Climate Change Adaptation in Clayoquot Sound

Ahousaht, Hesquiaht, and Tla-o-qui-aht Community-based Climate Change Adaptation Plan

Phase II Report

Edited by John Lerner

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Executive Summary

The Importance of Climate Change

Climate change may be the defining issue of our generation. Since the Industrial Revolution, the mean surface temperature of Earth has increased an average 0.6° C (Celsius) due to the accumulation of greenhouse gasses (GHGs) in the atmosphere.[1] Historically, the Earth is accustomed to experiencing wide-spread severe environmental change and has always been able to adapt to these changes accordingly. Yet, the difference now is the *speed* and *scale* of the warming that is currently occurring. Most of this change has occurred within the past 30 to 40 years, and the rate of increase is accelerating. These rising temperatures will have significant impacts at a global scale and at local and regional levels. As a result, climate change will increasingly impact natural and human systems to alter the productivity, diversity and functions of many ecosystems and livelihoods globally.

Climate Change in the Clayoquot Sound

The climate of the Clayoquot Sound is shaped by its proximity to the Pacific Ocean and by its steep topography. In general, the climate is wet and mild, indeed one of the wettest places in Canada. Climate change is expected to accentuate both of these characteristics over the next century. Indeed as local First Nation residents and scientists have observed, the changes have already begun. According to the ClimateBC model estimates, the following precipitation and temperature trends can be expected in the Clayoquot area over the next century:

• Annual warming	between 1.4°C and 3.9°C
• Winter temperature increases will be more significant	between 1.1.and 3.4°C
• Annual precipitation will increase mostly in the fall through to the spring	between 6% and 24%
• Less rain will fall in summer months	between 5% and 15%
• Less precipitation will fall as snow	between 35% and 68%
• Summer drought frequency could increase considerably	between 15 and 46%

Storm characteristics in the Clayoquot Sound may also change. Projections regarding rain and wind intensity are uncertain but there is reason to believe that these will increase as well during the coming century.

Climate and Ecosystems

Climate is one of the primary factors that govern the distribution of species and communities within nature. So, as climate changes, elements of the natural world also change. This report highlights some of the main changes that are predicted to occur, in marine, freshwater aquatic and terrestrial ecosystems. Changes can be direct or indirect - for example, snowmelt rates or stream water temperatures are a direct effect of rising air temperatures. Indirect effects include effects such as decreasing oxygen levels in the ocean due to increasing temperature and reduced mixing of the water due to stratification. Specific effects are actually difficult to predict because of the inter-connected nature of ecological systems. Ecosystems themselves will not shift with climate change – it is individual species that will move. Future ecosystems will therefore depend on the ability and rate of different species to move, and their tolerances to the changes that are coming.

Socio-Ecological Resilience

Resilience ideas provide a way of thinking about ecological and social systems that includes an understanding that nothing is naturally static, but that for humans and other species, a resilient system can bounce back after it is pressured, and also can change and continue to function. How resilient a system is in the future depends in part on how healthy it is today.

The forests of Clayoquot Sound are in relatively good condition, compared to most other watersheds on Vancouver Island and the southern portion of mainland BC and in the States to the south. Forests are relatively intact, and though significant harvesting and road building has occurred in some areas, significant watersheds remain intact today. This state buffers the immediate effects of climate change on the forested landscape – multi-storied old growth forests are resistant to climate change because they moderate their own microclimate, filter water and resist invasion by novel and invasive species.

Similarly, freshwater aquatic systems of the Clayoquot Sound are relatively high functioning today, compared with many places locally and globally. Forestry activities have altered hydrology, especially by building poorly located low elevation roads, and logging riparian areas in the past, though these practices are much improved today. Roads and harvesting on steep slopes also change how water and sediment moves across the landscape and have had localized impacts on freshwater processes. As a whole in Clayoquot Sound the large areas of intact forest buffer historic forestry effects and will continue to buffer the effects of increased amount and severity of rainfall as climate changes progresses (assuming precautionary management continues).

The state of the marine system today is more complex – historic pressures have been significant – resulting in significant shifts in species over the last 150 years, including extirpation of a keystone predator the sea otter, significant declines in the large whales that were historically abundant, changes to salmon populations, and introduction of commercial and non-commercial species of shellfish species such as oysters. In many respects, the marine system of Clayoquot Sound is currently rebounding from historic pressures. However, population trends of individual species are now caught up in the climate change trends – making it hard to infer what is really happening in this system and why.

The socio-economic state of the Clayoquot Communities (Ahousaht, Tal-o-qui-aht and Hesquiaht) is also complex and a result of historic pressures. They have experienced colonization, epidemics, the imposition of the reserve and the residential school systems, continued encroachment by outside interests intent on controlling their traditional territory and resources, the decline of the fishery and the forest sectors, a tsunami that wiped out one of their villages (Hesquiaht) and numerous ecological cycles. These pressures have left the Clayoquot communities struggling at times, and economically depressed, but nonetheless they remain determined to survive and are increasingly thriving. The people continue to fish, hunt and collect food; they not only own the forest tenures but have also managed to preserve large tracts of traditional territory in undisturbed forest. Although their economies are still relatively depressed, they continue to build their communities, with new schools, new infrastructure and new services, while reviving important cultural practices.

The Impacts of Climate Change on Ecological Systems

Climate change is expected to bring about a variety of changes to the natural ecosystem of the Clayoquot Sound; some of the general changes include:

- **Natural communities will change as temperature changes.**

With climate change, species are expected to move, adapt or die in their current locations, depending on their specific tolerances and opportunities to move. Species can move much more readily in the ocean than on land, and new marine species are already seen in Clayoquot Sound.

Salmon, particularly Sockeye and Chinook, are particularly temperature sensitive – they are tolerant of stream temperatures up to only 13.3 degrees. These fish species are likely to move north with further temperature increases. Clams may be negatively impacted by warmer sea temperatures though other species such as geoduck may thrive with the warmer temperatures.

Complex interactions such as increasing predation from increasing invasive species such as the European green crab, may also affect bivalve growth rates, though this may be reduced by sea otter populations which also feed on these crab species. Other marine species, including the feather boa kelp and the Humboldt squid, appear to be moving north in response to the warming waters off the west coast of BC.

Similar trends of movement northwards are predicted for terrestrial species as well. Some marine bird species such as the brown pelican are also being observed in the area and are expected to increase. However, less mobile species will have greater difficulties moving. For giant kelp, which is thought to be resistant to increasing temperatures, they are expected to persist for the foreseeable future and may increase this habitat type which tends to increase diversity within the shoreline ecosystem. Today's forest understory species may not be well adapted to the new regimes, and long term ecosystem diversity may be reduced as it will take a long time for new shrubs and herbs to colonize.

The ecosystem response to species shifts will be complex – we do not know if or when relatively stable populations will become established, or whether the arrival of new species may hasten the decline of less adapted 'original' species. Loss of species can lead to reduced ecosystem resilience, with fewer species to play functional roles.

- **The very nature of the ocean is already changing rapidly.**

The ocean is becoming more acidic as more CO2 dissolves in the water, creating carbonic acid. In addition, the ocean is becoming more stratified in some areas, as surface temperatures increase, and there is also decreasing oxygen availability at the surface, and also in 'dead zones'.

All these factors have been observed to be occurring already, which climate change will amplify and lead to a complex array of effects on species, which may be severe in some cases. Ocean acidification will severely affect marine life which uses calcium for its structure such corals, mollusks, some algae and phytoplankton. These creatures are likely to be significantly reduced if acidity levels increase sufficiently. In addition, the level of acidity alters the rate of many chemical reactions – having the potential to change basic physiological processes.

The impact to marine creatures from reduced oxygen levels may vary widely – most large species that can move away from low oxygen areas would do so, while many stationary species may die, depending on the specific levels of oxygen available. Key base prey species – such as krill (euphausiids) and sand lance are expected to be particularly sensitive to chemical changes in the ocean, and decreases in these populations will have significant cascading effects on many larger species that use them as important food sources (whales, sea lions, salmon, marine birds). Resilience of ecological systems may be reduced if functionally important individual species are lost or reduced locally.

- **The timing, abundance and quality of freshwater may change.**

Declines in snowpack in the mountains, with decreasing rainfall at certain times and increasing rainfall at other times will have differing effects depending on the specific watershed. On average, by 2080, precipitation is expected to increase during the winter and fall (by up to 50% and 20% respectively), and stay similar or decrease (up to 9% in summer). Spring freshet is already occurring earlier than in the recent past and is expected to become earlier and potentially larger in the near future, though in the long term this effect is thought to be insignificant as snow-dominated watersheds become more rain-dominated.

Water quality is likely to decrease if higher volumes of rainfall with sediments become more frequent. Similarly, winter flooding may also increase as high volume and intensity of rain combines with warmer, wetter snowpacks. Increasing sedimentation is expected to occur if storm severity does increase, and there is the potential for interactions between roads and harvesting to result in increased landslide rates. Increasing impacts to ecological values are expected if storm frequency or intensity occur. Similarly, human hazards – to roads and other infrastructure – would also be expected to increase. The recent flooding in Bella Coola and Kingcome village is the type of incident that may be expected more frequently on the coast.

On the wet west coast, droughts will likely not be significant in the way they may in interior regions or even the east coast of Vancouver Island, but the interplay with increasing temperature and decreasing stream water levels in summer may exacerbate effects for sensitive species such as spawning salmon. Also, the potential for saltwater intrusion into groundwater is likely to increase into the future.

- **Forests may be relatively buffered:**

Clayoquot Sound forests can be considered to be relatively buffered from the worst effects of climate change, because of the proximity to the ocean which moderates temperature today, and will continue to do so for some time into the future. Broadly speaking the character of the forest is likely to remain similar – with a conifer dominated overstory. Overall productivity of the land base may increase as the number of frost free days increases, and as general temperature increases. Areas that remain as old forest today are most buffered to the effects of climate change since they moderate their own microclimate and may remain in their current form potentially for many centuries into the future. Resilience theory predicts that harvested areas are more susceptible to change as these areas are open to the immediate effects of increasing temperatures and changes in precipitation, and there remains the potential that species from more southerly climes today may be able to move into this zone in the future as climate changes.

Overall, the future climate predictions for the forests, combined with the relatively intact state of Clayoquot Sound watersheds today, likely results in resilient forested ecosystems that are unlikely to transform into a radically different system within the reasonable future.

- **Natural hazards may increase:**

Increased intensity and amounts of rainfall, increased rate of snowmelt and rain on snow events will all affect slope stability and the possibility of flooding events. Future frequency and intensity of storm events are predicted to increase worldwide; however, the data relating to this area of the coast are less certain. Significant wave height (the height of the largest waves) already appears to be increasing in this part of the ocean, and this has the potential to combine with storm events and significantly impact coastal flooding and erosion. These factors increase human and infrastructure hazard, and also affects habitat values such as stream functioning, riparian systems and salmon habitat.

Socio-Economic Vulnerabilities of Climate Change

It is a credit to the Clayoquot communities' past adaptability and persistence that they have survived centuries of colonization and its ancillary pressures. However, now the communities face a new challenge in the form of climate change that will again impact many aspects of their lives. The ocean and to a lesser extent the forests on which they heavily depend are changing. Because the Clayoquot communities are so closely tied to the land and the ocean, they are particularly vulnerable. Chief among these vulnerabilities are threats to health and safety, food supply, livelihoods, infrastructure and shelter and various cultural, social and political resources. Past adaptation successes would suggest that the communities will adapt to these changes but how well they adapt depends on how well they are prepared. Based on current conditions, many important community assets might be considered at least moderately vulnerable while infrastructure assets might be considered highly vulnerable.

Summary Vulnerability Ratings for the Clayoquot Communities:

Community Asset	*Vulnerability Rating*
Health and Safety	Moderate
Food Supply	Moderate
Livelihood/Economy	Moderate

Infrastructure and housing	High
Social, Cultural and Political Resources	Moderate

Adaptation Vision, Goals and Objectives

Although the Heshquiaht, Ahousaht and Tla-o-qui-aht are very different communities facing different challenges and at are various stages of planning and development, they all share many of the same values and visions for sustainable development and climate adaptation. In general, all three communities believe it is better to respond proactively to climate change rather than react if and when climate impacts become apparent. Their general guiding principle is to live in balance or harmony with nature – to take what is needed but never more than what Mother Nature can sustainably provide. In so doing, it is believed that not only will the communities become more resilient to climate change but more resilient and sustainable in general.

• Adaptation Goals

The general adaptation goals of the Clayoquot communities are as follows:

- Slow the negative impacts of climate change on the land and the ocean by reducing unsustainable human use and by restoring natural habitats where possible. Slowing the negative ecological effects of climate change will allow time for the Clayoquot communities to adapt socio-economically.
- Build individual and community capacity to adapt to eventual climate and ecological changes by strengthening key community assets, including health and safety resources, local economies, food supply systems, housing and infrastructure and cultural, social and political resources.

• Adaptation Objectives

The climate adaptation objectives of the Clayoquot communities to achieve these goals include:

- Maintain the ecological health of the Clayoquot Sound
- Improve the health & safety of the communities
- Diversify the food supply of each community
- Diversify the livelihoods/economies of each community
- Strengthen the housing and Infrastructure of each community
- Strengthen the cultural, social & political resources of the communities

Community Adaptation Strategies

The climate adaptation strategies recommended for the three Clayoquot communities are intended to meet the communities' adaptation vision and goals and they are structured around the communities' objectives to do this. The strategies are largely regional or collaborative in nature because many of the same climate vulnerabilities or challenges are shared by all three communities and/or because many of the adaptation measures are more likely effectively implemented on a regional basis.

Above all else the number one priority in this report is to promote a culture of self-reliance and resilience among individuals and the community in general. In many respects the strategies in this report reflect this objective, whether through diversification or strengthening resources. The good news is that many of these strategies are already on the agenda in the Clayoquot communities as community development and resource management activities. The recommendations in this report are simply now adding a new perspective and impetus to work on them further.

The following list of adaptation measures are recommended for implementation by the communities.

Climate Adaptation Objectives	**Key Measures**
Maintain Ecological Health	• Reform fishery planning • Shift fishery catch • Protect and restore habitat
Strengthen Housing and Infrastructure	• Upgrade key assets for storm surges, flooding, rain, wind and wind throw. • Pay particular attention to ventilation and mould issues.
Diversify Livelihoods/Economies	• Increase investments in multiple economic sectors • Undertake risk reduction initiatives • Increase skill development support
Diversify Food Supply	• Shift subsistence fishery catch over time • Explore closed containment & multi-trophic aquaculture • Increase gardening and food preservation support • Educate youth on traditional practices and healthy diets
Improve Health and Safety Resources	• Update emergency preparedness planning • Coordinate early warning systems with government

	• Monitor for new pests and diseases
Strengthen Political, Social and Cultural Resources	• Integrate Adaptation Plan into community planning • Raise community awareness re Climate Change • Promote a culture of self-reliance, adaptation and continuous learning

All of the adaptation recommendations require time, funds and/or expertise to move them along in a timely fashion. And because the Clayoquot communities have very limited resources, the federal and provincial governments are encouraged to partner with the communities on a long-term basis to support their climate adaptation objectives.

Climate Adaptation in Clayoquot Sound

Ahousaht, Hesquiaht, and Tla-o-qui-aht Community-based Climate Change Adaptation Plan

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Chapter 8: Climate Change in the Clayoquot Sound: Monitoring and Research Needs

Prologue:

Everything is Inter-Connected

Imagine a sockeye salmon swimming back towards the coastline of Clayoquot Sound in 40 years from now - 2050.

It is 4 years old and ready to spawn.

The salmon's ancestors arose in the cold clear streams of Clayoquot Sound, where ancient forests covered all the mountainsides.

The historic salmon always had to respond to nature and its unpredictability – storms could create landslides and affect spawning habitat in entire watersheds; sometimes storm surges would affect eelgrass habitat where the juvenile fish waited in the near-shore eating food and staying safe from predators while getting large enough to head out to sea.

Competition between other fish, and avoiding predators was part of life. But for the salmon in 2050 the numbers of uncertainties have grown – now the sea itself is becoming difficult to live in. Increasing acidity of the water itself from the increased dissolved carbon dioxide, and lowered levels of oxygen make the ocean a more stressful place to live.

Close to shore, the eelgrass beds still provide a welcoming refuge from predators, but the near-shore is full of sediment, making avoiding becoming someone else's dinner more difficult.

Food itself is more scarce because the productivity of algae is lowered due to reduced light levels, and because krill abundance has changed due to changes in ocean upwelling– these are things the salmon has not encountered before.

Sediment has increased in the water partly from harvesting in watersheds, and exacerbated because the number and intensity of storms has risen.

Not taking time to wonder how the smelts will fare in the eelgrass, our sockeye enters the creek. Again, sediment seems to have reduced available spawning habitat – maybe it was that major storm that just occurred last week – unusual at that time of year.

But most noticeable is the temperature – the water feels much warmer than usual, and it is shallow too. Drought, increased air temperatures, and cutting of local forests all have contributed. Our salmon manages to contribute some young that year, and ends her life ground into the soil around a sitka spruce tree, after being dinner for a bear.

What will happen if sockeye salmon don't return in numbers sufficient to provide nutrients to the trees, streams and human communities who live close by, in future?

This is a story but it is based on a chain of events that are plausible in this generation's future because of climate change. The opportunity exists to take action now by building adaptation measures into our community plans which will mitigate some of these impacts and help us remain resilient into the future.

Chapter 1

Introduction, Background and Methodology

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Introduction

What is Climate Change Adaptation?

Climate adaptation maybe many things to many different people but it is essentially a process by which individuals or groups of people adjust their human or natural systems to actual or expected climate changes and their effects in order to moderate harm or capitalize on benefits[1].

Why is Climate Change Adaptation is Important?

Climate change may be the defining issue of our generation, since the challenge that it presents the world is so pervasive and complex. The mean surface temperature of Earth has increased an average 0.6^0 C (Celsius) since the Industrial Revolution and increasing scientific evidence suggests that this is due to the accumulation of greenhouse gasses (GHGs) in the atmosphere.[2] Historically, the Earth has been accustomed to experiencing wide-spread severe environmental change and has always been able to adapt to these changes accordingly. Yet, the difference now is the *speed* and *scale* of the warming that is currently occurring. Most of this change has occurred within the past 30 to 40 years, and the rate of increase is accelerating. These rising temperatures will have significant impacts at a global scale and at local and regional levels. As a result, climate change will increasingly impact natural and human systems to alter the productivity, diversity and functions of many ecosystems and livelihoods globally.

