Effects of Climate Change on Coastal Aquaculture in BC
An Examination Anticipated Impacts in the Strait of Georgia

By
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Outline and Organization

1. Introduction, Purpose & Objectives;
2. Background;
3. Study area description;
4. Methods/Analysis & Results;
5. Conclusion & Recommendations;

1. Introduction

Aquaculture is a growing food-production sector in the world;

It plays an important role in aquatic food production;

Makes significant contribution to the economies of many nations;

Aquaculture is being and will continue to be impacted direct and indirectly by the effects of climate change;

Direct effects: physiology and behavior and alter growth, mortality and distribution of marine and freshwater species;

Indirect effects: affect on productivity, structure and composition of the ecosystems on which aquatic species depend;

Purpose & Objectives

Purpose:

The purpose of this study is twofold:

- Investigate how climate changes would affect shellfish aquaculture in BC.
- Assess if the existing environmental databases provided by various agencies and institutions in BC can support the proposed study.

The focus for the study was bottom culture of Manila Clams and Pacific Oysters

Clam harvest. Courtesy of NOAA/Taylor Shellfish Farms

Objectives

1. Examine expected changes on SSS, SST, and beach albedo associated with sea level changes in BC;
2. Identify sites along the SoG that have capability for shellfish culture and quantify changes in beach albedo, beach exposure/inundation expected from sea level change;
3. Define capability indices for bottom shellfish culture in the SoG;
4. Assess how bottom shellfish culture capabilities will be affected by changes in SST, SSS, beach albedo and beach exposure/inundation;

2. Background

Marine ecosystems including fish and shellfish will be affected by CC in different ways;

These impacts will occur on various levels of biological organization;

Some of environmental factors that will have implication on fish and shellfish include:

- **Temperature** - Determine distribution pattern and affects growth;
- **Water movement** (exposure), **substrate**, and **beach slope** - Directly affect survival;
- **Salinity**, **DO** and **pH** - Indirectly affect growth and survival;

In addition, **SLR** may change some of the elements of coastal wetland causing changes in dependent species;

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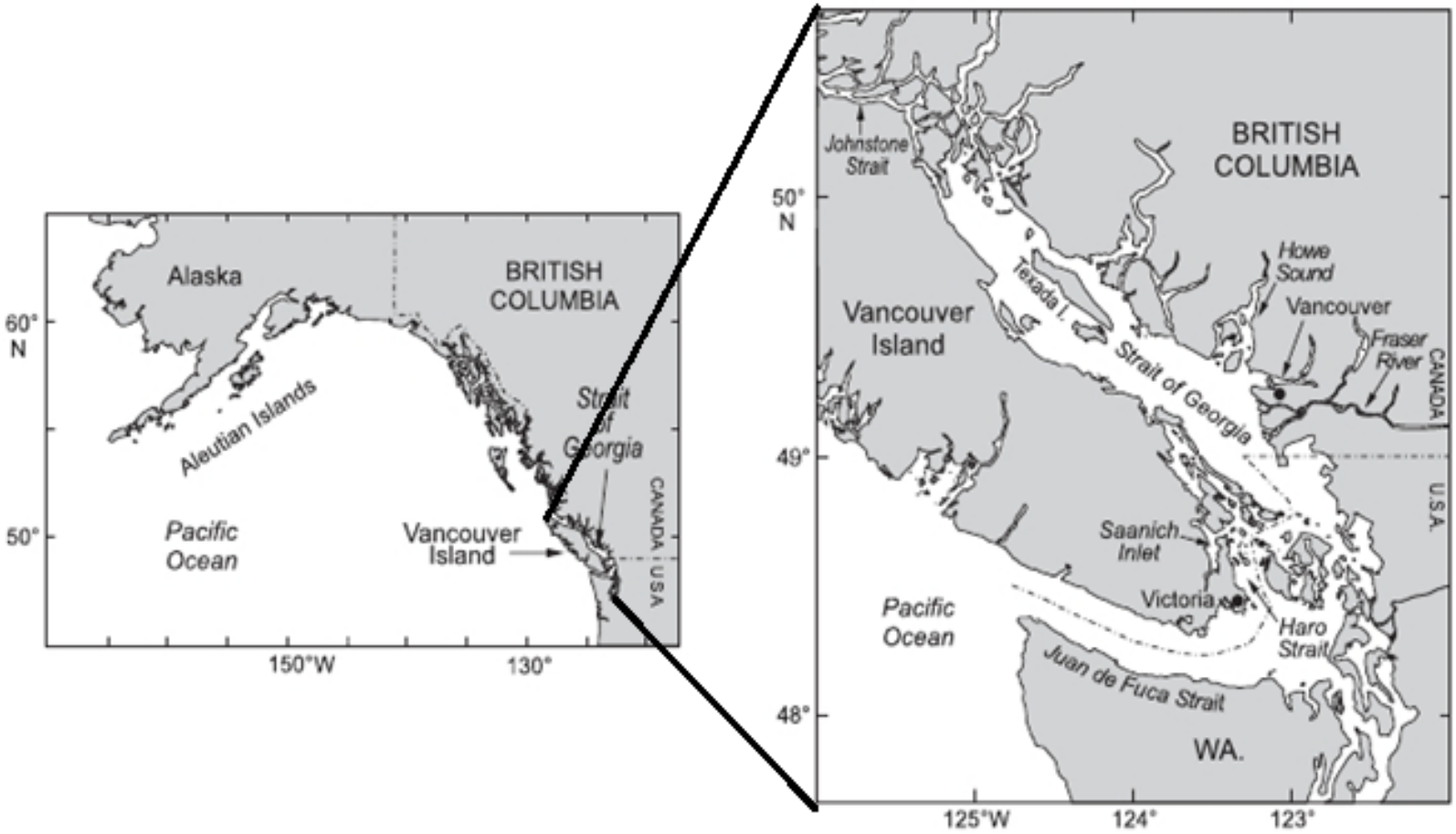
Expected Impacts of climate change in BC: (Ministry of Environment, 2011)

- Increased risk of flood in low-lying areas of the coastal zone due to sea level rise (about 88cm by 2100);
- Increasing storminess;
- Invasion of coastal water by exotic species;
- Likelihood change of salmon migration patterns and in spawning;
- Change in amount and timing of oceans and freshwater temperature, salinity and change in the rivers flow;
- Increase of conflicts in water management for freshwater fishers and aquaculturists;

There is a need to design and develop adaptation strategies for the aquaculture sector to adequately respond, cope and adapt to living in the changing climate.

3. Study Area Summary

The study was conducted in the northern Strait of Georgia (SoG) in British Columbia (BC), where many aquaculture operations are located.



