuary Restoration Program	Army Corps of Engineering	$1-2M per year
S. 2001	Cooperative Endangered Species Cons.	Fish & Wildlife Service	%75 of cost
2002-2005	Federal Aid in Wildlife Rest.	Fish & Wildlife Service	$3M per year
S. 2008	State Wildlife Grant	Fish & Wildlife Service	%75 of project cost
S. 2008	Climate Ready Estuaries program	Environmental Protection Agency	n/a
S. 2010	Coastal Program	Fish & Wildlife Service	$14M, $500K per project
2010-2011	Sustain. Comm. Regional Plan.	Housing & Urban Development	$165M

Timeline	Federal programs	Lead Insitution	Grant/funding
S. 2014	Green Infrastructure Collaborative	Environmental Protection Agency	n/a
S. 2015	Pre-Disaster Mitigation Grant	Federal Emergency Manag. Agency	varies
S. 2015	Coastal Resilience	Nat. Oceanic & Atmospheric Admin.	$50M per year
S. 2016	Coastal Resilience Fund	Department of Interior	$ 50M per year
S. 2016	Healthy Watersheds Consortium Grants	Endowment for Forestry & Commun. Environmental Protection Agency Agriculture	$4.2M
S.2016	Weatherization and Intergovernmental	Energy	$200M

Table C.6: The federal coastal and environmental programs in the United States.

C.8 The coastal and environmental programs in WA

Timeline	Federal programs	Lead Insitution	Grant/funding
n/a	Watershed Plan Implementation & Flow Achievement	Ecology	$4.5M
S. 1971	Shoreline Master Program Grants	Ecology	$1.4 M per 2 years
S. 1984	Flood Control Assistance Account	Ecology	$4M per 2 years
S. 1984	Aquatic Restoration Program	Natural Resources	ard $120K per project
S. 1987	Water Quality Combined Funding	Ecology	$150M per year
S. 1990	Regional Fisheries Enhancement Groups	Fish & Wildlife	varies
S. 1991	Aquatic Lands Enhancement Account	Ecology	$350K per year
S. 2000	Salmon Recovery Grants	Recreation & Conserv. Office	$18M per year
S. 2001	Puged Sound Marine and Nearshore Protection & Restoration	Fish & Wildlife Natural Resources	$20.75M
S. 2001	Watershed Protection & restoration	Ecology	$24M
S. 2003	Family Forest Fish Passage	Natural Resources	%75-100 of projec cost
S. 2006	Estuary and Salmon Restoration	Fish & Wildlife	$10M per 2 years
S. 2006	Stormwater Capacity Grants	Ecology	varies
S. 2006	Stormwater Grants of Regional or Statewide Significance	Ecology	$1.7M
S. 2013	Floodplains by Design	Ecology	varies
S. 2014	Coastal Protection Fund	Ecology	$50K per project
S. 2016	Landscape Scale Restoration Competitive Grant Process	Natural Resources	$240K per project

Table C.7: The coastal and environemtal programs in WA.