For resource-dependent communities, like many First Nations in BC, climate change may increasingly compound existing vulnerabilities as the availability and quality of natural resources that they heavily depend upon decline. Limited resources and capacities for responding to stresses, such as, storm surges, heavy rains and resulting floods, and sea water changes and resulting shifts in marine life will increasingly constrain their ability to meet basic needs and become self-governing. There is, therefore, an urgent need to reduce current vulnerabilities and increase adaptive capacity of the communities so that people of these communities can face the longer-term impacts of climate change with resilience.

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[1] Natural Resources Canada 2010

[2] IPCC 2000.

What is a Resilient Community?

A resilient community is one that takes on purposeful activities to enhance the personal and collective capacity of its citizens and institutions to respond to and influence the course of social, economic and ecological change.[3] This type of capacity implies an ability to absorb stresses or destructive forces through adaptation, to manage certain basic functions or structures during disruptive events, and to recover or bounce back after the event(s)[4].

Box 1: Key definitions associated with adaptation

Impact: The way a human or natural system is affected by environmental change, including climate effects.[1]

Risk: In the context of environmental change, risk refers to the threat posed by a change, i.e. the probability of an adverse impact. Climate change risk is a function of the magnitude of an individual hazard and/or change and the degree of vulnerability of a system (or a community) to that hazard and/or change. Unless a system (or community) is vulnerable to the hazard, there is no risk.[1]

Coping: Short-term actions to ward off immediate risk, rather than to adjust to continuous or permanent threats or changes – strategies usually rely on selling or using up assets or resources. Coping strategies are often the same set of measures that have been used before. When using coping strategies as the response to stress, it is possible that vulnerability will increase in the long term.[1]

Adaptation: Adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities.[1]

Adaptive capacity: The ability of a system to adjust to climate change (including climate variability and extremes) to moderate potential damages, to take advantage of opportunities, or to cope with the consequences.[2]

Vulnerability: The degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate variation to which a system is exposed, its sensitivity, and its adaptive capacity.[2]

Resilience: The ability of a community to resist, absorb, and recover from the effects of hazards in a timely and efficient manner, preserving or restoring its essential basic structures, functions and identity.[2]

It should be noted that the terms "adaptation" and "coping" are often used interchangeably. However, these two terms are distinctly different, as demonstrated by the below characteristics:[3]

Coping

- Short-term and immediate
- Oriented towards survival
- Not continuous
- Motivated by crisis, reactive
- Often degrades resource base
- Prompted by a lack of alternatives

Adaptation

- Oriented towards longer term livelihoods security
- A continuous process
- Results are sustained
- Uses resource efficiently and sustainably
- Involves planning
- Combines old and new strategies and knowledge
- Focused on finding alternatives

Sources: 1: ICIMOD, 2009. Local Responses to Too Much and Too Little Water in the Greater Himalayan Region; 2: IPPC, 2007 3: CARE 2009, Climate Vulnerability & Capacity Analysis Handbook.

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[3] Centre for Community Enterprise 2000
[4] Twig 2007

Background

Rationale of the Report

This report is the result of Phase I of a Community-Based Adaptation Project designed to help the Clayoquot First Nations, specifically the Ahousaht, the Hesquiaht and the Tla-o-qui-aht, to understand the potential risks of climate change and incorporate them into current and future land use and livelihood plans. The Ahousaht, the Hesquiaht and the Tla-o-qui-aht live in the Clayoquot Biosphere or their Ha'wiih's Ha-houlthee, located on the mid west coast of Vancouver Island of British Columbia.

The Clayoquot First Nation Community-Based Adaptation project was a two-phase initiative: Phase I involving initial awareness raising and community consultation, climate projections and vision development between Winter and Spring 2010; and Phase II involving an impact and vulnerability assessment and development of an adaptation plan occurring between Summer 2010 and Spring 2011.

The broad goals of the project were to:

- provide a preliminary assessment of historical and possible future climate changes in the Clayoquot Biosphere
- assess the biophysical impacts of climate change on the Clayoquot Biosphere
- assess the subsequent vulnerabilities of Clayoquot First Nations communities and
- Identify adaptation measures for improving their resiliency to climate change.

Objectives of the Study

Specific project objectives were to:

1. Raise awareness of climate change and its potential impacts in the Clayoquot community and region
2. Estimate changes in climate in the Clayoquot Biosphere in the medium term (to 2050) and longer term (to 2080) (with a focus on changes in temperature and precipitation)
3. Determine the environmental (biophysical) impacts of projected climate changes to the Clayoquot Biosphere
4. Carry out a Vulnerability Assessment to help determine key weaknesses in community resiliency.
5. Develop a realistic and practical Adaptation Strategy and Action Plan for improving community resiliency over the next 20 years
6. Develop manageable baseline indicators for monitoring climate change impacts over the next 20 years

7. Train members of the Ahousaht, Hesquiaht and Tla-o-qui-aht communities to measure key environmental impacts of climate change (in terms of short, medium and longer-term measures)
8. Begin implementing an adaptation action plan for the communities
9. Develop partnerships with other communities and agencies in the region

Methodology

Framework for Assessment

The study drew on several different conceptual frameworks. The main framework was provided by Centre for Indigenous Environmental Resources' (CIER) *Community Adaptation Framework* (manuals), which was complemented by the *Climate Vulnerability and Capacity Analysis Methodology* used by CARE International[5] and the Tyndall Group's Vulnerability Assessment Framework (WEHAB+)[6]. Together, these chosen methodologies provided the background to analyze vulnerability and capacity to adapt to climate change at the community level. They provided guidance and tools for participatory research, analysis and learning. The Resilience Alliance's Assessing and Managing Resilience Methodology[7] was considered and worked with initially but found to be overly complicated and difficult to actually implement and so was only used for guidance and concept development.

Tools and Methods

The tools and methods employed in this project were multifold, using a combination of community knowledge and scientific data and techniques to yield a better understanding about local climate changes and impacts (Table 1). Key informant interviews were used to collect information on historical climate trends and biophysical impacts. Key informant interviews were conducted primarily with community elders but also with other members. The interviews and associated discussions provided opportunities to link community knowledge with available scientific information on climate change. This served to honour local knowledge of the biosphere and the climate. It also helped local stakeholders understand the implications of climate change and it also served to check the validity of scientific conclusions. Secondary information in the form of historical climate data was also used to develop a climate baseline for the study

[5] CARE International 2009
[6] Tyndall Group for Climate Change Research 2007
[7] The Resilience Alliance 2007

and computer modeling was used to develop climate projections. Literature surveys and discussions with community members were used to inform vision statements.

Table 1: List of Study Parameters and Tools

Assessment Parameters	Tools
1. Historical trend analysis of climate changes and variability	Key informants interviews, data analysis
2. Future climate change and variability projection	Computer modeling
3. Vision Development	Reviews of community documents
4. Biophysical Risk Assessment	Review of data, expert analysis and literature review.
5. Community Vulnerability	Key informants interviews, data and infrastructure analysis
6.Adaptation strategy development	Community dialogue and interviews, and technical input.

More complete details of the methods used to complete the study follow here: Climate Projections, Community Engagement, Biophysical Impact and Community Vulnerability Assessments, and Adaptation Strategies.

Climate Projections

Climatic data have been produced by the computer program ClimateBC[8], which offers high resolution spatial climate data for current and future climate change scenarios [1]. This is particularly useful for remote regions like the Clayoquot Biosphere. Recent climatic variables have been averaged spatially (i.e. with a resolution of roughly 6 km^2) throughout the Clayoquot Biosphere and temporally for the periods 1961 – 1990 (which we consider as representative of present climate). Future climate projections are based on the Canadian Global Circulation Model version 2 (CGCM2) for two future emission scenarios as defined by the Intergovernmental Panel on Climate Change (IPCC). The A1F1 emission (or “worst case”) scenario describes a future world of very rapid economic growth, global population that peaks in the mid-century and declines thereafter, and rapid introduction of new and more efficient technologies with an emphasis on fossil fuel energy sources [2]. The B2 emission (or “best case”) scenario describes a world in which the emphasis is on local solutions to economic, social, and

[8] http://www.genetics.forestry.ubc.ca/cfcg/climate-models.html

environmental sustainability [2]. Both emission scenarios are projected for the 2020's (i.e., 2020 – 2029), 2050's (i.e., 2050 – 2059) time frames and 2080's (i.e., 2080 – 2089). In addition, both emission scenarios depict the same general trend; however, the intensity or scale of the trend is different.

By using Geographic Information Systems (GIS), a 500 m^2 gridded surface of the biosphere reserve was created to extract the Latitude, Longitude, and Elevation for 11042 points. These 11042 geo-referenced points were used as inputs for ClimateBC. In return, ClimateBC provided 19 annual climatic variables (see Table 6. in the Appendix) for each of the points for the desired time period and condition (e.g., future 2020's). The results are shown geographically on maps and summarized in tables below. Further details about the climate projection methodology in this study can be found in Appendix 1.

Community Engagement

The Clayoquot communities were involved in each stage of the project:

- **Project supervision:**

The local Forestry Steering Committee from the Clayoquot Forest Communities Program was used to guide the planning process and community consultation. The Steering Committee was comprised of one member from each community who meet up to four times a year and as necessary to provide input on projects. The committee met three times over the course of the project duration and members were involved in some of the planned events within the communities.

- **Community consultation process:**

General community feedback was collected through 6 public community meetings, with a special emphasis on the elders, and 2 school events and key informant surveys. Throughout Phase I and 2, wherever possible, local members were consulted on their knowledge of the land and weather and/or employed to assist in key informant surveys. All community meetings were held in the participating communities. The school events were held at Maaqtusis School in Ahousaht and Wikanninish Community School in Tofino. Slide presentations and video of the community and school meetings plus interviews with key members of the project team will be posted at www.ecotrust.ca and on http:livingatlas.org.

- **Progress reporting:**

Regular progress reports, initial findings and results of the study were communicated at the Steering Committee meetings and at the community meetings.

- **Awareness raising and capacity building:**

Capacity was built and awareness increased of climate change risks by involving community members in the supervision of the project (through the steering committee) and hiring of several community members to lead part of the research and consultation. In particular, community members were actively involved in the formulation of the key informant surveys. They also assisted in carrying out the surveys within the community and solicited feedback following events. The lead consultant on the project is a member of the Hesquiaht nation and their insight was invaluable to designing and delivering much of the community work.

Biophysical Impact and Community Vulnerability Assessments

The climate projection data compiled in phase 1 was used to provide the basis of a series of assessments of potential biophysical impacts which were carried out by professionals in the field of marine ecology, marine biology, freshwater aquatic ecosystems, terrestrial ecosystems and community infrastructure.

These professionals were, with the exception of the freshwater hydrologist, all working in the region and have extensive local knowledge and understanding of these systems in Clayoquot and some had extensive experience on the subject of climate change. This project was able to benefit from the marine planning project currently being run out of Port Alberni by West Coast Aquatic Tsawak Partnership[9] and both the marine ecologist and biologist are providing input to that. This local knowledge was extremely useful in understanding what the current baseline is, or in some cases was, for considering future or ongoing impacts from climate change.

It was clear from the marine environment perspective that climate related impacts are already evident at this moment when compared with even recent memory within the communities.

Assessments were carried out by reference to additional studies on climate change impacts carried out both locally or elsewhere by the team members or other groups, literature reviews, or in the case of the community vulnerability piece by research and meetings with the operations people in the communities. Work by the West Coast Aquatic Tsawak Partnership, Nu-chah-nulth Tribal Council fisheries department, the BC Ministry of Forests and Range and the Pacific Climate Impact Consortium's hydrological projections were all of great help in carrying out the work.

It was clear that detailed research on some of the sea level change and storm responses was not going to be possible in the budget and time frame of this project and so best available current data was used but it certainly has identified some areas which will

[9] West Coast Aquatic 2010

require future long term monitoring for baseline and changes. A number of maps identifying community infrastructure that will need to be considered were created to be available for ongoing indicator monitoring.

Adaptation Strategies

Based upon the completed biophysical impact and community vulnerability assessments a number of adaptation strategies were developed by the team and presented to the communities for feedback and development. Although each community has some fairly unique aspects which required individual responses, there were some very similar recommendations for all three because of the nature of the marine and terrestrial environments that they occur in. Even though some useful feedback was collected, it is clear that this is going to be a living document that will be adapted and updated as time moves on.

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Chapter 2

Socio-ecological Context and Historical Disturbances in the Clayoquot Sound

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Socio-ecological Context of the Clayoquot Sound

Geographic Boundaries

The Clayoquot Sound is located on the central west coast of Vancouver Island and is bordered to the south by the Esowista Peninsula, to the north by Hesquiaht Peninsula, to the east by the jagged peaks of the Vancouver Island range, and to the west by the Pacific Ocean (Figure 1). Including the land and the inlet waters, the size of the Clayoquot Sound is roughly 3,500 km².

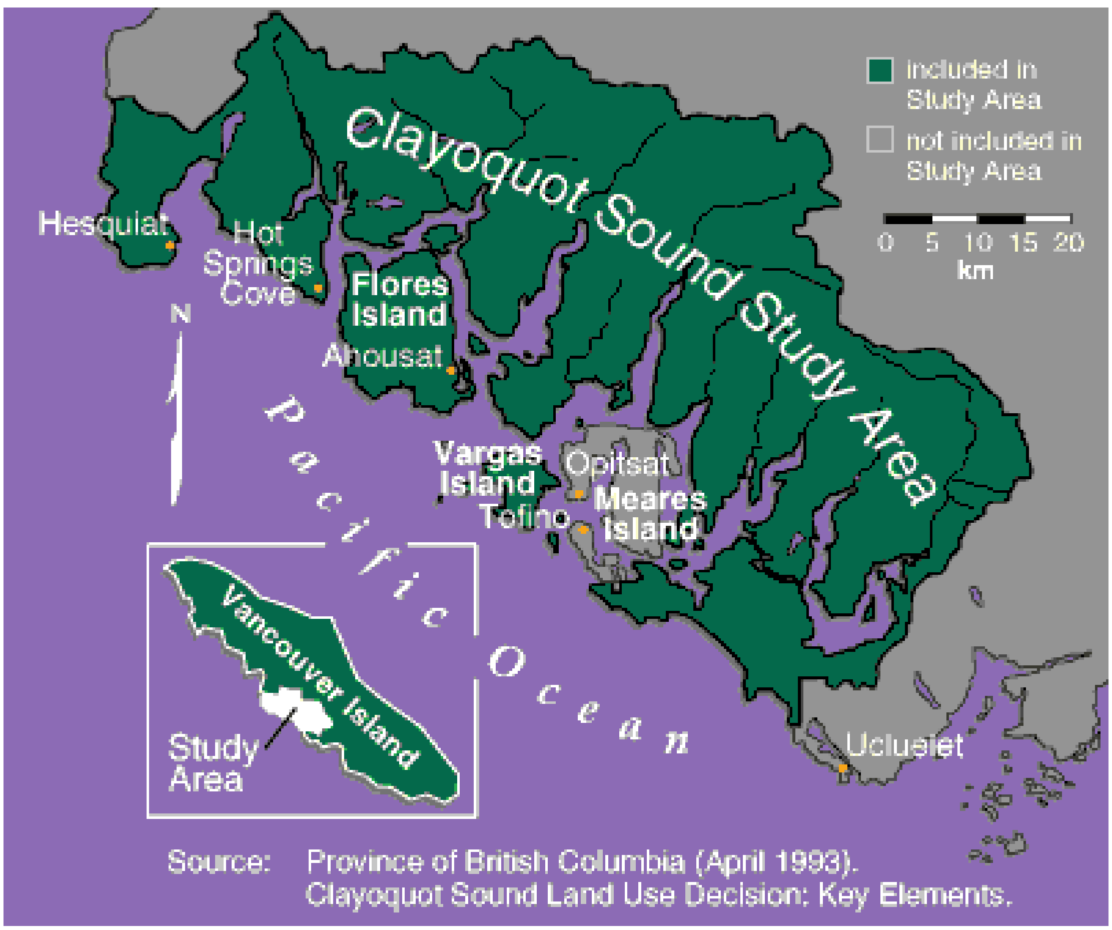

Figure 1. Boundaries of Clayoquot Sound

Ecosystems of the Clayoquot Sound

Terrestrial Realm

The outer west coast of Vancouver Island is part of the wettest climate regime in British Columbia, with annual rainfall of over 8000mm. This extreme oceanic climate combines high rainfalls with a moderate to relatively mild temperature regime which can result in the very luxuriant growth seen in the forests and the popular descriptor of the "temperate rainforest". This climate regime along with the steep and often unstable landform and a lack of significant large-scale disturbance through fire or insects and disease are the variables responsible for the terrestrial forested ecosystems that have developed.

- ### Climate Effects

Estevan Point at the northern extremity of Clayoquot Sound is a typical low lying coastal plain in the hyper-maritime subzone. Every year the precipitation in this area ranges between 2m and 4m with an average of 3.2m and only 45cm of snowfall. With over 60cm of growing season rainfall, 229 frost free days and only 10˚C separating the warmest and coldest months of the year, this the most extreme example of a maritime climate in BC and one which is very favourable for tree growth[10]. In fact the main issue with this subzone is the waterlogged soils on flat ground, which restrict tree growth. Stunted lodgepole pine bogs are a common feature in these areas. As elevation increases to around 200m, the subzone changes to the very wet maritime characteristics. Rainfall is similar in this subzone throughout the year but temperatures have slightly more variability between summer and winter and snowfall increases considerably. These changes produce a discernable difference in the forests that have developed. One climate feature which is distinctive and very important in these maritime ecosystems is growing season fog. Canopy interception of fog is an important source of water for trees and is one reason moisture deficits are very rare in these coastal forests.

- ### Landform Effects

The topography of the region is varied; steep mountains rising up from the ocean, wide and flat coastal plains, deeply incised coastal valleys occasionally flattening out into wider riparian floodplains. If the climate is the driving force behind the species of plants and animals in the region, it is the landform which controls where the plants express themselves and how.

[10] Ministry of Forests (1994) Site Identification Guide to the Vancouver Forest Region.

The steepness of slope dictates the depth of soils, the position on the slope dictates the nutrient availability for the plants and the combination of slope and soil depth defines important characteristics for moisture availability – whether enough or too much. In general terms the mid and lower slopes are the productive sites in these forests as moisture is passing through with nutrients and soil depths are moderate to deep (35 to 70cm). Closed canopy stands of western hemlock, amabilis fir and western red cedar occur, producing extremely large trees, especially on the toe slopes adjacent to the floodplains where Sitka spruce can be the largest trees growing. As slopes flatten water flow slows down and ponds, and this gradually restricts tree growth until eventually on the wide coastal plains bogs develop and tree growth finally becomes impossible.

Freshwater Aquatic Realm

The freshwater realm within the Clayoquot Sound study area consists of a complex of coastal lowlands, mountain highlands, islands, lakes and wetlands comprising a total area of 274,604 ha. A dozen or so major streams dissect the area, trending southwest and culminating in estuaries in various marine settings.