Source: Carswell et al., 2005 and Johannessen and Macdonald, 2009

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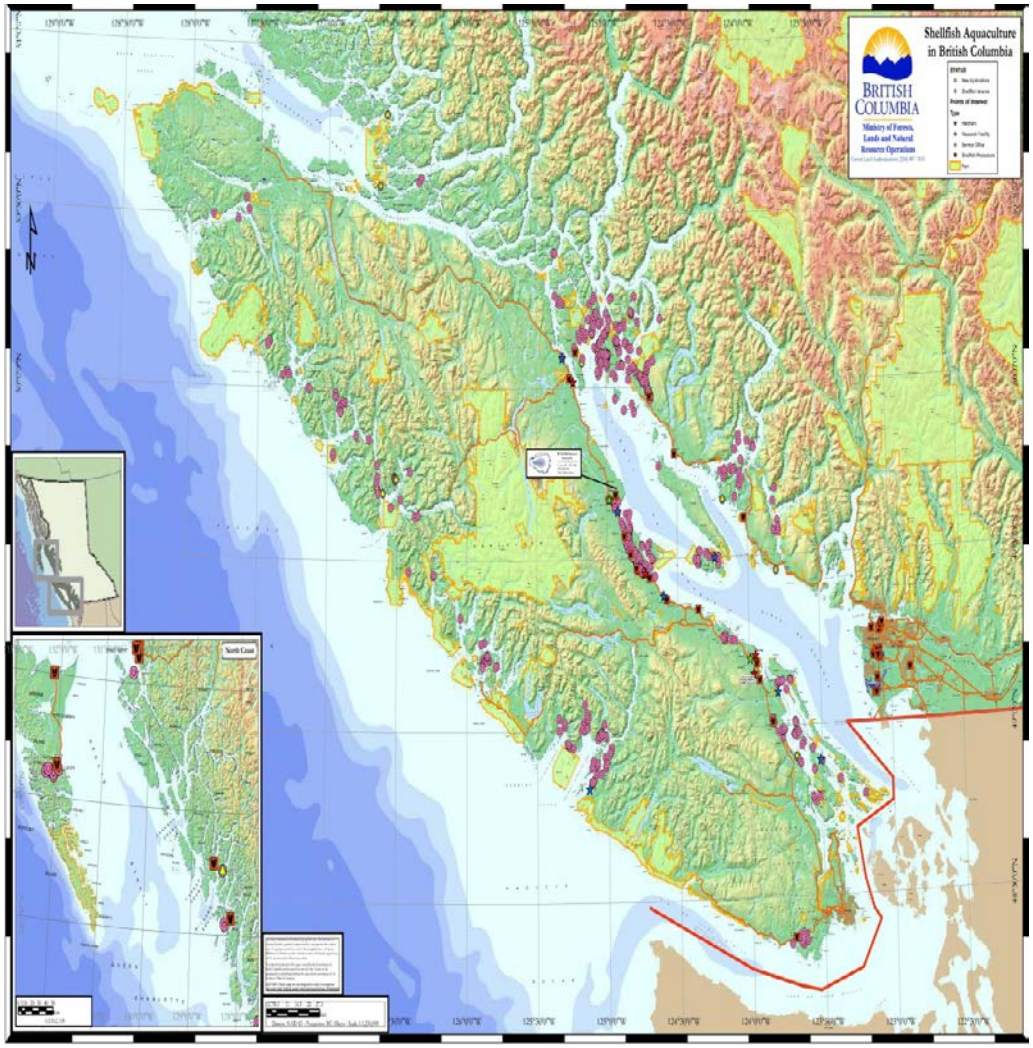


- The SoG is one of the largest estuary on the west coast of North America;
- About 460 licensed shellfish tenures occupy 2,114 ha in the strait;
- The majority of these tenures are located within the SoG around Vancouver Island;
- Baynes Sound is the most shellfish growing area in BC accounting for 29% of the tenure area and 52% of shellfish farm gate value;

4. Methods/Analysis & Results

Objective 1

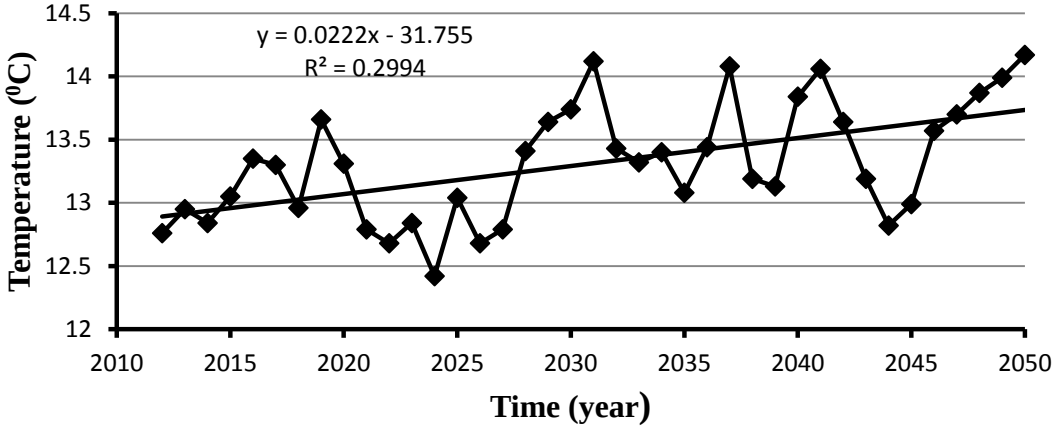
Examine expected changes in sea surface temperature and salinity

To examine the changes in physical conditions, this study:

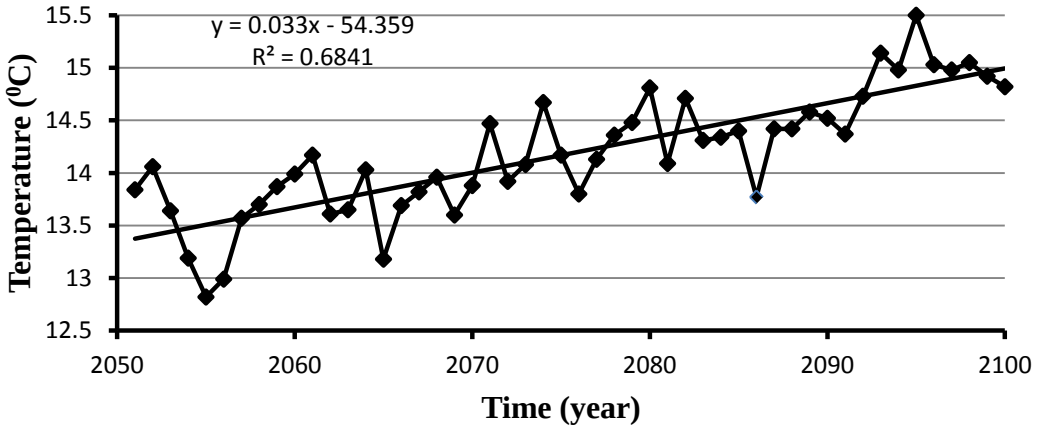
- Developed Scenarios of changes in SST and SSS and;
- Analysed the trends based on projections of SST and SSS of open ocean adjacent waters of BC's coast obtained from the Canadian Centre for Climate modelling and analysis, (CGCM3.1/T47).