- ### Surface Water Resources

Runoff on the west coast of Vancouver Island is highly responsive to weather and as a result, the timing and amount of rainfall has a strong effect on the peak and low flows associated with these drainages. In general, winter precipitation brings significant amounts of precipitation that falls as rainfall at lower elevations and as snow at higher elevations, though the split between these two varies widely through the winter with the freezing point. Snow accumulates during the winter at higher elevations and this snow melts during the spring freshet leading to higher flows in May and June. Lakes and wetlands buffer runoff, generally reducing winter flood flows and increasing summer low flows in comparison with equivalent drainages without these features.

Table 1 lists physical characteristics of the major drainages of the Clayoquot Sound area[11]. Although long-term gauging is unavailable for these streams, some generalizations can be made about these drainages based on their characteristics and based on monitoring of similar nearby rivers (Sarita River, Carnation Creek, and Ucona River all of which are located on the west coast of Vancouver Island)[12]. The Megin/Talbot, Moyeha, Bedwell/Ursus, and Kennedy/Clayoquot systems are the study area's larger drainages (listed from the northwest to the southeast). The first three flow into the ocean at the head of sheltered inlets, draining highly mountainous catchment areas that extend well into the Vancouver Island Ranges. These systems develop significant winter snowpacks leading to higher spring freshet peaks in the larger rivers

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[11] Madrone Consultants Ltd 2003. Terrain Inventory for the Clayoquot Sound Area - Year 4.

[12] Madrone Environmental Services 2003

draining these catchments. The Kennedy River drains an extensive complex of lakes and wetlands and as such would be expected to have a more moderated hydrograph than the Megin, Moyeha, and Bedwell Rivers. Megin and Sheila Lakes (and others) may provide some modest buffering in the behaviour of the Megin River at its mouth. The Moyeha and Bedwell systems have few lakes. Wetland information is unavailable but it is noted here that wetlands buffer hydrologic response in a similar manner to lakes.

The smaller drainages, with few lakes to buffer flood flows, generally have longer and lower low flow periods during the summer dry period. However, summer low flows are characteristic of streams in this area in general and can be expected to occur, and some years be more pronounced, in most of the medium-sized and smaller drainages in the Clayoquot Sound area. Sydney, Tranquil, Cypre, and Bulson watersheds drain areas of intermediate relief with lower average elevations than the larger rivers. Tofino, Cotter, Watta, and Pretty Girl form smaller watercourses less than 5,000 ha.

Table 1: Characteristics of selected surface streams draining the Clayoquot Sound area

Creek	Area (km^2)	Max. Elevation (m)	Notes
Megin	254	1750	Some lakes
Kennedy	229	1515	Extensive lakes
Bedwell	212	1850	Few lakes
Moyeha	181	1800	Few lakes
Bulson	81	1400	
Tranquil	65	1200	
Sydney	65	1200	
Cypre	58	1150	
Tofino	42	1360	
Cotter	31	1500	
Watta/Shelter	38	1450	

Source: adapted from Madrone Environmental Services 2003

- ## Groundwater Resources

There is little information available on the groundwater resources of the Clayoquot Sound area. Only the Lost Shoe Aquifer has been mapped by the Province of British Columbia.[13] BC Observation Well 329 is located within this aquifer at the Ucluelet highways yard and shows an annual cycle of recharge, rising through the rainy season

[13] EBA Engineering Consultants Ltd 2002

(starting in November) and peaking in April during the spring freshet, then dropping through the summer to the year's lowest levels in late September and into October. This pattern is generally synchronized with the dry and wet seasons experienced in this area. It is likely that other sand and gravel aquifers in this area follow a similar annual behaviour.

- ## Hydrologic Values

Three areas of hydrologic value in the Clayoquot Sound area that may be affected by climate change are recognized here: consumptive water use, fish habitat, and slope stability. Figure 2 shows the sources of drinking water for the major First Nations communities of Ahousaht (Anderson Creek), Hesquiaht (Refuge Creek), Opitsat (Brother Creek) and Esowista (groundwater). Most of this is surface water, removed from streams at licensed points of diversion as shown in Figure 2. There are additional consumptive uses, notably by the Village of Tofino with licenses on Sharp, Meares and Ginnard creeks. In addition, there is scattered groundwater use (though the extent is here unknown.) Ucluelet, just outside the study area, takes its drinking water from the Lost Shoe Creek sand and gravel aquifer.

Table 2: Selected Consumptive Water use in the Clayoquot Sound.

First Nation	Source Name	Area (ha)	Community Name	Population (2001 census)	Licensed Withdrawal (gallons/day)
Ahousaht	Anderson Creek	263	Ahousat (Marktosis)	560	370000 (2 PoDs)
Hesquiaht	Refuge Creek	408	Hesquiat	80	12500
Tla-o-qui-aht	Aquifer	n/a	Esowista	290	n/a
Tla-o-qui-aht	Brother Creek	154	Opitsat		71200 (2 PoDs)
Ahousaht	Anderson Creek		Ahousat		36.5 acre-feet storage

Source: adapted from Madrone 2003

The prevailing hydrology of the Clayoquot Sound area supports significant fish habitat on many major streams as shown in Map 1, particularly at their mouths. On the larger systems, such as Megin, Moyeha, Bedwell, and Kennedy/Clayoquot, fish habitat extends well upstream into the mountainous terrain of the Vancouver Island Ranges. It is the long-established interplay between the sediment and flow regimes combined with the nature/condition of the riparian areas and streambanks that collectively shape the characteristics of the fish habitat in these systems.

The slopes of the Clayoquot Sound area possess variable stability, as determined by each site's topography, soils, vegetation, and prevailing hydrologic regime, and as modified by roads and other human activities. See Map 1 for the locations of historic terrain instability.

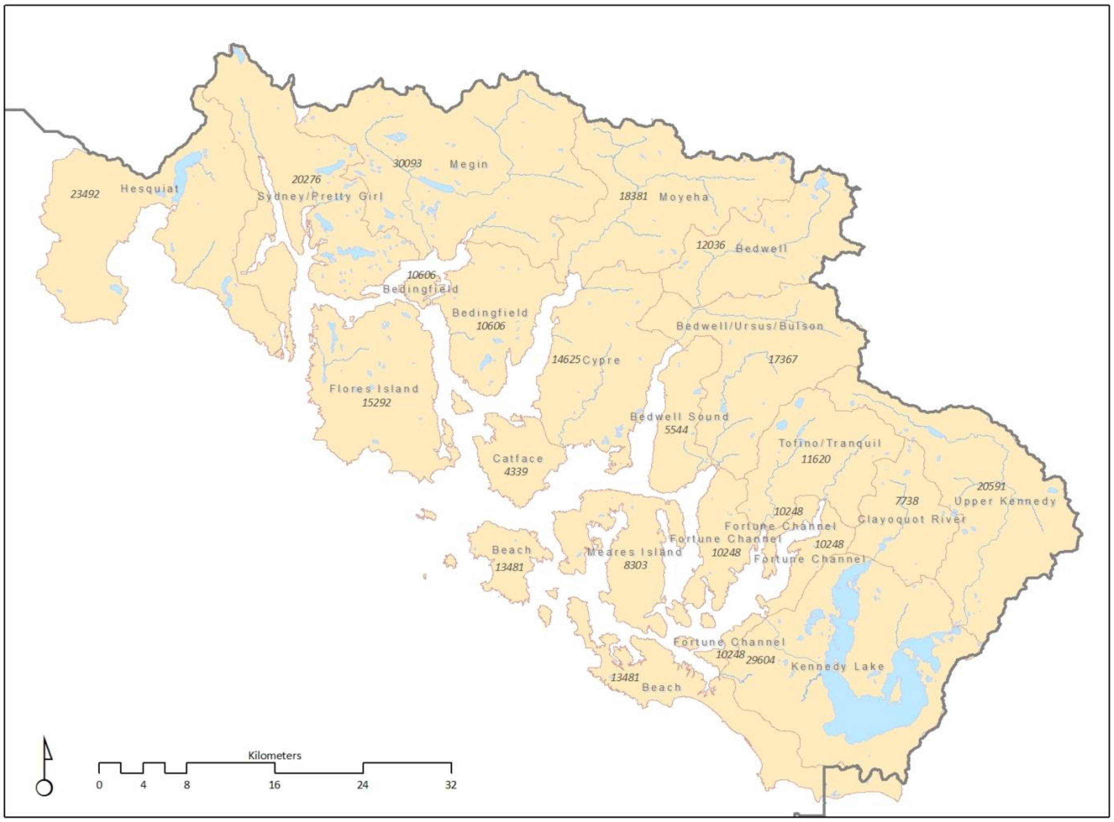

Figure 2. Major Watersheds of Clayoquot Sound with the area of each in Hectares.

Marine Realm

• Oceanographic Characteristic

The West Coast of Vancouver Island, including Clayoquot Sound, is a highly dynamic marine system and features unique oceanographic characteristics that lead to high productivity and a unique biodiversity.

The controlling landforms of the coastal mountains and the associated fjords and continental shelf and slope are originally the result of geologic processes that involve the Juan de Fuca tectonic plate moving east from the Pacific Ocean and slowly disappearing under the much larger and stable North American plate. A series of glaciations have carved the Vancouver Island's mountain landscapes since their formation with the most recent event, between 29,000 and 15,000 years ago, being responsible for the landscape and ocean terrain that we are familiar with today.

The inner continental shelf off the coast is dominated by gravel and boulders from glacial deposition. These coarse inshore substrates are densely covered by a variety of calcareous organisms including barnacles, sponges, hydroids and chitons, resulting in extensive calcareous sedimentation in this area[14] The ocean moves far inland in Clayoquot Sound up coastal fjords which accumulate sediment due to the influx of river-born geological and organic material as well as the influx of detritus from primary and secondary production both inside and outside the fjord[15]. The distinct layers of sediment in these fjords often go undisturbed due to anoxic conditions that exclude animals that would otherwise mix these sediment layers. The fjords of the west coast of Vancouver Island receive a unique mix of riverine input and interaction with outer-coast oceanographic conditions, including upwelling. The basin of Inner Tofino Inlet, for example, is permanently anoxic and that of outer Tofino Inlet is seasonally anoxic as Pickard and Stanton described British Columbia's inlets almost 30 years ago (1979, 1980). More recently, Greengrove et al. (2006) have been monitoring the physical, chemical, and biological conditions of Clayoquot Sound for a decade.

It is not surprising that the topographically rugged landforms on the west coast of Vancouver Island are continued into the ocean where a rocky coastline and sub-tidal features with small islands are interspersed with soft sediments on the shallow coastal shelf. As this drops away to a very rugged deeper zone below 180m depth on the continental slope strong multi directional currents move sediments around in conjunction with mass wasting events similar to those seen on land also occurring. There are two major currents in the region: the North Pacific Current, which brings

[14] Hay et al. 2007
[15] Okey et al 2010

warm waters from the central Pacific, and the California Current, which flows southward from British Columbia to Mexico.[16]

One of the reasons for the high productivity of the marine environment off the west coast of Vancouver Island is the freshwater that flows into the inlets which bring nutrients in the form of sediments, predominantly in the winter in this mostly rain fed climate. However, in addition to this there is a massive influence from the Fraser river outflow which pushes fresh water out through the Juan de Fuca and up the coast past Clayoquot Sound. As this is mostly fed by snow melt the peak flows are in late spring and early summer it provides a longer period of nutrient influx and fresh water mixing. In addition to these fresh water influxes, nutrient availability is further enhanced by upwellings from the deep ocean just off the coast of Vancouver Island and greatly enhances plankton production.[17]

Temperature, oxygen, salinity, nutrients, dissolved oxygen, and light transparency, are just some of the “controlling variables” for the system in Clayoquot Sound, and all of these vary at both broad and fine scales. Both fast and slow marine life are sensitive to these variables, and changes in these variables influence the productivity and the structure of the system’s biological components. These variables shape the system largely from the bottom of the food web, but they also influence organisms throughout the biological community directly.

The Northeastern Pacific Ocean naturally has some of the lowest pH waters in the world because it is at the end of the ocean conveyer belt, and CO_2 has built up from respiration in these old waters that upwell along this coastline.[18] Marine organisms of the area have thus adapted to these marginal pH conditions, but the pH of these waters is declining further due to acidification, and this may lead to severe ecological impacts and considerable change.

• Marine Species

The high spatial and temporal heterogeneity of the environment and habitats described above, its high productivity due to the nutrient inputs, and the dynamic range overlap of northern and southern flora and fauna have enabled the development of marine life that is both rich and diverse in Clayoquot Sound.[19]

This diversity is seen in all sections of the food chain, from the plankton and krill towards the bottom to the finfish, sea mammals and birds at the top of the chain. There are over 10,000 species known in total; mostly plants and algae (largely algae), molluscs, crustacean and other arthropods. However, it is the salmon, whales, otters, eagles and

[16] IPCC 2007
[17] Okey and Dallimore, 2010
[18] (Feely et al. 2008, Hauri et al. 2009
[19] Lo et al 2010

sealions which are the species closely associated with the west coast, and their relative numbers are still high enough to be a considerable draw for visitors to the region. Another important feature of the west coast and especially in Clayoquot Sound are the kelp forests and eel grass beds which both play very important roles in providing habitat for other animals.

Some of the key indicator species in the area include:

Marine Mammals:	**Finfish:**	**Shellfish:**
Grey whale	Salmon	Oyster
Steller sea lion	Rockfish	Manila clam
Sea otter	Sandlance	Geoduck

Marine birds:	**Marine plants:**	**Zooplankton:**
Cassin's Auklet	Eelgrass	Euphausiid (krill)
Marbeled Murrelet	*Macrosystis* (Giant Kelp)	
	Fucus gardneri (Pacific Rockweed)	

Socio-Economic Context of the Clayoquot Sound Communities

The socio-economic context of the Clayoquot Sound is as diverse as its ecological context. It is populated by First Nation and non-First Nation peoples spread over 8 communities with distinct economies and cultures. This report is focused on the three Clayoquot communities in the central north portion of the Clayoquot Sound (Ahousaht, Tla-o-qui-aht and Hesquiaht), so the various characteristics of all 8 communities will not be discussed here. Suffice to say that Tofino and Ucluelet are dominated by non-First Nation populations and tend to be economic hubs of the region. Macoah (Toquaht) is a very small hamlet with roughly 8 of its 138 members living there, and Ucluelet reserve is the third largest of the First Nation reserves, with 202 members on-reserve. Both Toquaht and Ucluelet reserves tend to be forestry and fishery focused.

Communities and Traditional Territories

The Hesquiaht traditional territory is located on the Hesquiaht Peninsula where the nation occupies two main reserves: Hesquiaht Habour and Hot Springs (Figure 3). The Ahousaht territory is situated between Hesquiaht Peninsula and Tofino and constitutes the largest territory of the Clayoquot tribes and includes the main settlement of Marktosis and numerous small seasonal outposts. The Tla-o-qui-aht traditional territory is situated between Pacific Rim National Park and Tofino on the mainland and also Kakawis, Meares Island and the Kennedy Lake area. The community of Opitsat (on Kakawis) and Ty'histanis-Esowista form the main settlements of the Tla-o-qui-aht Nation.

Most of the Clayoquot communities are located in sheltered coves and have settlements near the shoreline, often between 4m and 6m above sea level. Hesquiaht Harbour is the exception, with most of its settlement 6m to 10m above sea level.

Ahousaht

Tla-o-qui-aht

Hesquiaht

Figure 3. Geography of Clayoquot Traditional Territories[20]

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[20] http://en.wikipedia.org/wiki/File:Ahousaht.png, File: Hesquiaht.png, File: Tla-o-qui-aht.png.

Demographics

The Ahousaht First Nation is the largest Nation in the Clayoquot Sound and on the west coast of BC with a total population of roughly 684 members on-reserve and an off-reserve population of 1,216 members (Table 3). The Tla-o-qui-aht Nation is the second largest First Nation community of the Clayoquot tribes. It has 336 on-reserve members and 654 off-reserve members. Hesquiaht, the second smallest of the Clayoquot First Nation communities, has roughly 138 of its 680 members living on-reserve population for at least part of the year.

Although the total population of the three Clayoquot communities has grown consistently over the years, the on-reserve populations have tended to ebb and flow. Between 1996 and 2001 the population of Ahousaht grew 3.3% per year, whereas Hesquiaht and Tla-o-qui-aht shrank at -3.2% and -1.1% respectively. Between 2001 and 2006 all communities grew, especially Hesquiaht. Then between 2006 and 2010, Ahousaht and Tla-o-qui-aht populations marginally shrank but the Hesquiaht population grew significantly.

Despite these uneven growth trends, all of the communities have relatively young populations, with between 68% and 77% of the population 40 years or younger.

Educational attainment in all three Clayoquot communities is relatively low but is rising slowly. Between 9% and 14% have graduated from high school, between 14% and 19% have completed trade school or college training and up to 9% have completed a Bachelor of Arts of higher.[21] Note although these figures are relatively low, they may under-represent educational attainment levels, since many of the educated members in the community often leave the reserves due to a lack of employment opportunities.

[21] Note that education figures for Ahousaht are for 2001 and those for Hesquiaht and Tla-o-qui-aht are for 2006. This means that Ahousaht figures are likely low, given increases in population and improvements in the educational programs and facilities in the community since 2001.

Table 3: Demographics of the Clayoquot Communities

Indicators	Ahousaht	Hesquiaht	Tla-o-qui-aht
Total Population 2010	1974	680	990
On-reserve Pop 2010	641	138	336
Pop Growth Rates	3.3% (1996-2001) 3.7% (2001-2006) -0.6 (2006-2010)	-3.2% (1996-2001) 7.5% (2001-2006) 5.1 (2006-2010)	-1.1% (1996-2001) 4.2% (2001-2006) 0.7 (2006-2010)
Pop Age (40yrs or less)	77%	68%	70%
Education Levels	6% - BA or higher 19% - trade or college 10% - high school grad (2001)	9% - BA or higher 18% - trade or college 9% -high school grad (2006)	0% - BA or higher 14%- trade/college 14% - high school grad (2006)

Source: Statistics Canada & INAC, 1996, 2001, 2006 & 2010

Economy

- ### Employment and Diversification

Generally, the economies of the Clayoquot communities have been relatively depressed. As Table 4 illustrates labour force participation rates have been relatively low in all communities (between 59% and 67%), dependencies on social assistance are relatively high (between 21% and 28%), unemployment rates are relatively high (between 13% and 27%) and earned incomes are relatively low (between $14,000 and $18,102).

The Ahousaht community has the largest and most diverse economy among the Clayoquot communities, with employment in finfish aquaculture, the fishery and shellfishery, forestry, construction, transportation, education, health and public and retail services (Table 4). The Tla-o-qui-aht economy is less diversified but is distinct from the other communities by its focus on the tourism sector, which employs roughly 42% of its labour force (Table 4). Hesquiaht's economy is less diversified still, largely depending on the public sector (public administration and education), the tourism/transportation sector and fishery research. In all communities, the public sector (administration, health and education) is typically the largest employer, often responsible for between 24% and 50% of the full-time jobs.

These figures do not capture recent improvements in employment in the Ahousaht and Tla-o-qu-aht communities. Normally, the construction sector represents a relatively small proportion of the economy in these communities but recent investments in a new school in Ahousaht and new housing in Ahousaht and Ty'histanis-Esowista have boosted employment. Although there are no exact figures, it is expected that the construction sector will employ a higher proportion of community members over the next 5 years.

Table 4: Employment in the Clayoquot Communities

Indicators	Ahousaht	Hesquiaht	Tla-o-qui-aht
Employment Distribution	2001 23% Resource/Mfg/Const 23% Services* 24% Pub admin Anecdotal 2010 31% Fishing & fish farms 31% Construction 5% Forestry 28% Band Admin 28% Education 1% Tourism 6% Transportation	2006 14% Resource/Mfg/Const 21% Services** 36% Public Admin	2006 27% Resource/Mfg/Const 51% Services (42% Tourism) 21% Pub Admin
Labour Force Participation **	67% (2001) 75% (2010 Anecdotal)	64% (2006)	59% (2006)
Unemploy-ment Rate	17% (2001) 25% (2010 Anecdotal)	27% (2006)	13% (2006)
Earning - % Income	76% (2001)	70.5% (2006)	75% (2006)
Gov't Transfers - % Income	24% (2001)	28% (2006)	21% (2006)
Median Earnings	$18,102 (2001)	$14,000 (2010 Anedotal)	$14,224 (2006)

* Labour Force Participation describes the percentage of the population aged between fifteen years and sixty five years who are in the labour force or seeking work.
**Services include health, education, wholesale & retail trade, transportation, admin support, professional, accommodation and food services arts and recreation etc.

- **Licenses and Agreements**

Although the Clayoquot communities hope to ultimately secure rights and title to their lands and resources, in the interim they have obtained licenses and agreements over parts of their resources to provide economic benefits to their people. These agreements include uses pertaining to forestry, the fishery, aquaculture, tourism, real estate development and mining (Table 5).

All of the Clayoquot communities are shareholders in Iisaak Forest Resources Inc., which owns a sawmill and operates seven forest tenures within the Clayoquot Sound, covering a total land base of roughly 91,200 ha.. This enterprise provides roughly 17 forest management, logging and milling jobs to the Clayoquot Nations. The Ahousaht also possess a woodlot (#19) which they intend to develop for their housing needs.

Each of the communities also possesses communal fishing licenses, which are used to provide individual households with salmon. Each of the communities also has several fishermen who possess First Nation commercial fishing licenses, under which they fish for commercial purposes. The Ahousaht also have a protocol agreement with Mainstream Canada (an aquaculture company) to provide access to Ahousaht traditional marine territory for the siting of salmon farms in exchange for employment opportunities, tenure fees and environmental monitoring and management improvements. This agreement provides 60 to 70 jobs annually for the Nation.

The Tla-o-qui-aht have a management agreement with Best Western Hotels to manage their resort property (Tin Wis) on Mackenzie Beach as well as an agreement with West Coast Wild to share revenues on a zipline-kayaking venture in their Kennedy Lake territory.

Lastly, the Ahousaht also have a memorandum of understanding with Selkirk Metals to explore the feasibility of developing Catface Mountain into a copper/gold mine.

Table 5: Business Licenses and Agreements in the Clayoquot Communities

	Ahousaht	**Hesquiaht**	**Tla-o-qui-aht**
Forestry	• Shareholder in Iisaak Forest Resources • #19 Woodlot	• Shareholder in Iisaak Forest Resources	• Shareholder in Iisaak Forest Resources
Fishery	• Communal Fish License • Commercial Fishing Licenses • Agreement with Mainstream Canada re aquaculture	• Communal Fish License •	• Communal Fish License • Spawn-on-kelp license • Commercial Salmon and Halibut Licenses

Tourism			• Management Agreement with Best Western Hotels • Revenue sharing agreement with West Coast Wild
Mining	• MOU with Selkirk Metals re Catface Exploration		
Real Estate			• Protocol Agreement with District of Tofino re several parcels

Source: Interviews with community members, 2011.

• Financing & Insurance

The Indian Act limits private property on reserves, which has prevented many First Nations in the past from owning their own homes and accessing financing. Rather they have tended to rent Band owned housing and gone without financing. Recently, credit has started to loosen up as many of the Bands have started offering 99 year leases to members so that they can own their own homes. They now access loans through CMHC and the banks (with the underwriting of the Band Council) and use these homes as collateral for business loans. There is also a number of First Nation lending programs that offer financing to First Nation enterprises.

First Nation properties (public and private) are eligible for insurance, including renter's insurance for personal property, homeowner insurance for privately owned homes and business insurance for business owners. No specific data is available on the actual usage of these insurance instruments in the Clayoquot communities but survey evidence suggests that many homeowners and renters do not buy insurance. The same goes for business owners, unless they need the insurance for credit or licensing.

As well, although many of the Bands insure their public buildings, the remaining infrastructure (water, sewer, etc.) is not insured. In the event infrastructure failure or damage, the communities must use their block funds or INAC and Provincial emergency funding to repair or replace these assets.

Infrastructure & Shelter

The Clayoquot communities manage a wide variety of infrastructure, much like a small municipality (Appendix 1). And because Hesquiaht communities, Opitsat (Tla-o-qui-aht) and Ahousaht are remote (accessible only by boat or plane) most of their infrastructure systems are off-grid (O), although Ahousaht and Opitsat are tied into the BCHydro power grid (G) and Hesquiaht, Opitsat and Ahousaht are tied into Telus' microwave communications system (Table 6). The wharves or docks in Ahousaht, Hesquiaht and Opitsat are all government owned and maintained assets. Ty'histanis-Esowista (Tla-o-qui-aht), the closest community to Tofino, is probably the most integrated into the grid system of the Clayoquot communities. They are tied into the Tofino sewer system as well as the power and telecommunication grid, the public road systems and the solid waste system coordinated by the Regional District.

Table 6: Infrastructure in Clayoquot Communities

Infrastructure	Ahousaht	Hesquiaht	Tla-o-qui-aht	
			Opitsat	Ty-histanis/ Esowista
Water	O	O	O	O
Sewer	O	O	O	G
Storm Water Drainage	O	O	O	O
Wharves/Docks	G	G	G	n/a
Breakwater	O	O	O	n/a
Telecom	G	G	G	G
Energy	G	O	G	G
Roads	O	O	O	G
Solid Waste	O	O	G	G

Source: Interviews with community members, 2011
KEY: O – Off-grid. G – Grid

All of the communities receive block funding for the assets that they manage. This includes funding for staffing and maintenance. They also have access to capital funding for new projects but this is not always readily available. Staffing for operations and maintenance is minimal and skill levels vary from community to community. There is some advisory support from INAC and the NTC but if a system fails in the community, generally there are limited supplies and equipment to fix the problem. Nonetheless, the communities generally make do, until specialists can be brought in or funds made available to upgrade. At present, the infrastructure in most of the communities is pretty functional and in some cases undergoing significant upgrades (e.g. Ahousaht, Ty'histanis-Esowista).

In addition to basic infrastructure, the communities also manage a range of public facilities and houses. The Ahousaht have the greatest variety and scale of facilities and housing among the communities, followed by the Tla-o-qui-aht and then the Hesquiaht. All of the communities are challenged in maintaining their existing rental housing stock because many renters do not pay rent regularly, which reduces available funds for housing maintenance.

In addition, to the assets listed in Table 7, the Ahousaht plan to build 160new homes and the Tla-o-qui-aht plan to build 160 new homes in Ty'histanis-Esowista. Most of these will be private homes (Appendix 1).

Table 7: Public Buildings and Band Housing in the Clayoquot Communities

Infrastructure	Ahousaht	Hesquiaht	Tla-o-qui-aht	
			Opitsat	**Ty'histanis/ Esowista**
Public Facilities	• Band Office • Elementary School • High School • Holistic Centre • Hall • Community Kitchen • Discovery College • Diner-Convenience Store • Lighthouse (small hall) • Fisheries office • Youth Centre • Guest house	• Band Office • Elementary School • Hall	• Band Office • Hall	• Band Office • Daycare • Tin Wis Hotel • Hall
Band Housing	Total 149 units (? Units Band owned)	Total 37 units (20 units Band owned)	Total 82 units (21 units Band owned)	

Source: Interviews with community members, 2011

Health and Safety

The health and safety resources of the three Clayoquot communities are fairly modest given their needs. The communities all have a fairly high birth rates and young populations and therefore have a variety healthcare needs associated infants and youths. The communities also have a number of elders in need of regular geriatric care, as well as problems with tuberculosis and respiratory illnesses, injuries related to outdoor working, problems with diabetes, heart disease, and obesity,substance abuse, mental illness and suicide. Yet in all communities (except Ty'histanis-Esowista) they only have a couple of trained First Responders and home care workers, minimal clinic space and visiting nurses and doctors (Table 8). Ty'histanis-Esowista has fairly easy access to doctors and hospital services in Tofino. The Ahousaht have one or two resident community health nurses and a holistic centre for mental health and addiction counselling. For emergency care, patients from the Ahousaht, Hesquiaht and Opitsat communities must be ferried or flown to Tofino, Port Alberni or Nanaimo.

Emergency preparedness resources in the Clayoquot communities are also modest. The emergency preparedness coordinators or First Responders in the communities are trained in dealing with fire, tsunamis, earthquakes, and epidemics. A VHF early warning system is available to all of the communities in the event of a tsunamis, storms and rogue waves. They also have support from the Coast Guard and the RCMP in the event of an emergency, although only the Tla-o-qui-aht and Ahousaht have immediate access to these resources. The Ahousaht appear to be the best prepared and organized for emergencies among the Clayoquot communities and indeed are regarded as leaders in the province.

Due to its proximity to Tofino, Ty'histanis-Esowista has fairly easy access to emergency services in Tofino. All communities also have access to the First Nation Emergency Services Society (FNESS) and the Provincial Emergency Program for training and advisory support. The Clayoquot communities also have a very strong family ties that are a very effective resource in dealing with emergencies. These ties ensure that families help each other in crisis and lend support afterwards.

Table 8: Health and Safety Resources in the Clayoquot Communities

	Ahousaht	Hesquiaht	Tla-o-qui-aht
Health Facilities	• Community Heath Nurse • Basic Health Clinic • First Responders • Home Care workers • Visiting Doctors • Holistic Recovery Ctr. (counselling)	• First Responders • CHR • Very basic health clinic • Home Care workers • Visiting Doctors & nurse	• Nurse / CHR • Very basic health clinic • First Responders • Home Care workers • Hospital & Doctors in Tofino or Ucluelet

Emergency Preparedness Resources	• EP Coordinator & Volunteers • Fire Hall (volunteer) • RCMP Detachment (4)	• EP Coordinator & Volunteers	• EP Coordinator & Volunteers

Source: Interviews with community members, 2011

Food Supply

The Clayoquot communities depend heavily on seafood for their diet. Approximately 60% of their annual protein is derived from wild marine sources (fish, clams, oysters, sea urchin etc.). Much of this seafood is provided on a relatively regular basis through seasonal household fishing and collecting activities as well as through the community food fish program, household smoking and canning and community bartering. Hunting for deer, ducks or geese as well as collecting and preserving wild plants and berries, supplement the largely seafood diet for at least part of the year (Appendix 2). Fresh produce, dry goods and non-wild meats are obtained mainly off reserve. Gardening for fresh produce is being re-introduced to the communities through training and the construction of communal gardens and greenhouses. At the moment; however, only about 1% of the population in these communities gardens for their food. Although most members slaughter game and fish inside or outside their homes, the Ahousaht are constructing a commercial-grade community kitchen in the community in order to facilitate fish and game slaughtering and preserving and catering for large events.

Political, Social and Cultural Resources

The political, social and cultural resources of the Clayoquot communities are numerous and diverse. Those related to climate adaptation are briefly enumerated here.

• Political/Administrative

All of the Clayoquot communities share a dual governance structure: 1) elected chief and council and 2) hereditary chiefs. The division of labour varies amongst the communities but generally the elected Band government takes on the administration of the day-to-day activities of the community and the hereditary chiefs take on the role of preserving the Nuu-chah-nulth culture, ceremonial duties and in some cases economic development decisions. The Band government is supported by a Band staff, the size of which depends on the size of the community and its budget. The Ahousaht Band government, for example has a relatively large staff of 75 people; whereas the Tla-o-qui-aht Band government has a staff of 30 and the Hesquiaht have a relatively small number of staff (18). All of these workers ensure that the communities continue to operate as best as possible. The bigger the staff, the more complex level of service they can offer.

The communities under the supervision of the Band Council or the Hereditary Chief have also undertaken a range of planning initiatives for the betterment of the community. Those planning initiatives range from community emergency preparedness planning to community food security initiatives (Table 9). They also include regional planning initiatives related to forestry, value-added development and fisheries management.

Table 9: Recent Planning by Clayoquot Communities

Ahousaht	Hesquiaht	Tla-o-qui-aht
• Emergency Preparedness • Infrastructure Upgrades • Waste Mgmnt • Energy planning • Land Use (Sub-divisions, School, mining) • Forestry (Woodlot) • Food Security (gardening)	• Emergency Preparedness Infrastructure Upgrades, • Community planning, • Communications • Food Security (gardening) • Alternative Energy	• Marine (dock) • Waste mgmt (Opitsat) • Land Use (Tribal Parks, Sub-divisions) • Alternative Energy • Food Security (gardening)

Source: Interviews with community members, 2011

• Social Resources

The backbone of any community are its families and this is especially the case in most First Nation communities, since families often take on what businesses or governments would otherwise do in urban centres. Moreover, they are guardians of historical hunting and fishing territories as well as keepers of ceremonial roles and sites. As indicated above, in times of crises, families in First Nation communities rally together to share resources and provide moral support to help each other, often much more effectively than governments can do. They can't do this over long periods or repeatedly without serious stress but they can do so occasionally.

At the same time, there are also social services in the Clayoquot communities to support families and individuals. In the Clayoquot communities, this support usually includes facilitating access to social assistance and medical assistance as well as providing family, mental health and addiction counselling and youth counselling (Table 10). The Ahousaht have perhaps the most numerous on-reserve social service resources through the Holistic Recovery Centre. The Hesquiaht have the smallest number of resources and the Tla-o-qui-aht have access to a mix of on-reserve and off-reserve resources in Tofino.

Table 10: Social Resources in the Clayoquot Communities

	Ahousaht	Hesquiaht	Tla-o-qui-aht
Social Services	• Family care workers, Family violence worker, Alcohol and • Drug Counsellors, • Youth Counsellor, • Justice Worker, • Health Circle Manager • Youth Ctr Workers (2)	• Family Care workers • CHR	• Counsellor • Family Care Worker • Youth Coordinator

Source: Interviews with community members, 2011

One area where there are very few social resources is in the area of First Nation and non-First Nation relations, particularly as regards resource use and land use disputes. When there are disputes, typically they are dealt with through government regulators or the RCMP, which usually intervene only after an incident arises.

• Cultural Resources

The traditional Nuu-chah-nulth culture is very important to the identity of the Clayoquot communities and despite prolonged attempts at assimilation from the non-First Nation culture, it continues to survive and and revive with the help of its elders and local leaders. The Nuu-chah-nulth culture provides important principles and practices for living that have allowed the First Nations of the area to adapt to numerous cycles of ecological and socio-economic change. Currently, the culture of the Clayoquot communities is passed on through families, elders, hereditary chiefs, local gatherings, and the First Nation curricula in the school system. Presently, about 25% of the Hesquiaht population, 14% of the Ahousaht populationand 13% of the Tla-o-qui-aht population on-reserve speak fluently or somewhat the traditional Nuu-chah-nulth language...

Socio-ecological Disturbance History

Profound ecological changes define the ecological and socio-economic histories of the West Coast of Vancouver Island, including Clayoquot Sound area. Its marine and terrestrial life began arriving, developing, departing, and arriving again long before dramatic geological processes had finished forming its modern landscape about two million years ago and it continues today.

Forests

The natural disturbance regime of Clayoquot forests might be characterized very stable; where large scale disturbances are rare and forests grow and develop very slowly and steadily over many hundreds of years. Regeneration occurs through small gaps being created by individual trees or small clumps dying and producing canopy openings, or through mass wasting events on steep slopes providing seed beds for natural regeneration. Windstorms cause the majority of canopy openings and although some can blow down massive areas (1908 hurricane at north end of the Island) generally it typically occurs in small patches. In this very wet climate fire is very rare and insect damage is generally endemic. The result is forests that have quite a small range of natural variation, tend to be mostly in old or very old states but contain multi-aged trees throughout these stands. These old-growth forests are primarily western red cedar and western hemlock with small amounts of Amabalis fir and Sitka spruce on higher nutrient sites. Much of the forest is very old, in TFL 57 (quite representative of the whole area) over 65% of the forest is over 250 years and nearly 80% is older than 140 years (Figure 4).