These trends were then compared with the trends of observed SST and SSS in five selected stations (Entrance Island, Chrome Island, Sister Island, Departure Bay and Active Pass) collected from 1915 to 2011 in the SoG.

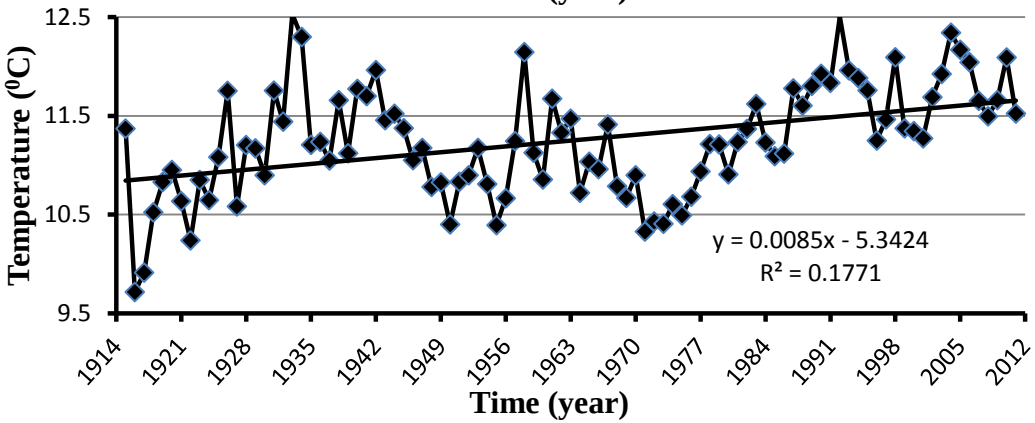
Results of Projected and Observed Sea Surface Temperature



Projected SST (2012-2050) of open ocean adjacent waters to the BC's coast
Temp. will increase approx. 1 ^{0}C at a rate of 0.0222 ^{0}C/ yr

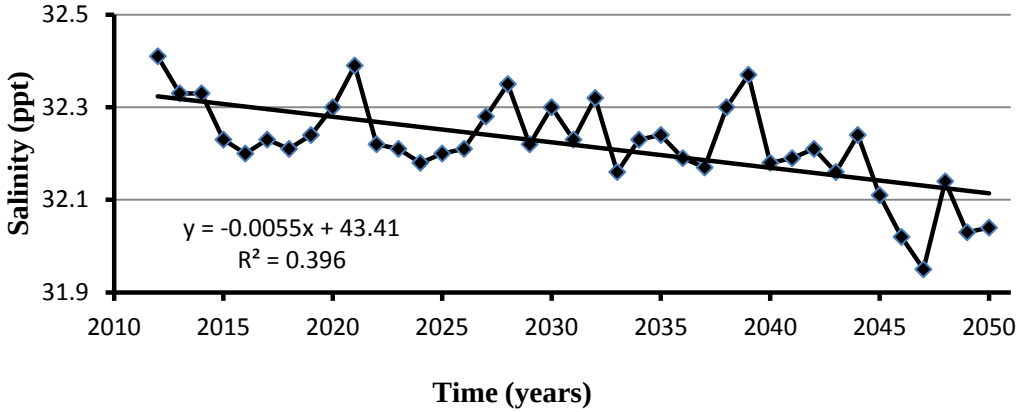


Projected SST (2051-2100) of open ocean adjacent waters to the BC's coast
Temp. will increase approx. 2 ^{0}C at a rate of 0.033 ^{0}C/ yr

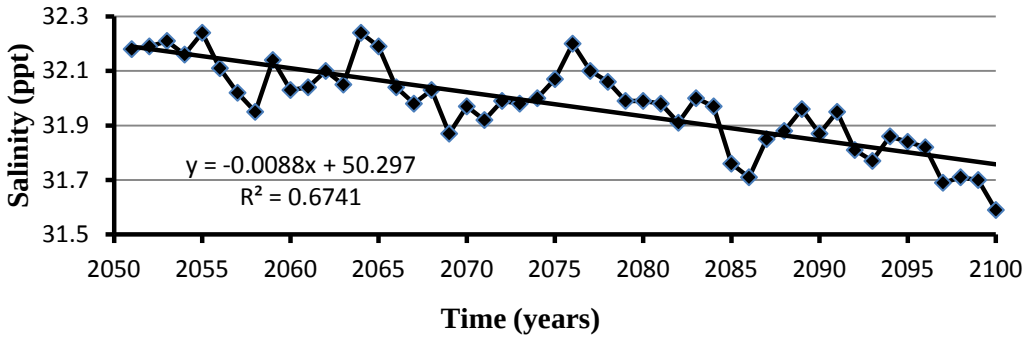


Observed SST (1915-2011) in the SoG. Temp increased approx. 1 ^{0}C at a rate of 0.0085^{0}C/yr

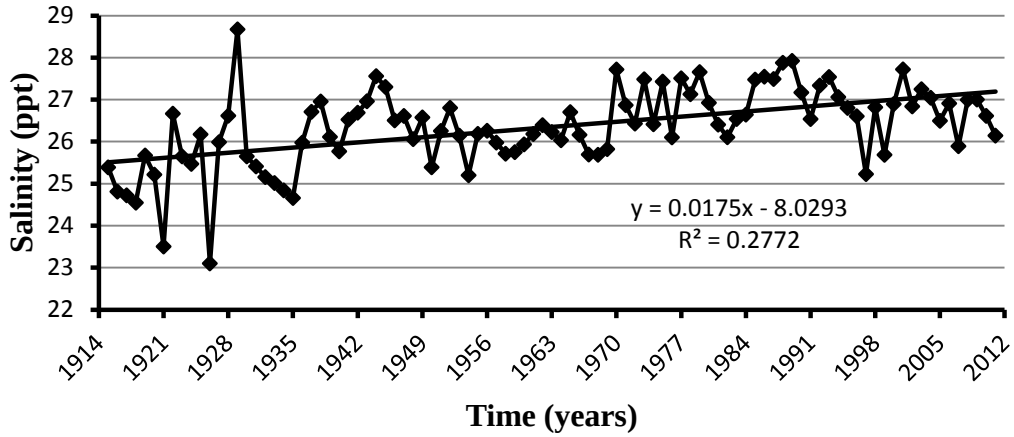
Results of Projected and Observed Sea Surface Salinity



Projected SSS (2012-2050) of open ocean adjacent waters to the BC's coast. Salinity is expected to decrease approx. 0.21 ppt at a rate of 0.0055 ppt/ yr



Projected SST (2051-2100) of open ocean adjacent waters to the BC's coast. Salinity is expected to decrease approx. 0.43 ppt at a rate of 0.0088 ppt/ yr