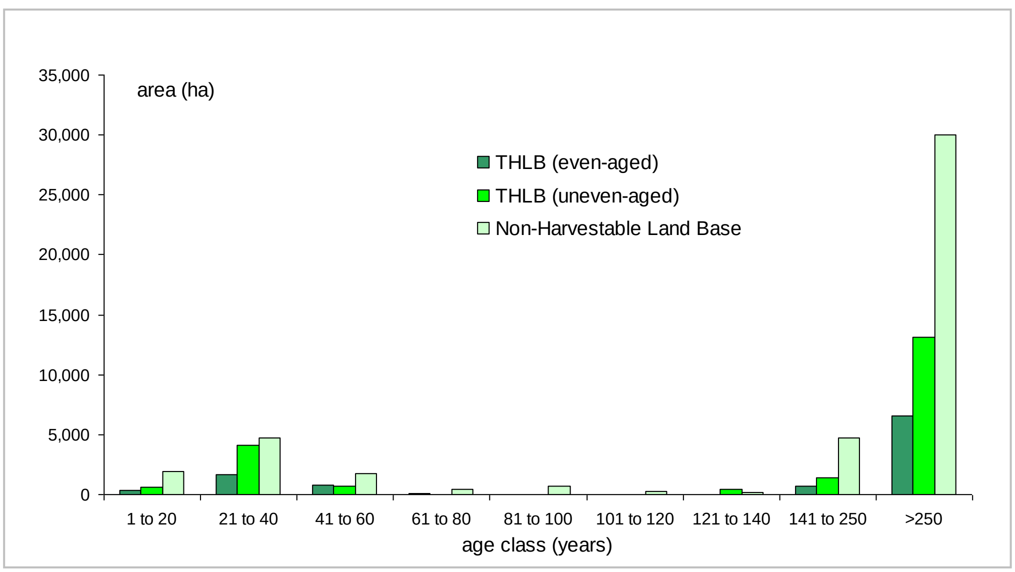

Figure 4. Current age class distribution in TFL57 (Ecotrust Canada, 2009)

Intense rainfall events during the autumn and winter months in conjunction with strong to gale force winds can result in localized and occasionally large landslides. On steep slopes where shallow soils over bedrock become saturated and strong winds are causing excessive canopy sway roots can give way and landslides are initiated. These failures can be on uniform slopes but are more often in gullies and irregular terrain, and the failures can reach right down to bedrock or just be surficial. The speed with which failures revegetate depends on whether soil remains or if bedrock is exposed and requires further deposits to build up before anything can germinate. Windthrow events also occur without landslides, and again they can be just a single tree or a small clump to extreme events where a whole hillside can be blown down. When roots are pulled out of the ground, mixing of mineral soil and organic layers occurs which encourages regeneration of the next stand of trees. Death of individual trees however results in little disturbance to soil and vegetation and regeneration can be very slow.

Insects and fungal pathogens can and do cause mortality in these coastal forests, but not in the often epidemic way that occurs in many interior and boreal forests. More often there is a progression of pests slowly impacting old trees until eventually mortality occurs. Some insects and pathogens which cause widespread damage in the interior are present on the coast but are unable to become serious pests, examples include the pathogens Armilaria and Heterobasidion or the spruce terminal weevil. Cedar also is naturally very resistant to decay which is why it is used in exterior building applications.

First Nations actively use the forest in many ways to sustain and support their communities, historically and today. Longhouses, canoes and cultural items (ceremonial ornaments) are made from cedar trees; bark stripped from cedar is used for a variety of purposes from baskets to clothing; understory plants are gathered for food and medicine and forest gardens and estuary gardens used tended to increase production of valued items. Actively using the forests in these ways occurred at similar scales to the natural process dynamics of the forest and so did not cause impacts to processes at the landscape scale. Hence the belief by western settlers that the forest was “virgin” or undisturbed.

The first major impacts to the forest ecosystems began in the 1950s with the initiation of commercial timber harvesting and the growth of the two communities of Tofino and Ucluelet. The forests of Clayoquot Sound have some of the best western red cedar available on the coast and it has been and still is in high demand for the construction industry. Slow grown with lots of clear wood due to large diameters, this timber has been used for exterior housing products such as siding and decks with roof shakes a very valuable addition. Harvesting followed the typical pattern, with progressive clearcutting of the easiest access sites first. Clearcut harvesting continued until recently in this region, and is a radical change from the natural patterns and process of forest renewal - and the result has been some loss of ecosystem function at the stand scale, and an increase in landslides from cutblocks and roads, with runoff causing siltation or the complete choking of streams with the resultant loss of spawning habitat for salmon.

Although local impacts have occurred, particularly at lower elevations where extensive harvesting did occur, Clayoquot Sound is unusual for Vancouver Island however, because of the relatively limited harvesting that has occurred there – due largely to the blockades that occurred in 1995 that resulted in the Clayoquot Sound Science Panel, and recommendations to increase protection levels in these watersheds to maintain natural processes. The timber harvesting on the two main tenures are now wholly under the ownership of the First Nations and are a test case for ecosystem based management in BC.

The single biggest stressor on the system is likely the clear cut harvesting that has been carried out in Clayoquot from the 1960's to the early 1990's. The weather and geological processes which have been forming the ecosystems in the region are both "slow drivers", while anthropogenic impacts are "fast drivers". This general observation is confirmed by interviews with the Clayoquot communities, wherein they indicate that harvesting or "over-harvesting" has had the biggest impact, followed by climate changes, pollution, disease and high winds (Appendix 2).

The shifts from a closed canopy, gap dynamic system to large scale stand replacement have altered how the system functions – likely increasing stress on the system. Removing all the forest at one step provides little opportunity for the natural resilience of the system to cope at the landscape scale in which harvesting is occurring. The impacts of harvesting disturbance is seen in increased run off rates and siltation in streams which affects salmon spawning, displacement and probable impacts to birds and mammals such as marbled murrelets and shifts in the vegetation complexes growing on the sites.

Freshwater Aquatic

In the period following de-glaciation, the Clayoquot Sound area gradually developed equilibrium in which hill slopes and streams developed stability punctuated by periodic disturbance largely due to infrequent weather and climate events. This long period of dynamic equilibrium has recently been interrupted by two major disturbance types. The first is various human activities (largely undertaken in the 1900s) and including corridor/infrastructure developments, rural/urban development associated with increased population and tourism, and forestry. It is the road building (particularly on steep slopes) and forest harvest activities associated with forestry that have had the most widespread impact on the hydrology of the Clayoquot Sound area. More recently, changes in the type, total amount and intensity of precipitation are collectively altering flow and sediment regimes, jeopardizing water values. Changes in hydrologic processes due to forestry and climate change disturbances are discussed below.

In the 1970s through to the early 1990s, conventional industrial forestry was carried out by BC Forest Products and MacMillan Bloedel resulting in roads and harvest in selected watersheds including parts of the Atleo, Bedwell, Bulson, Cypre, Tranquil, Tofino and

Kennedy drainages. Roads and harvest on steep coastal slopes increased waterborne erosion and landslide hazards. Surface erosion increased due to direct disturbance of the surface soils in conjunction with associated activities such as traffic that maintain the disturbance. Increased landslide hazard resulted from water diversions onto steep slopes usually due to road drainage. Where harvesting takes place on steep slopes, landslide hazard also increased due to increased water loading and, many years after harvest, due to loss of root strength as the stabilizing function of the roots was lost upon decay. Other important effects arise from riparian harvest and windthrow and in particular these activities each increased stream sedimentation. Riparian harvest can reduce shading thereby increasing stream temperature. Whereas these hazards generally diminish with time, landslide hazards can remain elevated for long periods if hill slope drainage is changed in ways that put more water on unstable or potentially unstable terrain.

The unfolding history of forestry activities in the Clayoquot Sound area differs from that of much of the rest of the province due to citizen protests of the 1990s that led to a sharp change in the area's forest management. The Clayoquot Sound Scientific Panel concluded in 1995 laying down a new direction for forest management for the area that included, in its hydrologic focus, detailed inventory and monitoring work, variable-retention silvicultural systems, and stronger protection of the hydroriparian system. Broadly stated, it was a move toward ecosystem-based management. This approach has been variably applied since it was recommended.

Marine

Natural marine natural ecosystems in Clayoquot Sound are constantly in flux. Organisms living in these ecosystems each survive within a range of environmental conditions

Natural variability in 'bottom up' forces, 'top down' forces, and natural disturbance regimes can be thought of as "healthy" for the ecosystem, the component species, and the resident human communities. This ecological texture (variability and complexity) nurtured the evolution, adaptation, and colonization of a broad diversity of organisms that inhabit the complex array of spatial, temporal, and functional niches resulting from these forces and the diversity of habitats.

These system dynamics are modified by the introduction of new types of pressures and stressors by humans throughout the last 10,000 years or so of human habitation of the area. These pressures and stressors have changed, and generally increased, during that time thereby leading to the observed degradation of the system. This ecosystem degradation has manifested by changing the 'bottom up' forces, 'top down' forces, and natural disturbance regimes in addition to direct effects on valuable ecosystem components. Climate change is the latest stressor category, and the most worrisome in the long-term because of the expected increases in the relative importance its effects, but also because local climate change impacts are a manifestation of global scale changes that cannot be managed locally.

Clayoquot Sound once supported an abundance of culturally and environmentally important species, such as salmon, sea otters, whales, and clams. It also supported a human population many times greater than today's.[22] Early industrial marine harvest exploited resources that seemed limitless at the time. For instance, a salmon cannery operated at the mouth of the Kennedy River from 1895 until the 1940s, providing an economic boom for the region. But a combination of overharvest, habitat destruction and poor climatic conditions led to documented declines in all species of salmon in the late 1940s through the mid-1970s. The 1980s provided optimal growing conditions for many marine species, including salmon, which were outside of ranges experienced during the preceding 50 years.[23] Unfortunately, in the next decade, oceanic conditions turned poor again for many marine organisms, and these conditions have persisted to the present day.

Many marine organisms that Clayoquot communities have historically depended on are currently in decline. For instance, most of the key indicators discussed in this section are thought to be declining locally, affecting all other species in the Clayoquot marine environment. Salmon, rockfish, forage fish and Cassin's auklets are at an all-time low; oysters, manila clams, geoduck, rockweed and euphausiids (krill) are all experiencing a drop in population numbers. It can be difficult to pinpoint the exact causes for these declines, especially since most organisms are threatened by a combination of overharvest, predation, loss of key habitat, competition with invasive species, natural climatic changes (i.e., pacific decadal oscillation, El Nino/La Nina), and changes to their environment brought on by climate change.

These observations are supported by interviews with the Clayoquot communities, wherein they indicate that fish stocks are perceived to have significantly declined over the last 30 years and those that persist are smaller and more sickly (Appendix 2). The cause of this change is seen to be due to a mix of factors including: warming of the ocean waters and drying of spawning streams due to climate change, overharvesting/poor fisheries management, the increase in sea otter populations, the increase in pollution, fish farming and sea lice, increasing population pressures and human greed.

However, on a more positive note, some important marine species are increasing in number, such as grey whales, Steller sea lions, sea otters, eelgrass, and giant kelp. Many of these species are rebounding from past all-time lows because harvest pressures (by humans and predators) have decreased. So while some key marine species are declining at alarming rates, the overall diversity of marine organisms is higher now than it was 50

[22] Druker, 1951
[23] Beamish et al 2000, Hare and Mantua, 2000

years ago. Many components of Clayoquot Sound's marine communities are healthy, though they are changing, and we are losing culturally and ecologically important species.

So, it is interesting to note that even through these poor environmental conditions and a recent history of overharvest, Clayoquot marine communities have increased in diversity, and that diversity can provide resiliency to Clayoquot communities.

Socio-economic

Just as human society and natural disturbances have impacted natural ecosystems in the Clayqouot Sound, these impacts have had cascading effects on human society, particularly on the Clayoquot First Nations.

The Clayoquot First Nations are known to have continuously occupied the west coast of Vancouver Island for at least 5000 years. The population at the time of the first European contact (1774) is thought to have been approximately 30,000 in number.[24]

Prior to European contact the tribes of the area fished, hunted and collected in ascribed territories based on seasonal patterns. Salmon, halibut, herring and eulachon were taken in huge numbers. Seals, sea lions, porpoises and whales were also hunted by harpoon from canoes. Clams, mussels, abalone, barnacles, sea urchin and sea weed were collected as were roots, bulbs and a wide range of berries. Salmon streams, herring spawning areas, clam beds, berry patches were the exclusive property of particular kin groups. They undoubtedly reduced the abundances of some of the species that were hunted and gathered [25]which undoubtedly led to secondary ecological (cascading) effects such as increases and decreases in a variety of species that were not targeted.

The coming of Europeans and maritime trade in 18th century constitutes the beginning of the most significant human-induced ecological changes. Beginning with the Fur Trade, human activities and exploitation of the area led to an increased focus on hunting for furs, changing their traditional hunting patterns eventually leading to the local extinction of the sea otter by the end of 18th century. After this extinction, contact with the Europeans significantly declined until the mid-19th century when the British began settling Vancouver Island in greater numbers. With increasing British colonial contact and trade came small pox and measles epidemics, which greatly reduced Clayoquot populations and forced the abandonment of many villages. Great social and economic changes took place in the following decades. Christian missionaries began to interact

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[24] Paul R. Magosci, Editor. .*An Encyclopaedia of Canada's People*. (Toronto. University of Toronto Press., 1999) p109

[25] Simenstad, C. A., J. A. Estes, and K. W. Kenyon. 1978. Aleuts, sea otters, and alternative stable-state communities. Science (Wash.) **200**:403-411.

with the remaining communities discouraging them from continuing with the traditional beliefs and practices (traditional gods, potlatches, etc.).[26]

By the 1890s, a scattering of homesteads dotted the Esowista Peninsula eventually forming what is now Tofino. Fishing, sealing and whaling by Norwegian, Scottish and English crews began to increase, providing economic opportunities for some local First Nations but also increasingly disrupting traditional fishing and hunting opportunities. No legal treaty or other negotiations ceded the Clayoquot lands or resources to the Europeans. Instead, the federal government created the Indian Act, making the First Nations "wards of the state" and assigned reserves to each Clayoquot group consolidating them into villages thereby reinforcing claims on the remaining traditional territories. At the same, time the federal government with the support of the Churches began forcing First Nation children into Indian residential schools in an attempt to hasten assimilation. Instead, the reserve system, the Indian Act and the residential school system created great social distress and dislocation. The residential schools closed in 1983 but the Indian Act and the reserve system continues to this day.[27]

Forestry and the fishery sectors began industrializing in the 1950s, with the expansionist policies of the federal and provincial governments, new technologies and a new road connecting Port Alberni to Tofino and Ucluelet. Many First Nations gained employment in these industries during this time as fallers, truck drivers, fishermen and cannery workers.[28]

In the early 1960's as the Clayoquot communities were beginning to enjoy a higher standard of living, a devastating tsunamis hit the area. And while many shorelines saw inundation, the Hesquiaht at Hot Springs Cove was completely inundated, destroying the entire village.[29]

By the late 1960 and early 1970s, however, the highly extractive liquidation of the west coast timber and fish stocks started to produce increasing conflicts as industry's capacity to extract superseded the ecosystem's ability to supply and as First Nations began looking for a greater share of the benefits and for a greater say over their traditional territories. In the fisheries sector the federal government reacted by shifting from a policy of development and open access to a policy of increased licensing and regulation and dependence on "scientific management". In the forest sector, the provincial government permitted greater consolidation.[30]

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[26] Paul R. Magosci, p110
[27] Paul R. Magosci, p111
[28] Mary K. Liston. *Building resilient coastal communities in British Columbia: A case study of climate change and adaptability in Ucluelet, BC* (Masters' Thesis University of Victoria,2010) p64
[29] Wikileaks, Hesquiaht.
[30] Mary K. Liston, p66

This did little to slow resource degradation and conflict the fishery and forest sectors in the following decade and so in the face of a market slump in the 1980s the governments sought to make resources systems more productive and economically efficient. This succeeded in increasing resource flows for the short-term but led to further resource degradation and increasing conflict with Clayoquot First Nations and environmental organizations in the 1990s. In 1993, the "war in the woods" and increasing international pressure forced a shift in forestry policy in the Clayoquot Sound. About the same time, with growing recognition of fisheries decline, the federal government began overhauling in the regulation of the salmon fishery. As a result, by the mid-90s, the annual allowable cut in the Clayoquot Sound was significantly curtailed and fisheries licenses and quotas were significantly reduced.[31]

This resulted in mass sell offs of fishing licenses and closers of canneries as well as mass layoff in the forest workers; many of which were First Nation. Over 500 jobs were lost in the forest industry in the Clayoquot Alberni area and several hundred in the fishery. (Clayoquot Socio-econ 2009). With the layoffs, came increased stresses on First Nation and non-First Nation individuals and families and community services and increased social problems (substance and family abuse etc.). [32]

The decline in fish stocks also impacted the subsistence fishery, making less fish available for the Clayoquot communities, forcing them to shift consumption to other seafoods, wild plants, wild meat and store bought groceries.[33]

Since the new millennium, the Clayoquot communities have continued to press for greater authority over the traditional territory while exploring opportunities to build their economies. They have invested in small scale forestry, aquaculture, tourism and construction as well as local government services. The process of replacing livelihoods, healing from past physical and cultural harms and reviving culture is slow but continuing today. [34]

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[31] Mary K. Liston, p68
[32] Mary K. Liston, p70
[33] Based on key informant interviews.
[34] Mary K. Liston, p72

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Appendix 1

Infrastructure and Shelter of the Clayoquot Communities

Table 11: Description of Ahousaht Infrastructure, 2011

Infrastructure Asset	Description
Water	Anderson Creek Dam (concrete-faced, rockfill) and water supply intake and pipeline leading to the Estuary at Matilda Inlet, then submarine pipeline to village pumphouse, from pumphouse to elevated reservoir and water treatment plant then treated water reservoir. Treated water reservoir to village pumphouse and village distribution system.
Sewer	Gravity sewer to community septic tank equipped with some pumping capacity to gravity marine outfall. Future lift stations and pressurized sewer will be constructed concurrent with new subdivision development.
Energy	BC Hydro supplies power via submarine cable from overhead power on Meares Island at Kakawis. Backup power generator at water treatment plant only.
Stormwater Drainage	Mostly overland flow with road cross-drain culverts and discontinuous roadside ditching.
Breakwaters	Stacked rock breakwaters along foreshore at existing cemetery and along east side of village area opposite government dock.
Wharves	Government (main) dock and floating wharfs, Hydro dock and floating wharves
Roads	Water Treatment Plant/landfill/sawmill access road, Road from Barge Loading Ramp past new subdivision into original village area, Barge ramp and Dam Access Road
Solid Waste	Existing solid waste landfill
Tele-communications	Telus microwave tower at Maaqtuusis, on McKay Island (repeater) sent to Tofino via Barrs' Mountain to Mount Ozzard, then overhead line to Port Alberni
Housing	149 existing units 160 new planned for construction in next 10 years

Source: Don MacKinnon

Table 12: Description of Tla-o-qui-aht (Opitsat) Infrastructure, 2011

Infrastructure Asset	Description
Water	Brother Creek weir and intake, overland piping to pump house at Kakawis, where additional water supply (Christy Lake) and infiltration gallery near pumphouse can be added to supply that is pumped to tank and water treatment plant. Water treatment plant pumps to elevated reservoir then gravity flow to village distribution system.
Sewer	Gravity piping to community septic tank along foreshore.
Energy	BC Hydro supplies power via submarine cable from overhead power at Tofino to Port Alberni. Power from Opitsat is directed via overhead poles to Kakawis then submarine cable to Maaqtuusis.
Breakwaters	Existing timber breakwater extends from Government Dock westward toward Band Office, but stopping short, and in need to re-construction.
Wharves	Access wharf at Government Dock with floating wharves
Roads	ATV trail to existing landfill and along BC Hydro easement to Water Treatment Plant and on to Kakawis and Brother Creek intake, Road from Village to Water Treatment Plant.
Solid Waste	Existing landfill (recently capped) and new transfer station area where collected waste is loaded in bins for transport to ACRD Landfill via Tofino and Pacific Rim Highway.
Tele-communications	Telus is provided by submarine cable with satellite dish receiving internet signals from Barrs Mt in Tofino
Housing	82 existing homes (21 Band owned) 160 units planned for construction in next 10 years