Observed (1915-2011) in the SoG. Salinity increased approx. 1.68 ppt at a rate of 0.0175 ppt/yr

Objective 2
Quantify changes in beach exposure/inundation

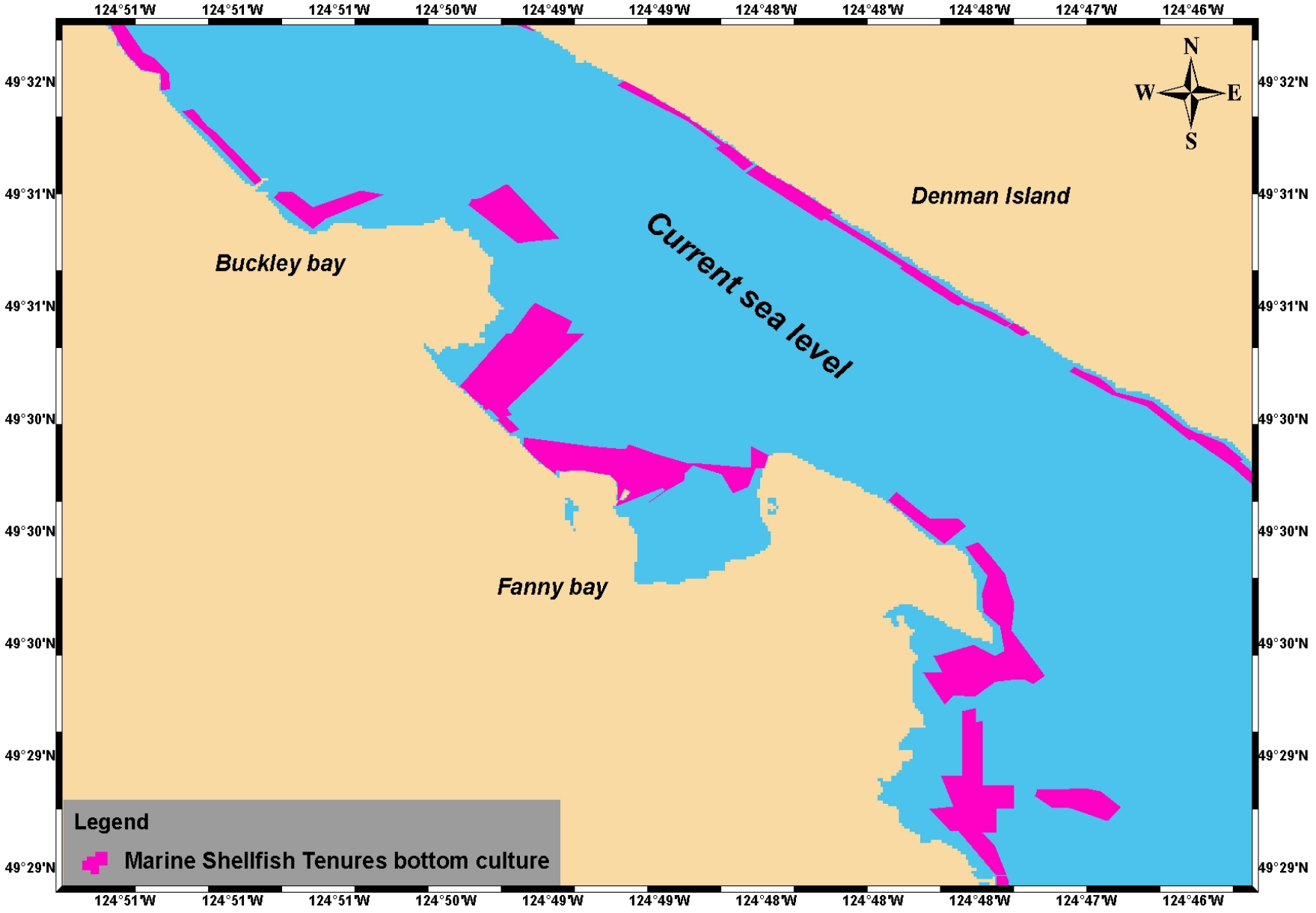
This study simulated and mapped areas (Baynes Sound and Texada Island) along the SoG prone to flood risk due to SLR. The analysis was based on the SLR projections developed Thomson et al., (2008)

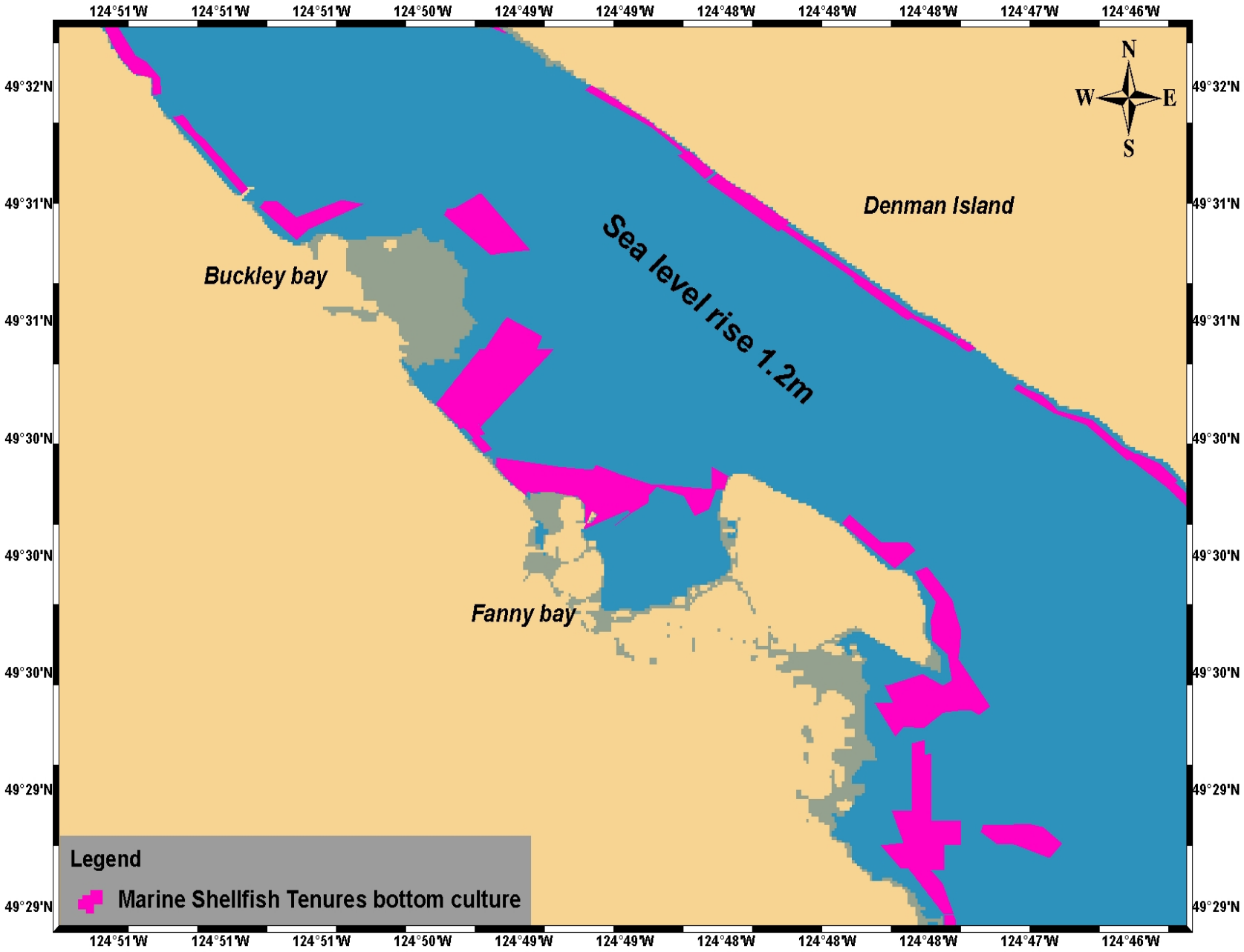
Location	SLR based on extreme low estimate of global SLR (m)	SLR based on mean estimate of global SLR (m)	SLR based on extreme high estimate of global SLR (m)
Prince Rupert	0.10-0.31	0.25	0.95-1.16
Nanaimo	-0.04	0.11	0.80
Victoria	0.02-0.04	0.17-0.19	0.89-0.94
Vancouver	0.04-0.18	0.20-0.33	0.89-1.03
Fraser River Delta	0.35	0.50	1.20