Source: Don MacKinnon

Table 13: Description of Tla-o-qui-aht (Ty'histanis-Esowista) Infrastructure, 2011

Infrastructure Asset	Description
Water	ACRD well, concrete reservoir and pumphouse/disinfection system, pressurized piping across Tofino airport property to Ty-histanis pumphouse and Esowista/Ty-histanis distribution system.
Sewer	Existing combination of gravity sewers and pressurized forcemains discharging to existing septic field on Tofino airport property (ACRD), soon to be connected via pressurized forcemain to Tofino's Regional wastewater collection and disposal facility.
Energy	BC Hydro is provided via overhead lines from Port Alberni
Stormwater Drainage	Existing road culverts across Esowista Creek in Lower Esowista, existing roadside ditches in Esowista and Ty-histanis, discharge facilities to stormwater retention facilities prior to discharge to Esowista Creek and its tributaries, road cross-culverts leading drainage north from Ty-histanis across Pacific Rim Highway and flowing towards Grice Bay.
Breakwaters	None existing
Wharves	None existing
Roads	Paved roads in Esowista and Ty-histanis
Solid Waste	Serviced by municipal pickup and delivery to ACRD Municipal Landfill
Telecommunications	Overhead service by Telus
Housing	82 existing homes (21 Band owned) 160 units planned for construction in next 10 years

Source: Don MacKinnon

Table 14: Description of Hesquiaht Infrastructure, 2011

Water	Infiltration gallery intake and two concrete sedimentation tanks into overland (along Refuge Creek) gravity supply line, then submarine pipe to Village Pumphouse/Disinfection treatment at Refuge Cove, then pressure pipe to elevated Reservoir, then gravity distribution system for Village
Sewer	Gravity piping to community septic tank along foreshore.
Energy	Community (diesel) power system and overhead distribution system
Stormwater Drainage	Roadside ditches and cross-drain culverts along existing Village road/trail system, New school collection system into stormwater retention pond, then into improved , existing roadside ditches
Breakwaters	Timber breakwater near Government Dock has been removed by erosion (2010)
Wharves	Government docks are floating concrete attached to upland area created by metal sheet pile wall, other wooden docks are present in Refuge Cove.
Roads	Existing access roads to Kanim Lake, from Barge Ramps in Sydney Inlet and Refuge Cove to logging access roads adjacent to Refuge Creek (east and west sides of Refuge Creek community watershed
Solid Waste	Existing incinerator not typically used, village operates central transfer station to collect and load-out collected solid waste.
Telecommunications	Telus service is provided via microwave transmission from Maaqtuusis, then McKay Island, then Alto Lake to Refuge Cove.
Housing	37 existing units (20 Band owned) 1 unit planned for construction in next 10 years

Source: Don MacKinnon

Appendix 2

Current Observations about Ecological Disturbances

The communities of Ahousaht, Heshqiaht and Tla-o-qui-aht were consulted about a range of ecological and community changes they have experienced or observed over the years. All communities indicated significant changes, many of which were seen as negative and many of which were linked in part to climate change but also to poor resource management, population pressures and pollution.

General Observations about Ecological Changes

When asked about general impressions regarding how the local ecology has changed over the years, 46% indicated that the ecosystem had become *greatly degraded*, 29% indicated that the ecosystem had become *somewhat degraded* and the remaining 25% did not express an opinion or could not judge. In general, the community members indicated that there appears to be less rain in the summers and milder winters. There are fewer fish, shellfish, basking sharks and whales, fewer deer and birds but more sea lice, clams, sea otters and algae blooms. Some of the migratory animals are staying longer or returning earlier. The medicine plants have moved, there are more mudslides on Cat Face Mountain and there is increasing destruction of the natural habitat. Most of these changes have been observed over the last 30 years and are thought to have been caused by a range of factors including: increased population pressures, climate change, overharvesting, pollution and general human greed. These observations are segmented into marine changes, land changes and community changes and elaborated below.

Marine-based Changes

- **Water and Shoreline Observations**

Community members were asked to comment specifically on changes they have witnessed to the marine ecosystem, including sea level changes, water quality and shoreline erosion. As regards sea level changes, most members responded that that tides or water levels seem to higher than when they were children (Table 15). Coastal erosion also appears to have increased, citing the loss of sand and beach grass from the beaches. Water quality appears to have changed such that the ocean waters are warmer and are experiencing more Red Tide and algae blooms. The causes of these changes are thought to be due to a mix of factors such as bigger storms, higher tides, climate warming, pollution and higher boat traffic.

Table 15: Water and Shoreline Observations

Water & Shoreline Qualities	Observations	Perceived Causes
Sea Level	Mixed impressions but more of the opinion that tides/water levels were lower when they were children	A mix of causes. Bigger storms, higher tides, climate change, boat traffic, climate change and pollution
Coastal Erosion	More erosion. Much of the sand and beach grass is gone, leaving only rocks	
Water Quality	Warmer, more Red Tide and algae blooms.	

Source: key informant interviews, 2010

- ## Marine Life Changes

Marine life, including fish stocks, non-fish stocks and marine mammals, are very important to the Clayoquot First Nations as a primary source of food, a source for cultural products and stories and as a source for livelihoods. Many members of the Tla-o-qui-aht, Heshquiaht and Ahousaht communities still fish hunt and collect, although these activities have declined over the years as commercial foods have become more accessible and lifestyles have changed. Despite this decline in wild food gathering, the state of most marine life is perceived to have declined significantly over the last few decades.

- ## Fishery Resource

Of all the species, fish are perhaps the most important marine resource to the Clayoquot First Nations. All salmon species are highly regarded as a source of food but so too are tuna, herring, ling and black cod, halibut, red snapper, sardines, pilchard and quillback fish (Table 16). Roughly one-third of respondents still actively fish for their seafood, one-third relies on the Band food fish program and one third buys their fish off local fishermen. Fish stocks are perceived to have significantly declined over the last 30 years and those that persist are smaller and sicklier. The cause of this change is seen to be due to a mix of factors including: warming of the ocean waters and drying of spawning streams due to climate change, overharvesting/poor fisheries management, the increase in sea otter populations[35], the increase in pollution, fish farming and sea lice, increasing population pressures and human greed.

[35] Sea Otters in require a huge amount of food (somewhere in the region of 32lbs per day per individual), and they are having a significant impact on traditional FN fish an non-fish resources (Stephanie Hughes).

Table 16: Fishery Resource Observations

Key Species	Uses	Changes	Perceived Causes
All salmon species (sockeye, Coho, Chinook, Chum, spring), tuna, herring, ling and black cod, halibut, red snapper, sardines, pilchard, quillback fish as well as salmon and herring roe.	Food, culture, livelihood About 1/3 of respondents fish for own fish, 1/3 receive from Band and 1/3 buy from local fishermen.	Fish stocks are down and fish are smaller and sicker looking. Invasion of mackerel, sea lice, jellyfish and algae.	Mix of factors. Climate warming the waters and drying the spawning streams. Overfishing/poor management. Poor logging practices. Pollution. Fish Farms. Population pressure. Sea lice. Greed.

Source: key informant interviews, 2010

- ## Non-Fish Marine Resources

Non-fish marine stocks are also important to the Clayoquot First Nations as a source of food, culture products and livelihood resources. Key species include: cockles, clams, mussels, gooseneck barnacles, crab, prawns, shrimp, sea urchin, oysters, abalone, gooey duck, chiton, sea cucumber, kelp and seaweed (Table 17). Many community members still collect these species but these stocks have also declined and the existing stocks are also less healthy than decades ago. The key causes of this decline are similar to those cited above but particular concern was again expressed regarding the growth in sea otter populations and their voracious appetites. It is interesting to note that one member observed that sea urchin populations have migrated to deeper cooler waters than before because shallow waters too warmed now.

Table 17: Non-fish Marine Resources

Key Species	Uses	Changes	Perceived Causes
Cockles, clams, mussels, goosenecks, herring eggs and crab, sea urchin, crabs, kelp, prawns, shrimp, herring eggs, oysters, abalone, gooey duck, herring eggs, Chiton, seaweed and sea cucumber	Food, culture and livelihood Many still harvest some of these species.	Stocks are down and they are smaller and sicker.	DFO mismanagement/ over-harvesting/ lack of balance. Climate Change warming waters. Sea Otter predation. Boat traffic. Water pollution.

Source: key informant interviews, 2010

• Marine Mammals

Marine mammals, including harbour and fur seals, Grey, Killer and Humpback whales, some ducks, sea otters, and California and Stellar sea lions are important to the Clayoquot First Nations but less so than fish and non-fish species (Table 18). There are impressions from community members that whale populations have gone down over the decades but also that their migratory patterns have changed (returning sooner). California sea lion populations have recently increased with were more than 1000 over-wintering in Indian Bay this year, which is larger than anyone has witnessed before. Sea otter populations, which were recently re-introduced to the area, have also increased significantly year round. They are a red listed species and hunting them is strictly prohibited but their numbers and their voracious appetite for seafood are to seen to have significantly impacted fish and non-stocks.[36]. As a result many respondents from the community expressed interest in culling the population. Whales used to be an important source of food and oil but they are no longer hunted. Seals and sea lions are hunted for their meat and oil and pelts and ducks for their meat.

Table 18: Marine Mammal Resources

Key Species	Uses	Changes	Perceived Causes
Harbour and fur seals, Grey, Killer and Humpback whales, some ducks, Sea Otter, California ans Stellar Sea Lions.	Food, oil culture. Minor harvesting. No harvesting of whales or sea otters.	Fewer whales but they come earlier. Many more sea otters and sea lions and seals.	Climate warming, less hunting, northern migration of sea otters, and seals and sea lions stay all year.

Source: key informant interviews, 2010

Land-based Changes

The state of the terrestrial ecosystem in the Clayoquot Biosphere is also perceived to have changed significantly over the decades. Community members indicated that freshwater is more scarce in certain parts during the summers and more abundant in the winter/spring and that certain trees and other vegetation and terrestrial animals are in decline.

• Freshwater Resources

The Clayoquot Biosphere is one of the wettest places in Canada with a mean annual precipitation rate of roughly 4079 mm/yr.. Nevertheless, there appears to be growing

[36] Discussion with Stephanie Hughes, EcoTrust Coordinator in Clayoquot.

seasonal pressures on freshwater supplies in the area (Ahousaht and Tofino). This is perceived to be a result of warmer and drier summers (climate change) but also factors such as poor logging practices and increased population pressures (Table 19).

Table 19. Freshwater Resources

Key Events	Perceived Causes
Rivers and lakes low are lower in the summer. More flooding in winter/spring. Potable is good quality because of water systems but water restrictions in summer in Ahousaht and Tofino but not in Tla-o-quiaht and Hesquiaht.	Climate change, poor logging practices and increased population pressures.

Source: key informant interviews, 2010

- ## Trees

The forests of Clayoquot Sound are an important source of wood and bark for livelihoods, cultural products, medicines, heating and building but also important habitats for the plants and animals that sustain them. Species of importance include red and yellow cedar, douglas fir, red alder, spruce, hemlock, yew, pine, balsam and crab apple (Table 20). These trees are used for housing, carving, canoes, totems, paddles, firewood, smoking food, basketry, tools and medicinal/spiritual purposes. The forests are perceived to be changing noticeably by the Clayoquot communities, with old growth cedar and fir harder to find, more occurrences of second growth and more occurrences of crab apple trees. The reason for the change is said to be primarily related to over-harvesting, although factors such as climate change, pollution, disease and high winds are also mentioned.

Table 20. Trees

Key Species	Uses	Changes	Perceived Causes
Red and yellow cedar, fir, red alder, spruce, hemlock, yew, pine, balsam and crabapple	Housing, carving, canoes, totems, paddles, firewood, smoking food, basketry, tools and medicine/spiritual purposes.	Old growth cedar and fir harder to find. More second growth. Smaller and weaker trees. More crab apple trees.	Over-harvesting and greed, climate change (Drier weather killing cedars), pollution, strong winds, and disease.

Source: key informant interviews, 2010

- ## Other Vegetation

Other vegetation such as wild berries, roots, and grasses are collected by many of the community members and are used for food, medicines, weaving (grass, cedar bark), and cultural ceremonies (Table 21). Important plants for these purposes include blackberries, cranberries, salmonberries, blueberries, huckleberries, raspberries, Devil's Club, Indian Medicine, wild and swamp grasses for weaving, thimble berry, goose berry, Salal, Yarrow, bear root, ferns, wild rose, and dandelion. Most community respondent indicated that they have seen changes in these plants recently in the sense that it is less predictable how much will be available, where they will available, and when they will ripen. Causes for these changes are perceived to include hotter and drier summers (climate change), over-harvesting, invasion of new competing species (Scotch Broom), and pollution.

Table 21. Other Vegetation

Key Species	Uses	Changes	Perceived Causes
Blackberries, cranberries, salmonberries, blueberries, huckleberries, raspberries, Devil's Club, Indian medicine, wamp grasses, thimble berry, goose berry, salal, yarrow, bear root, ferns, wild rose,and dandelion.	Food, medicines, weaving (grass, cedar bark) and cultural ceremonies	Unpredictable - sometimes less or more, different locations, earlier or later. Less in logged areas. More crab apples than before.	Climate change (hotter-drier summers make it harder to grow), clearcuts/over-harvesting, invasive species, and pollution.

Source: key informant interviews, 2010

- ## Land-based Mammals

Land-based mammals such as Deer, geese, ducks, bear, moose and cougar are important to the Clayoquot First Nations as sources for food and/or pelts (Table 22). Community members indicated that they have seen changes in a number of mammal species recently, with more wolves and ducks and less deer and cougars. Geese are also perceived to stay longer during the year or not leave at all. Perceived causes for these changes include climate change, loss or disturbance of habitat, logging and pesticides.

Table 22: Land-based Mammals

Key Species	Uses	Changes	Perceived Causes
Deer, ducks, bear, moose and cougar	Food and culture (pelt for regalia)	Less deer, cougars and birds. More wolves and ducks. Bears still out in Nov. Geese don't fly south. More females than males.	Climate change, loss/disturbance of habitat, logging and pesticides.

Source: key informant interviews, 2010

They claim that a big contributor to this situation is shift away from a wild fresh food diet to a diet involving more sugar, salt and processed foods. This shift is said to be due in part to the decline in availability of wild foods but also due to increased access to commercial foods. Other contributors to worsening health include a shift to more sedentary lifestyle (less hunting, fishing, and collecting), more pollution and a lack of community leadership. Climate change may be said to be a contributor to the worsening health of the Clayoquot communities insofar as it has affected wild food supplies.

Chapter 3

Climate Change in the Clayoquot Sound: Current Trends and Future Projections

contents

Study area

Figure 1 highlights the study region (hereafter referred as Clayoquot Sound) which is located on the west coast of Vancouver Island, BC. The Clayoquot Sound is subdivided by Biogeoclimatic Ecological Classification (BEC) zones, subzones, and variants (hereafter referred as BEC regions). There are seven identified BEC regions within the biosphere reserve (see Figure 1); however, only six of these regions are represented in the analyses because the insignificant area (≈0.01km^2) of the CWHmm1 BEC region. The BEC region abbreviations are as follows:

CMAunp: Coastal Mountain-Heather Alpine, Undifferentiated and Parkland,

CWHmm1: Coastal Western Hemlock, Submontane Moist Maritime,

CWHmm2: Coastal Western Hemlock, Montane Moist Maritime,

CWHvh1: Coastal Western Hemlock, Southern Very Wet Hypermaritime,

CWHvm1: Coastal Western Hemlock, Submontane Very Wet Maritime,

CWHvm2: Coastal Western Hemlock, Montane Very Wet Maritime,

MHmm1: Mountain Hemlock, Windward Moist Maritime.

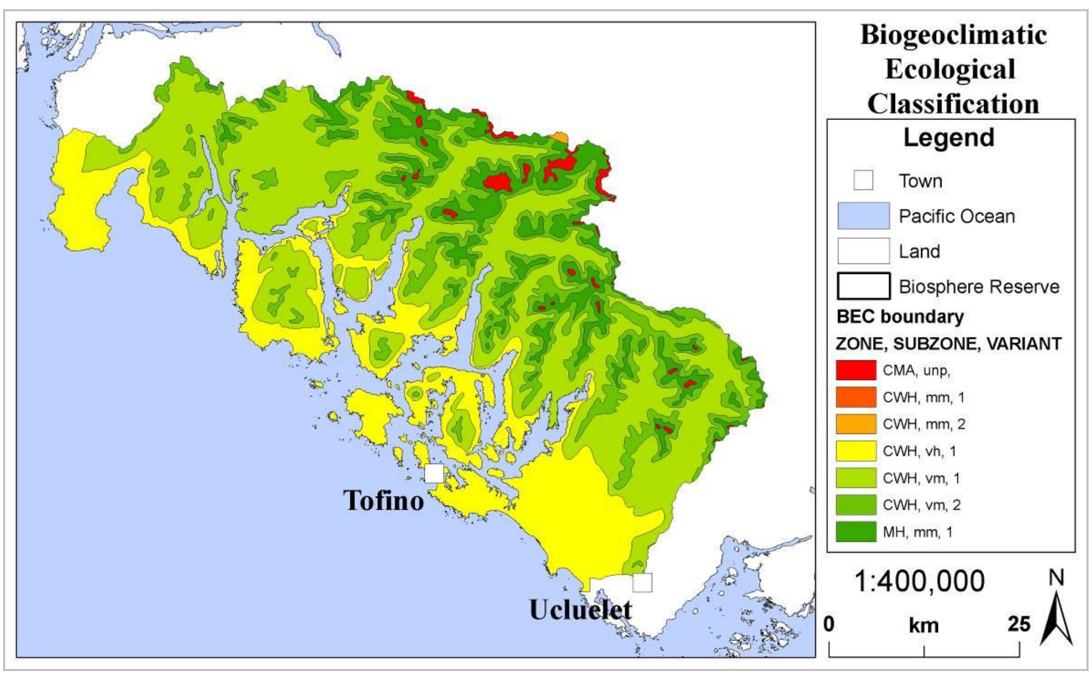


Figure 1. Biogeoclimatic Ecological Classification zones for Clayoquot Sound.

Current Climate and Weather in the Clayoquot Sound

The climate of the Clayoquot Sound study area is shaped by its proximity to the Pacific Ocean and by its steep topography. Winter is an active season with a series of frontal systems moving into the area associated with low pressure cyclonic systems, bringing heavy precipitation including embedded cells of short-duration high-intensity rainfall and high winds (CSSP 1995). The small size of these cells makes them difficult to detect given the sparse rainfall gauge network found in this area. In general terms, precipitation is understood to increase with elevation and decrease inland in the Clayoquot Sound area. The maximum 24-hour precipitation values at the Tofino, Ucluelet, and Estevan climate stations are 184.2, 185.1, and 218.9 mm respectively (reported in Madrone Environmental Services 2003) In contrast, at the Brynmor Mines, in the mountains behind Ucluelet, rainfall intensity records were set for British Columbia for 2 hours (70.9 mm), 6 hours (139.4 mm), and 24 hours (489 mm). .

Temperatures are moderated by the ocean so that winters are mild and summers are cool relative to inland locations (See Figure 2). The lowlands and inlets are cooled by maritime winds and, in summer, blanketed by morning fog. The main effect of the warm temperatures is to minimize the depth and duration of snow cover at low elevation. While temperatures decrease with elevation, the point at which freezing occurs varies widely through the winter; rain often falls at higher elevations (on snow) while snow sometimes falls at sea level. On average, Tofino, Estevan, and Ucluelet have only 12, 13, and 9 days respectively of measurable snowfall annually (reported by Madrone Environmental Services 2003). Prolonged periods of freezing temperatures are uncommon. While there is no marked dry season, the summer months are relatively dry due to the prevalence of high pressure systems and fewer storms during the summer season.

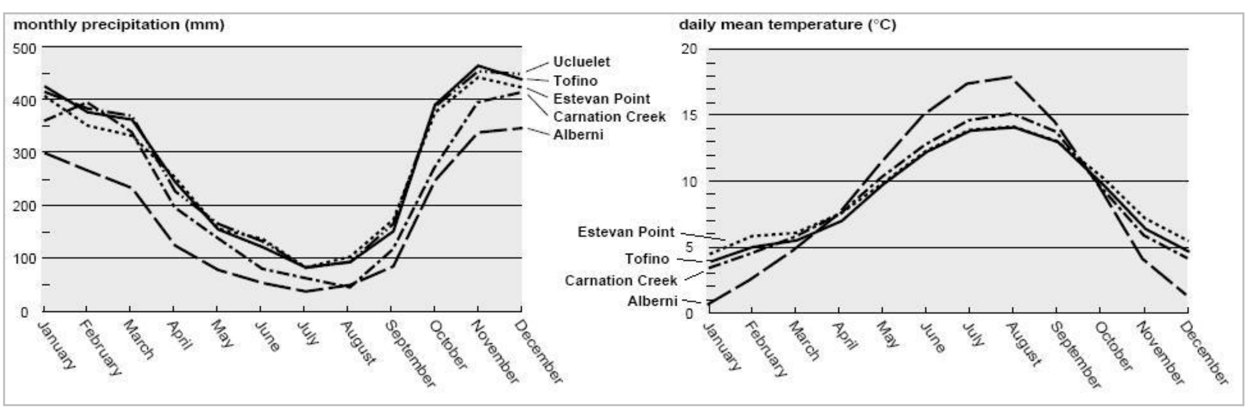


Figure 2. Mean Precipitation and Temperature Changes in the Clayoquot Sound

Community Observations about Recent Climate Trends

To complement the scientific climate data, qualitative primary data was acquired through key informant surveys, which sought to capture community observations on past and current climatic changes. Twenty-eight individuals across three Clayoquot communities (Tla-qui-aht, Heshquiaht and Ahousaht) were interviewed by four community members. The individuals surveyed included twenty-two men and six women of which the average age was 50 years old.

Table 1 sums up the main responses from the Clayoquot community members, in response to a question on how the seasons have changed climate-wise between now and their childhood. Since the majority of the interviewees have lived between 40-60 years in the study area, their responses provided a rich amount of information.

Table 1: Seasonal climate observations – Past and Present:

Summer Climate
About temperature: • Summers are hotter and longer than before • Not unusual to see 30C or hotter in the summer whereas before it was more normal to see 25C **About precipitation:** • Less frequent rain but heavier showers when it comes • Less lightening **Noticeable signs of climate changes:** • In the past the snow would stay on the mountain tops all summer but not anymore • Migratory birds and animals are staying longer than they used to. Sea urchins have gone deeper • Kennedy Lake and Christie Lake water levels are lower on a consistent basis.
Winter Climate
About temperature: • Winters are milder than they used to be. It was common to have ice. Not anymore. **About precipitation:** • There is less snow and more rain than before • Storms are less frequent but stronger winds **Noticeable signs of climate changes:** • The lakes, ponds and even inlets used to freeze with thick ice so we could walk or skate on it. There is no ice like this anymore. • The migratory birds and animals are staying longer and coming back earlier because the weather is milder than before

Source: Key Informant Survey, 2010.

Future Climate Projections (2020's, 2050's and 2080's)

The Clayoquot Sound on the west coast of Vancouver Island, British Columbia, is expected to experience climate change in the future (2020's, 2050's, and 2080's). By its very nature, predicting climate change is full of uncertainty and doing so over the next 70 years is even more so, not just because of the difficulty of defining the level of carbon emissions into the atmosphere but also in knowing how to model the interactions of the many climate variables. For the maritime location of Clayoquot the biggest uncertainty may be around modeling the changes to ocean currents and cloud formation, which could have major consequences upon predictions[37]. Recognizing these limitations, the climate change projections below should be seen as estimates and not as definitive predictions. It is advised to focus on the general trend (e.g. temperature will increase by 2°C by the year 2050) of the climate change projections rather than the absolute values (e.g. the mean temperature will be 7.53°C by 2050). Two different carbon emission scenarios A1F1 (increasing emissions) and B2 (stabilizing emissions) are considered for these projections and are developed with assistance of the ClimateBC model.

Figure 3 depicts the topography within the Clayoquot Sound. The mountainous topography within the biosphere reserve plays an important role on the geographic distribution of temperature and precipitation. Temperature generally becomes colder with altitude (environmental lapse rate) and precipitation generally increases with altitude (the orographic effect). These trends become apparent in the figures below and in the distribution of BEC regions (see Figure 1. above).

For simplicity, only the seasonal and annual temperature and precipitation means are shown graphically and summarized in tables below. Annual refers to the yearly 12-month average (Jan. – Dec.) and seasonal refers to three month averages: winter (Dec. – Feb.), spring (March – May), summer (June – Aug.), and autumn (Sept. – Nov.). A brief summary of growing season is also provided. Additional summary tables of the other variables calculated by ClimateBC are provided in the Appendix.

Considering the largest communities, Tofino and Ucluelet, lie within the WCHvh1 BEC region, most people will readily be able to identify with the results presented in this BEC region (oppose the entire biosphere reserve). The climate change projections are based on what science can predict; however, it is important to keep in mind that the results are only estimates and not definitive. For ease of interpretation, it is advised to focus on the general trend (e.g. temperature will increase by 2°C by the year 2050) of climate change projection rather than the absolute values (e.g. the mean temperature will be 7.53°C by 2050) of the climate change projections given by ClimateBC.

[37] Jones 2008

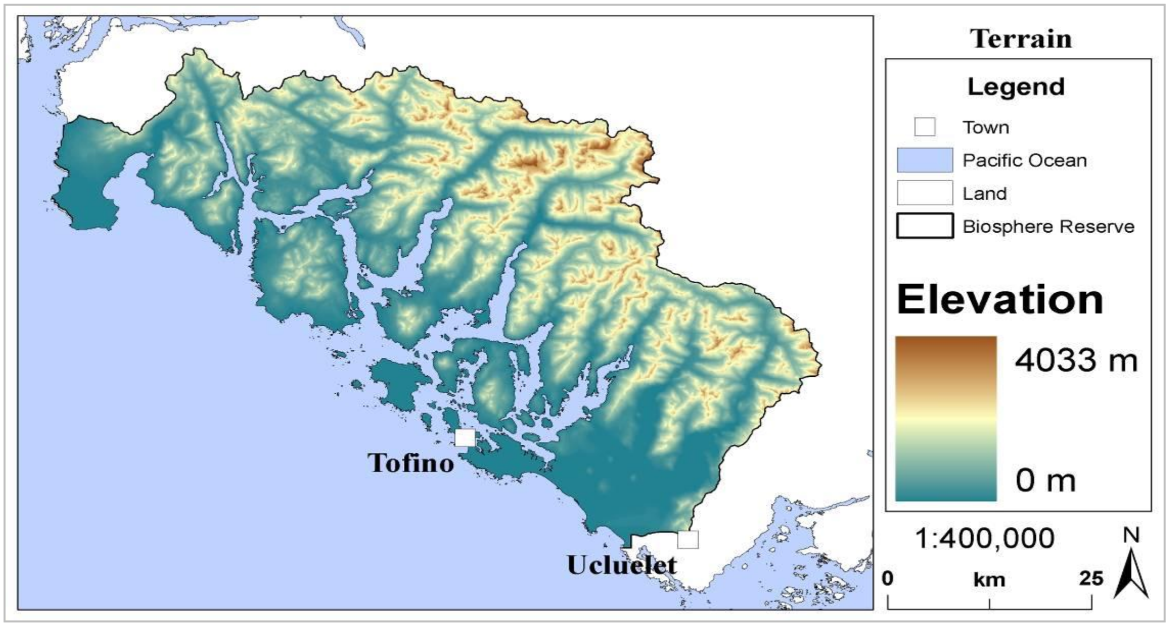


Figure 3. The diverse topography within the Clayoquot Sound.

Mean Annual Temperature

The Mean Annual Temperature (MAT) for the reference period 1961 – 2000 is 7.81°C (see Table 2 and Figure 4A) and is considered representative as the present' climate. For the A1F1 emission scenario we can expect an increase in MAT to 8.69°C for the 2020's, to 10.13°C for the 2050's, and to 11.76°C in the 2080's (see Figure 3Bi,ii,iii). Similarly, For the B2 emission scenario we can expect an increase in MAT to 8.63°C for the 2020's, to 9.29°C for the 2050's, and to 9.91°C in the 2080's (see Figure 3Ci,ii,iii). For each of the BEC regions we can expect the same increment of MAT increases across the landscape. Notably for the 2080's time period, MAT for the A1F1 emission scenario is nearly a full 2°C warmer than that of the B2 emission scenario.

Seasonally, the increase in temperature is almost uniform throughout the seasons; although there are slight differences (see Table 3). Temperature will increase the most in the spring; however, it will also increase in the summer, winter, and autumn to a lesser degree.

Table 2: Mean annual temperature (°C) projected for each BEC region within the biosphere reserve.[38]

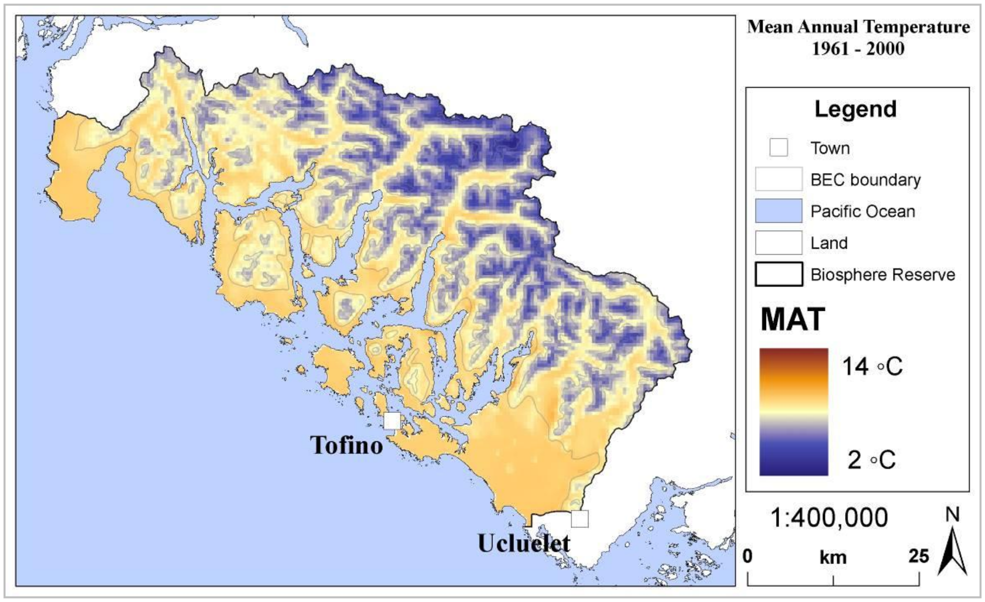
	1961 - 2000	2020's		2050's		2080's	
		A1F1	B2	A1F1	B2	A1F1	B2
CMAunp	4.24	5.13	5.06	6.57	5.73	8.21	6.36
WHmm2	6.01	6.92	6.84	8.34	7.53	10.00	8.14
CWHvh1	9.15	10.03	9.96	11.46	10.62	13.09	11.24
CWHvm1	8.15	9.04	8.97	10.47	9.63	12.10	10.25
CWHvm2	6.70	7.58	7.52	9.03	8.18	10.66	8.81
CWHmm1	5.49	6.38	6.31	7.82	6.99	9.46	7.61
Biosphere Reserve	7.81	8.69	8.63	10.13	9.29	11.76	9.91

Table 3: Average seasonal temperatures (°C) projected for winter, spring, summer, and autumn[39].

	Average Seasonal Temperature (°C)			
	Winter	Spring	Summer	Autumn
1961-2000	1.94	6.74	14.22	8.35
A1F1 - 2020's	2.81	7.65	15.10	9.22
A1F1 - 2050's	4.19	9.24	16.53	10.57
A1F1 - 2080's	5.77	11.03	18.17	12.06
B2 - 2020's	2.73	7.58	15.05	9.15
B2 - 2050's	3.39	8.32	15.72	9.73
B2 - 2080's	3.99	9.00	16.35	10.30

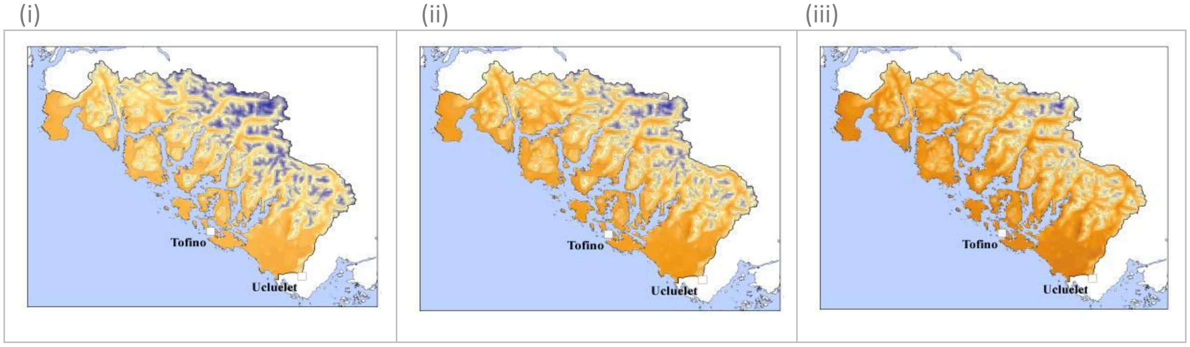
[38] Values are shown for the 2020's, 2050's, and 2080's for the A1F1 and B2 carbon emission scenarios. Future projections are tabulated against historical values for the period 1961 – 2000 as means for comparison.
[39] Values are shown for the 2020's, 2050's, and 2080's for the A1F1 and B2 carbon emission scenarios. Future projections are tabulated against historical values for the period 1961 – 2000 as means for comparison.

A) 1961 – 2000



B) B2 carbon emission scenario for (i) 2020's, (ii) 2050's, (iii) 2080's

(i) (ii) (iii)



C) A1F1 carbon emission scenario for (i) 2020's, (ii) 2050's, and (iii) 2080's.

(i) (ii) (iii)

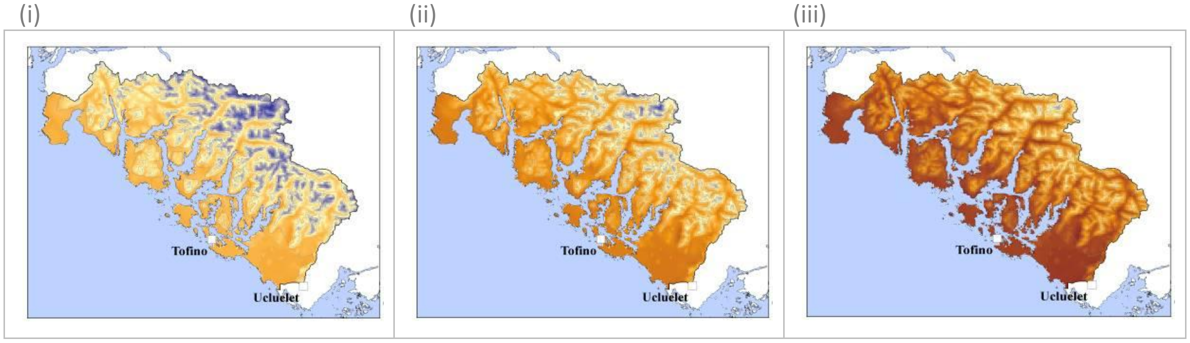


Figure 4. A series of maps showing the mean annual temperature projected geographically for the biosphere reserve for the A) 1961-2000, B) B2 Scenario and C) A1F1 Scenario.

Mean Annual Precipitation

The mean annual precipitation (MAP) for the reference period 1961 – 2000 is 4079-mm (see Table 4 and Figure 5A) and is considered representative as the 'present' climate. For the A1F1 emission scenario we can expect an increase in MAP to 4331-mm for the 2020's, to 4660-mm for the 2050's, and to 5045-mm in the 2080's (see Figure 5Bi,ii,iii). Similarly, For the B2 emission scenario we can expect an increase in MAP to 4331-mm for the 2020's, to 4316-mm for the 2050's, and to 4407 in the 2080's (see Figure 5Ci,ii,iii). For the BEC regions throughout each time period we can expect areas of higher elevation (e.g., CMAunp) to receive proportionately more precipitation than areas of lower elevation (e.g., CWHvh1) across the landscape. Notably, by the 2080's future time period, MAP for the A1F1 emission scenario is 638-mm wetter than the B2 emission scenario.

Table 4: Mean annual precipitation (mm) projected for each BEC region within the biosphere reserve[40].