Inundated areas of the selected sites

		Sea Level Rise 1.2 m Area inundated (ha)	Sea Level Rise 2 m Area inundated (ha)
Baynes Sound	Buckley Bay	121.0	195.2
	Fanny Bay		
Texada Is.	Henry Bay	37.3	51.4

Sea Level Rise Simulation for Baynes Sound

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124°47'W
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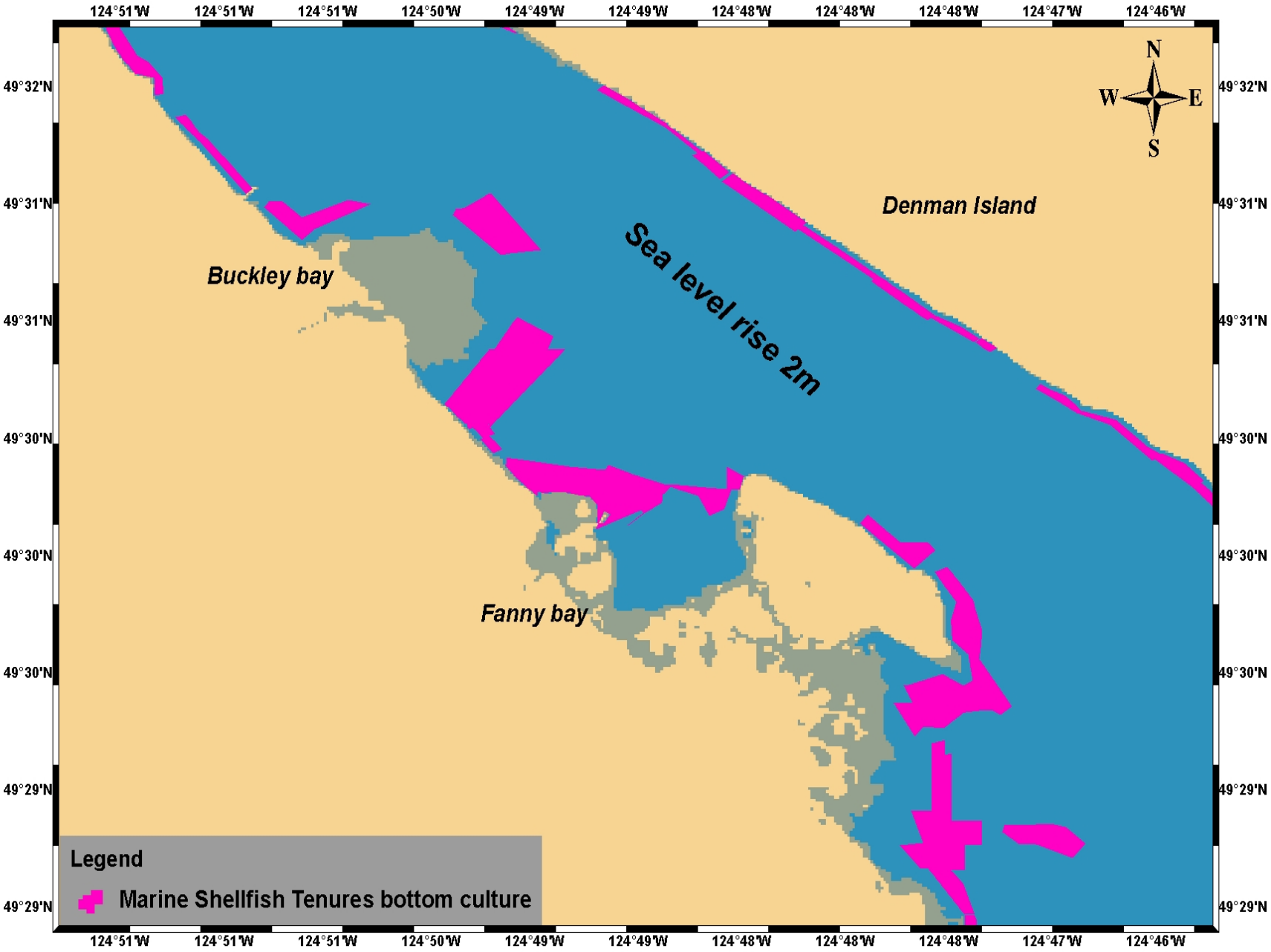
49°32'N
49°31'N
49°31'N
49°30'N
49°30'N
49°30'N
49°29'N
49°29'N
N
W
E
S
Denman Island
Sea level rise 1.2m
Buckley bay
Fanny bay
Legend
Marine Shellfish Tenures bottom culture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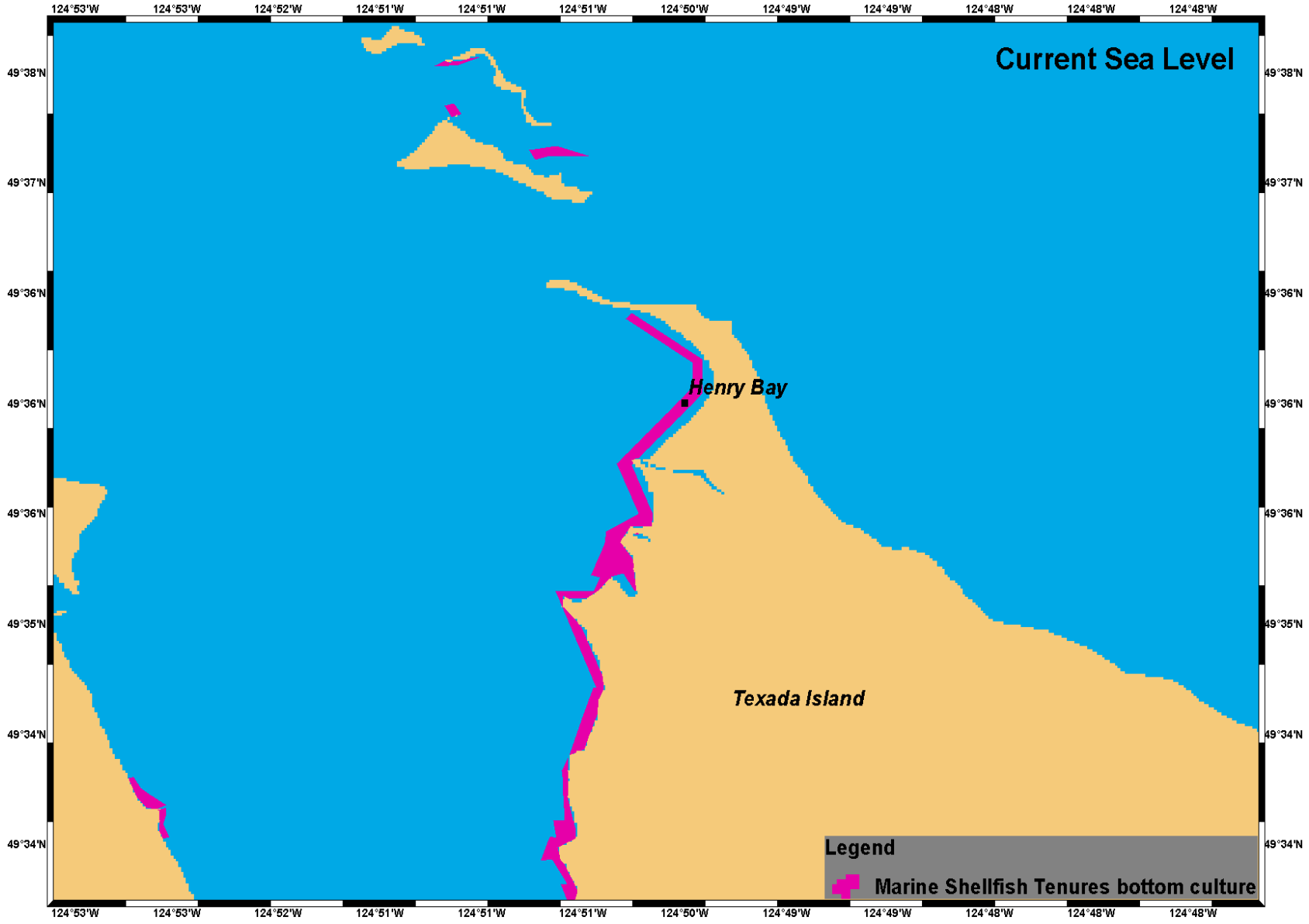
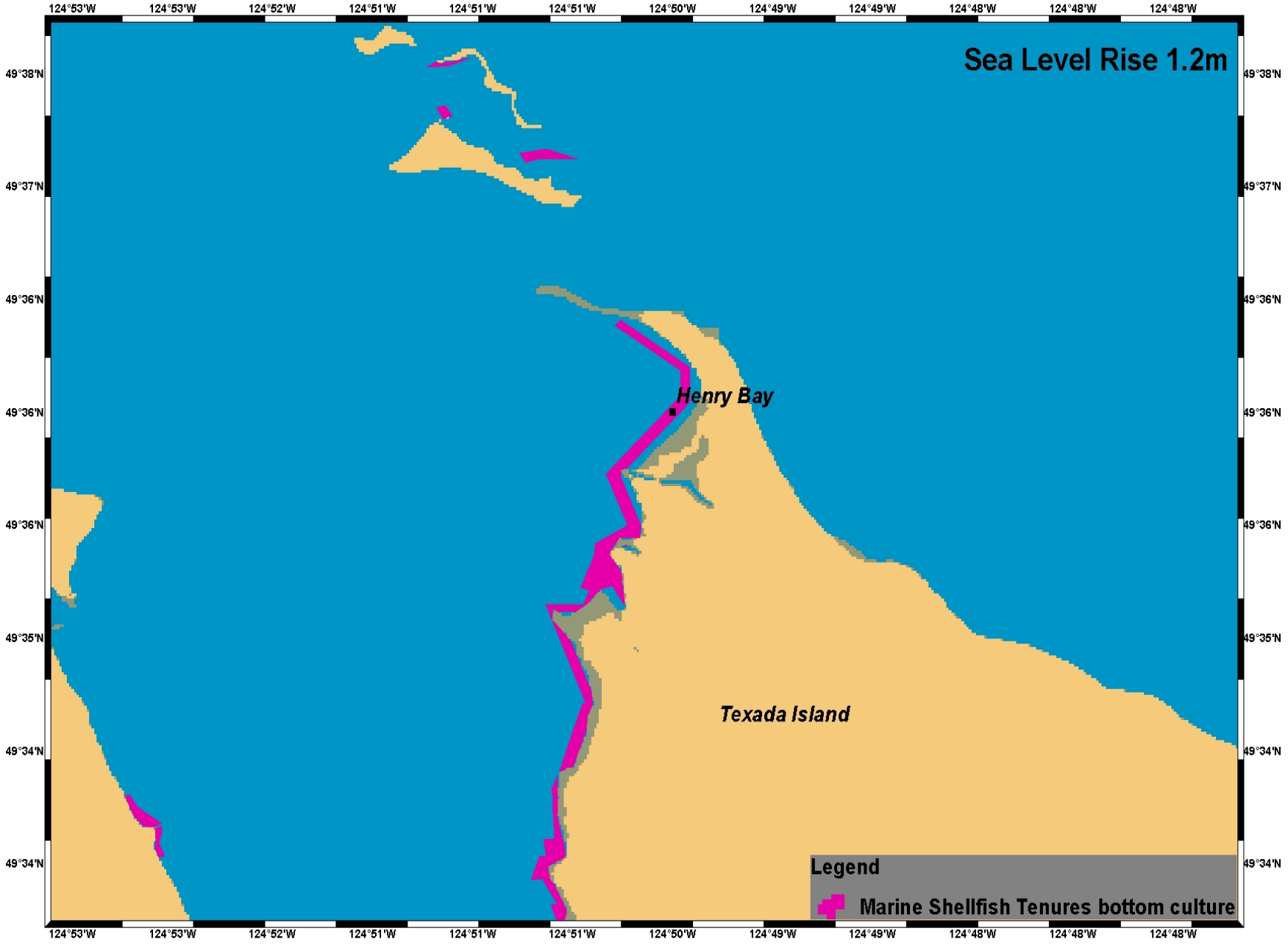
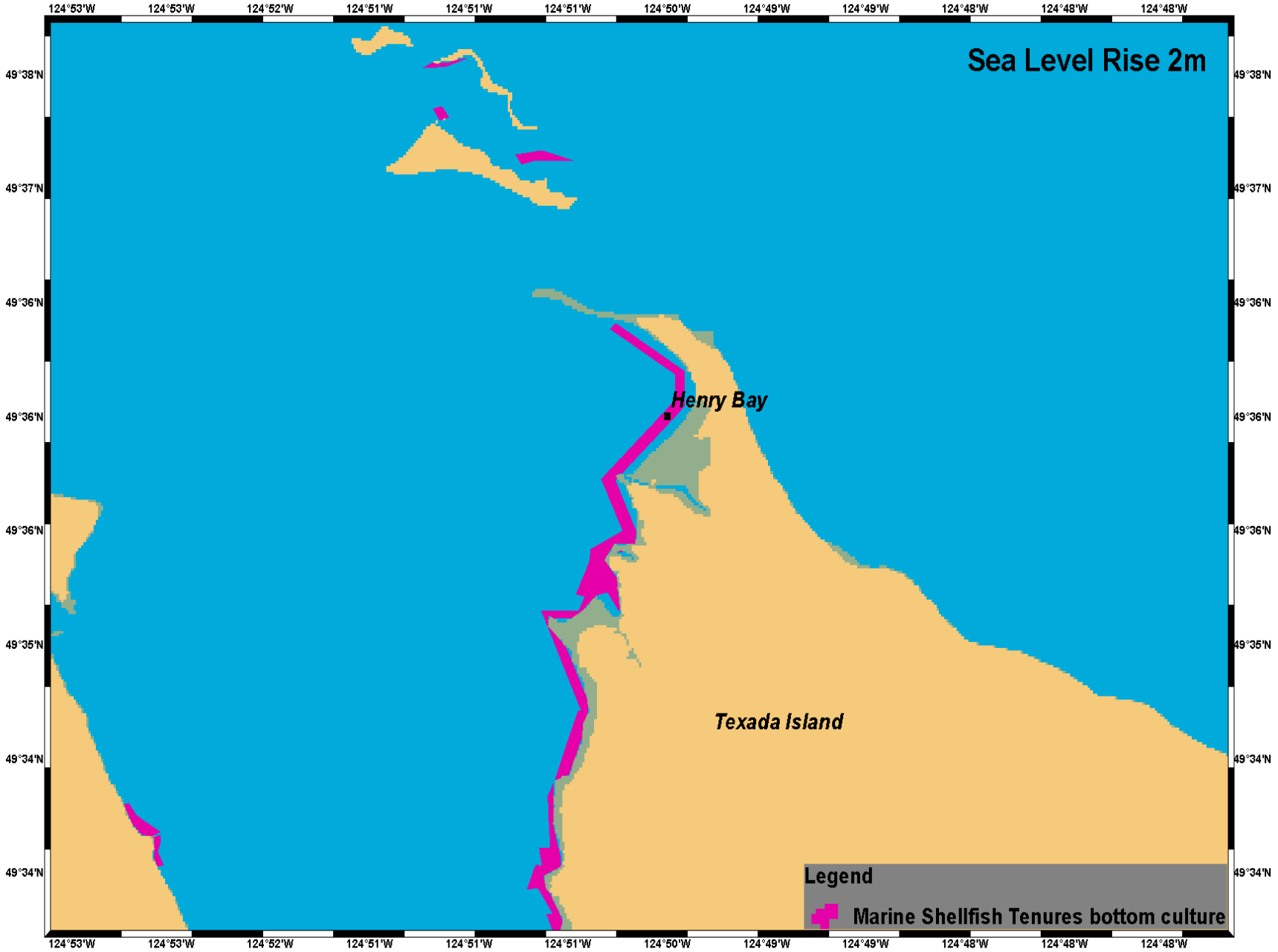
Denman Island
Sea level rise 2m
Buckley bay
Fanny bay
Legend
Marine Shellfish Tenures bottom culture

Sea Level Rise Simulation for Texada Island



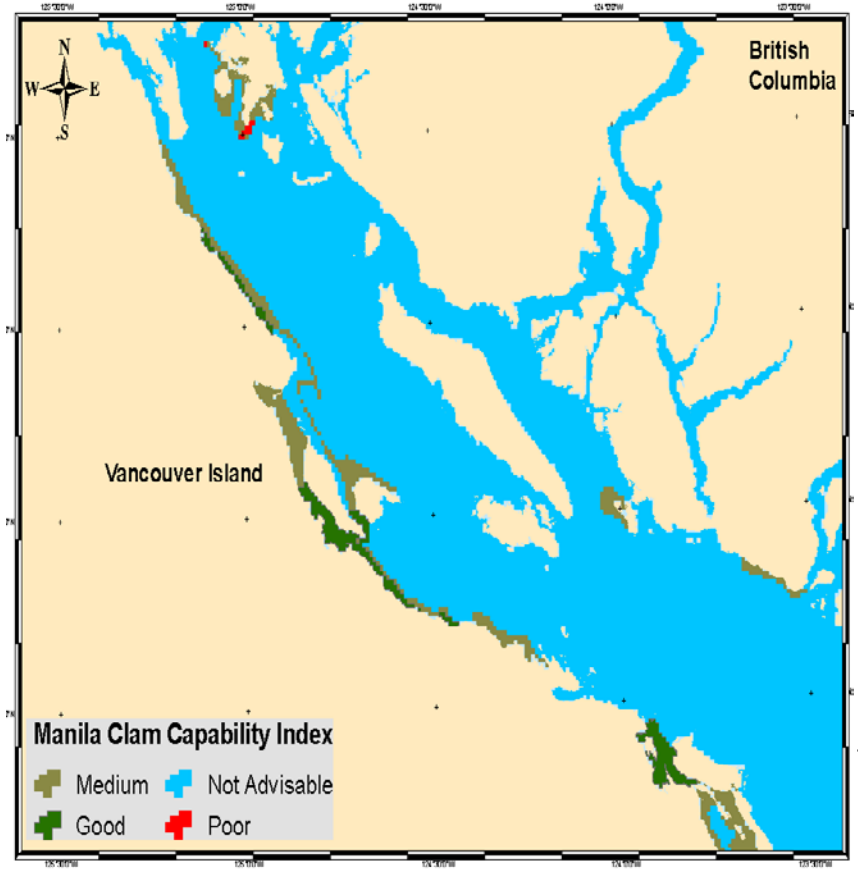

Sea Level Rise 1.2m
124°53'W
124°52'W
124°51'W
124°50'W
124°49'W
124°48'W
49°38'N
49°37'N
49°36'N
49°35'N
49°34'N
Henry Bay
Texada Island
Legend
Marine Shellfish Tenures bottom culture

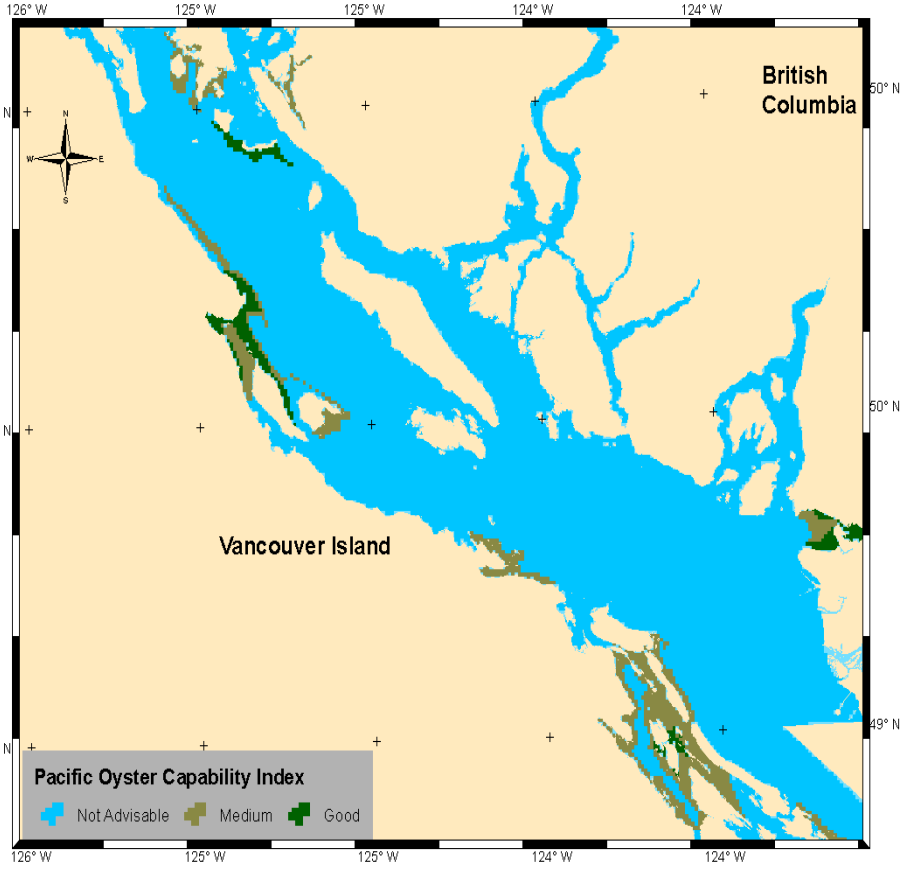

Sea Level Rise 2m
124°53'W
124°52'W
124°51'W
124°50'W
124°49'W
124°48'W
49°38'N
49°37'N
49°36'N
49°35'N
49°34'N
Henry Bay
Texada Island
Legend
Marine Shellfish Tenures bottom culture

Objective 3

Define capability Indices for Shellfish Aquaculture

To define capability indices for M. Clam and P. Oyster culture along the SoG, six variables (temperature, salinity, slope, substrate, exposure and depth) were used as criteria taking into account the range of tolerance levels of these species (Cross and Kingzett, 1992).





Objective 4

Assess how Shellfish culture Capability will be affected

To assess how shellfish culture capability in the SoG will be affected by changes in SSS and SST, result of scenarios of expected changes in these parameters developed previously in this study, were compared with the critical and preferential levels of tolerance of the species to evaluate whether the selected species can withstand these changes .

	M. Clam range	P. Oyster range	Obs. average (2011)	Exp. change (2012-2050)	Exp. change (2051-2100)
Salinity (ppt)	13.5 to 35	10 to 35	26.14	-0.21	-0.43
Temp. (^{0}C)	0 to 30	8 to 34	11.52	0 to 1	1 to 2

*The (-) signal means a decrease.

5. Conclusion and Recommendations

Conclusion

- The existing datasets provided by various agencies and institutions are accessible and can be used to investigate anticipated impacts of CC on coastal aquaculture in BC, however there is lack of some datasets to perform this type of analysis:
  - Numerical models that provide projected changes in sea surface salinity and sea surface temperature at local scale (in the Strait of Georgia) taking into account the effects of climate change;
  - Beach albedo and;
  - LIDAR (Light Detection and Ranging) dataset;
- There is gap in observed SST and SSS. One of lighthouses sampling stations (West Vancouver, DFO Lab) located in the SoG is discontinued;
- Changes in SST and SSS associated with sea level rise will not adversely affect Manila Clams and Pacific Oysters bottom culture in the Strait of Georgia;

Cont.

- Site capabilities to support bottom culture of these shellfish will not be impacted by expected changes in sea surface salinity and sea surface temperature;
- SLR will have negative impact on shellfish bottom culture, as most of the operations in the SoG occur on the intertidal substrate where SLR will directly affect access to these lands through changes in the high and low tidal ranges;
- Coastal property lands and intertidal aquaculture tenures will need to be redefined as SLR will change beach profiles landward and reduce access to the aquaculture sites, given that beaches adjust to SLR;
- The optimal growing areas for shellfish may be shifted off of the grower's tenures.

Recommendations

- There is need to provide additional datasets:
  - Elevation datasets with higher accuracy in order to meet the objectives proposed in this study and the data requirements of future similar studies;

    The elevation data should be of higher vertical resolution than the DEM used in this study (vertical resolution 1 m). It is suggested the use of LIDAR dataset (vertical accuracy 10-30 cm) to determine an accurate representation of SLR;
  - Numerical models that provide projected changes in SSS and SST at local scale by 2100 taking into account the effects of CC, although there have been efforts to model the circulation in Salish Sea (Sutherland, MacCready, Banas, & Richey, 2011) for 2005-2006;
- There is a need to improve the nature of benthic and pelagic shapefile dataset. These dataset should be provided as continuous data instead of discrete data or polygons as presently available;

Cont.

- This study was unable to locate appropriate beach albedo information (observed and projected data) for BC's coast including the SoG. Given that, it is recommended an additional research to:
  - Provide beach albedo data;
  - Assess the impacts of changes in the albedo on shellfish bottom culture.

    This would determine if the beach sediments will support larval settling and early growth, as well as, would investigate whether changes in beach area may result in cooler or warmer micro-environments which could reduce or increase habitable areas;
- Several studies (Harley, et al., 2006; Barton et al., 2012; BC-Shellfish Grower's Association, 2012) suggest that increasing CO_2 concentrations are causing changes in seawater pH, this study recommends an investigation of the impacts of water pH on shellfish culture in BC.

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Thank You