	1961 - 2000	2020's		2050's		2080's	
		A1F1	B2	A1F1	B2	A1F1	B2
CMAunp	4448	4730	4607	5104	4711	5543	4814
WHmm2	3842	4099	3983	4440	4075	4840	4166
CWHvh1	3393	3594	3510	3855	3585	4158	3658
CWHvm1	4155	4411	4300	4747	4393	5140	4485
CWHvm2	4540	4825	4704	5201	4811	5640	4916
CWHmm1	4577	4866	4742	5247	4850	5695	4957
Biosphere Reserve	4079	4331	4223	4660	4316	5045	4407

Seasonally, the increase in precipitation is neither the same throughout the seasons nor the same for the carbon emission scenarios (see Table 5). For the A1F1 emission scenario precipitation will primarily increase in the winter (+764-mm) and autumn (+251-mm) seasons (values are based on the difference between the "present" and 2080). Precipitation is projected to decrease slightly in the spring (-16-mm) and summer (-33-mm).

[40] Values are shown for the 2020's, 2050's, and 2080's for the A1F1 and B2 carbon emission scenarios. Future projections are tabulated against historical values for the period 1961 – 2000 as means for comparison.

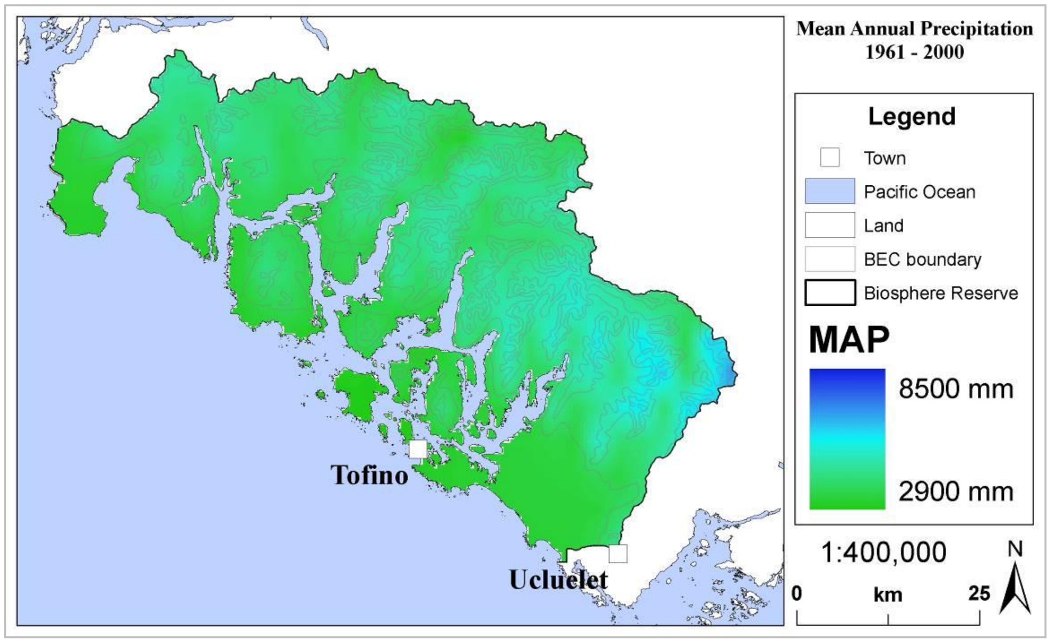
Seasonal precipitation for the B2 emission scenario is slightly different than that for the A1F1 scenario. Precipitation for the B2 emission scenario will increase in the winter (+314-mm) and spring (+44-mm); however, precipitation will decrease in the summer (-27-mm) and autumn (-3-mm).

Table 5: Projected average seasonal precipitation [41].

	Average Seasonal Precipitation (mm)			
	Winter	Spring	Summer	Autumn
1961-2000	1601	898	352	1228
A1F1 - 2020's	1783	901	339	1308
A1F1 - 2050's	2051	891	330	1388
A1F1 - 2080's	2365	882	319	1479
B2 - 2020's	1726	923	337	1237
B2 - 2050's	1823	931	330	1231
B2 - 2080's	1915	942	325	1225

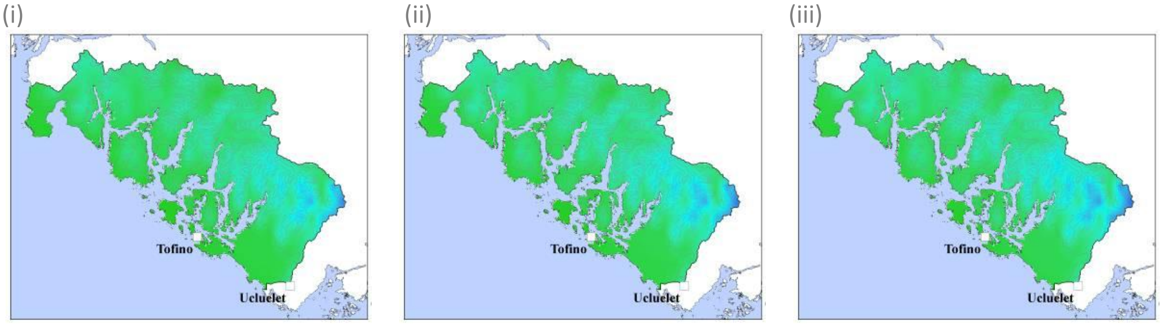
[41] Values are shown for the 2020's, 2050's, and 2080's for the A1F1 and B2 carbon emission scenarios. Future projections are tabulated against historical values for the period 1961 – 2000 as means for comparison.

A) 1961 – 2000



B) B2 carbon emission scenario for (i) 2020's, (ii) 2050's, (iii) 2080's

(i) (ii) (iii)



C) A1F1 carbon emission scenario for (i) 2020's, (ii) 2050's, and (iii) 2080's

(i) (ii) (iii)

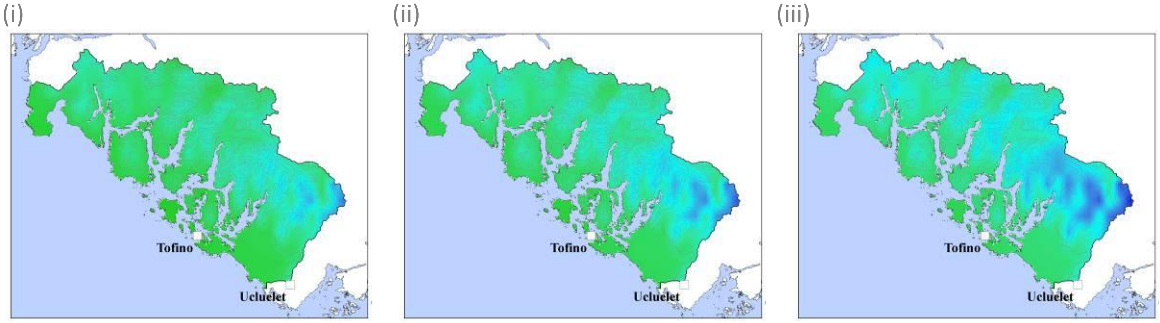


Figure 6. A series of maps showing the changes in mean annual precipitation projected geographically for the biosphere reserve for A) 1961-2000, B) B2 Scenario and C) A1F1 Scenario.

Growing Season

Temperature and precipitation distributions and magnitudes on the landscape can have a great effect on the quality and quantity of the growing season for plants. With regards to this, ClimateBC provides two climatic variables useful to this parameter (see Table 6). The frost free period (FFP) determines or restricts the length of the growing season and is the number of continuous days without frost forming. From the present to the 2080's, it is predicted that FFP will increase from 167 days to 233 and 291 days for the B2 and A1F1 emission scenarios, respectively.

Another, useful variable is growing degree days (>5˚C; GDD)[42] which is a measure of heat accumulation throughout the year. GDD is useful to predict how fast a plant will mature, when flowers will bloom, and when fruit will grow, etc.. From the present to the 2080's, it is predicted that GDD will increase from 1538 to 2140 and 2755 for the B2 and A1F1 emission scenarios, respectively.

Table 6: Average frost free period and growing degree days shown for the 2020's, 2050's, and 2080's for the A1F1 and B2 carbon emission scenarios[43].

		2020		2050		2080	
Biosphere Reserve	**1961 - 2000**	**A1F1**	**B2**	**A1F1**	**B2**	**A1F1**	**B2**
Frost Free Period (days)	167	193	190	243	212	291	233
Growing Degree Days	1538	1771	1755	2207	1948	2755	2140

Storm Changes

There is relatively good agreement that storm frequency is generally shifting poleward globally, meaning that increases in high latitudes and decreases on low latitudes, but there is considerable uncertainty about mid-latitude storms, where the Clayoquot Sound is located[44]. The Eastern Pacific is highlighted as a unique area with a **possible strengthening of storms and an equator-ward shift of storms, but not increases in frequency[45]**. A recent ensemble analysis of IPCC global climate models[46] also indicated a poleward shift in storm activity globally including a 6% increase in storm frequency near the Aleutian Islands by 2100 but only about a ~1% increase in frequency off the

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[42] *To calculate GDD, the hottest and coldest temperatures measured in a day are averaged. Then 5˚C is subtracted from the average temperature before summing the calculated values for every day for that year. For example, if 200 days a year have an average temperature of 15˚C above 5˚C, then the GDD would be 3000 (i.e. 200 × 15).*

[43] Future projections are tabulated against historical values for the period 1961 – 2000 as means for comparison.

[44] Easterling et al. 2000

[45] Bengtsson et al. 2006

[46] Ulbrich et al 2008

coast of British Columbia. These projections, although relatively uncertain, indicate a possible increase in storm severity and a decrease in storm frequency in the Clayoquot Sound area, which agrees with recent community observations.

Summary of Changes

In sum, this report highlights how climate is projected to change in the future for the Clayoquot Sound. Notably, MAT is projected to increase as much as 4°C by the 2080's. Throughout the seasons temperatures will increase slightly more in the spring and summer than in the winter and autumn. MAP is projected to increase as much as 764-mm by the 2080's. However, throughout the seasons the bulk of this precipitation will occur in the winter months. Depending of the carbon emission scenario, it will either become slightly drier in the spring and summer but wetter for in the autumn (i.e., for the A1F1 scenario) or slightly drier in the summer and autumn but wetter in the spring (i.e., for the B2 scenario). The combination of changes in temperature and precipitation will likely lengthen the growing season as well as ocean temperatures. These changes may in turn increase the severity but not necessarily the frequency of storms in the mid-latitude Pacific.

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Appendix 1

Climate Projection Methodology Notes

ClimateBC

Climatic data for this report have been produced by the computer program ClimateBC (version 3.21) which is freely available online at **http://www.genetics.forestry.ubc.ca/ cfcg/ climate-models.html.** ClimateBC calculates seasonal and annual climatic variables for specific locations when given latitude, longitude, and elevation coordinates. Historical climate, as well as, future climate change predictions can be calculated for British Columbia (BC), Yukon Territory, and western Alberta. This program is particularly useful for remote regions where climate data is not readily available.

In detail, ClimateBC is a climate model that extracts and downscales PRISM (Parameter-elevation Regressions on Independent Slopes Model) monthly data for the reference period, 1961 - 1990 (Daly *et al*., 2002). Through bilinear interpolation and elevation adjustments techniques, ClimateBC improves monthly temperature and precipitation data resolution produced by PRISM. Although PRISM only provides a spatial resolution of roughly 4 × 4 km, ClimateBC calculates resolution-free climate data ideal for complex terrain (e.g., mountains) (Spittlehouse, 2006). More recently, ClimateBC incorporated downscaled and integrated historical (1901 – 2002) datasets from Mitchell and Jones (2005) and future climate datasets (i.e., 2020's, 2050's, and 2080's) generated by various global circulations models (GCM).

Considering ClimateBC incorporates datasets from PRISM and Mitchell and Jones (2005), any poorly calculated or predicted climatic values from these datasets will in turn be transparent in the ClimateBC model. Such transparencies include: (1) poor dataset representation in a region because there are few weather stations; (2) weather stations used in the datasets are recorded at 1.5m height and in open areas which is not representative of most environments; and (3) micro-climate of small-scale topographic features (e.g., frost pockets, rivers, etc…) will not be represented by the large scale application of ClimateBC (Spittlehouse, 2006).

Knowing these limitations and methodologies, the accuracy of ClimateBC is best for areas that incorporate datasets with high densities of weather stations. Based on calculated estimates, ClimateBC uses on average one weather station for every 1900 km^2 of land, whereas the study region for this report is represented by one weather station for every 550 km^2 of land. Through validation techniques by Wang *et al*. (2006), the accuracy of climatic data calculated from ClimateBC has been shown to be well represented on the landscape.

Climate Model and Carbon Emission Scenario

The second generation of the Coupled General Circulation Model (CGCM2) from the Canadian Center for Climate Modeling and Analysis (CCCma) was used for future climate projections with ClimateBC. Two future carbon emission scenarios, as defined by the Intergovernmental Panel on Climate Change (IPCC), are used with CGCM2. The A1F1 emission (or "worst case") scenario describes a future world of very rapid economic growth, a global population that peaks in the mid-century and declines thereafter, and a rapid introduction of new and more efficient technologies with an emphasis on fossil fuel energy sources (IPCC, 2000). The B2 emission (or "best case") scenario describes a world in which the emphasis is on local solutions to economic, social, and environmental sustainability (IPCC, 2000). The A1F1 and B2 scenarios were selected because other carbon emission scenarios can generally be interpolated to have results between the selected scenarios mentioned above. Both emission scenarios use projected time frames of 2020's (2010 – 2039), 2050's (2040 – 2069), and 2080's (2070 – 2099). In addition, both emission scenarios depict the same general trend; however, the intensity or scales of the projected trends differ substantially. Projected climate will be compared against the climate for the period 1961 – 2000 which represents the 'present' climate.

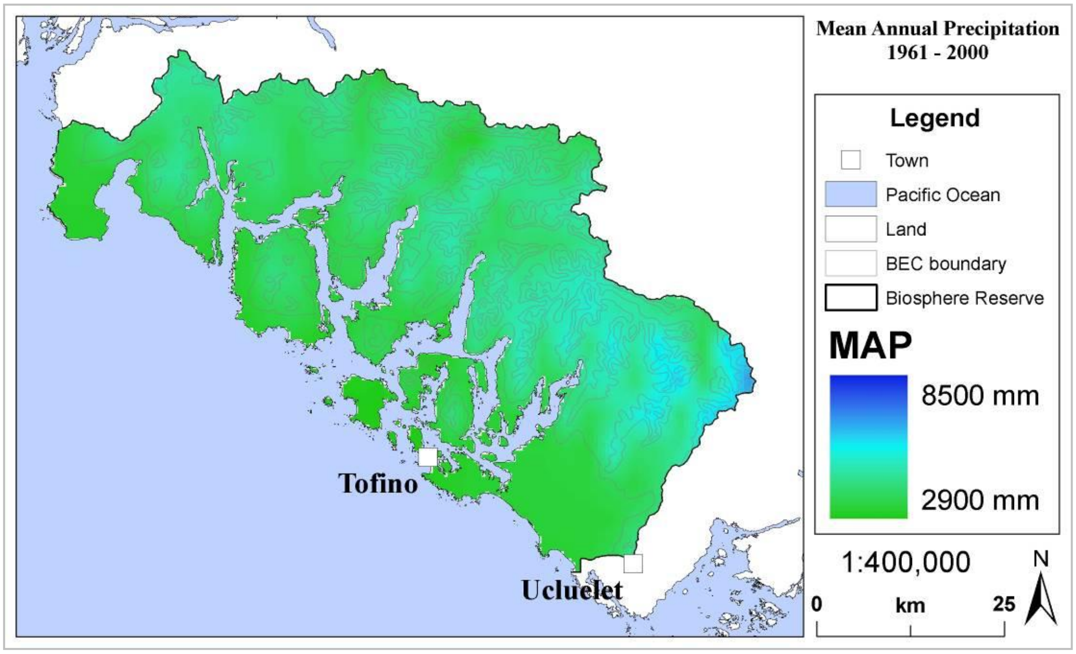
Table 7 - Table showing the climatic variables available from ClimateBC.

Monthly	Seasonal	Annual
January to December mean temperature (°C)	Winter mean temperature (°C) (Dec-Feb)	Mean annual temperature (°C) (MAT)
January to December mean maximum temperature (°C)	Spring mean temperature (°C) (Mar-May)	Mean temperature of the warmest month (°C) (MWMT)
January to December mean maximum temperature (°C)	Summer mean temperature (°C) (June-Aug)	Mean temperature of the coldest month (°C) (MCMT)
January to December mean minimum temperature (°C)	Autumn mean temperature (°C) (Sept-Nov)	Difference between MWMT and MCMT (°C) (DT)
	Winter mean maximum temperature (°C) (Dec-Feb)	Mean annual precipitation (mm) (MAP)
	Summer mean maximum temperature (°C) (June-Aug)	Mean May to September precipitation (mm) (MSP)
	Autumn mean maximum temperature (°C) (Sept-Nov)	Annual heat: moisture index (AH:M) (MAT+10)/(MAP/1000)
	Winter mean minimum temperature (°C) (Dec-Feb)	Summer (May to Sept) heat: moisture index (SH:M) (MWMT)/(MSP/1000)
	Spring mean minimum temperature (°C) (Mar-May)	Extreme min. temperature over 30 years (°C) (EMT)
	Summer mean minimum temperature (°C) (June-Aug)	Precipitation as snow (mm water equivalent) (PAS)
	Autumn mean minimum temperature (°C) (Sept-Nov)	Degree-days below 0°C, (chilling degree-days) (DD < 0)
	Winter precipitation (mm) (Dec-Feb)	Degree-days above 5°C, (growing degree-days) (DD > 5)
	Spring precipitation (mm) (Mar-May)	Day of the year on which DD > 5 reaches 100, date of budburst ($DD5_{100}$)
	Summer precipitation (mm) (June-Aug)	Degree-days below 18°C, (heating degree-days) (DD < 18)
	Autumn precipitation (mm) (Sept-Nov)	Degree-days above 18°C, (cooling degree-days) (DD > 18)
		Number of frost-free days (NFFD)
		Frost-free period (days) (FFP)
		Day of the year on which FFP begins (sFFP)
		Day of the year on which FFP ends (eFFP)

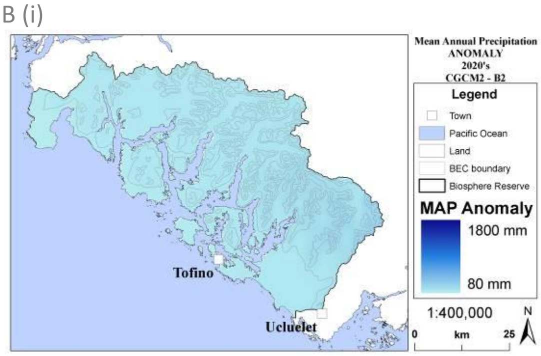
(Spittlehouse, 2006)

Mean Annual Precipitation Anomaly (alternative version of showing MAP)

A.



B (i)



C (i)

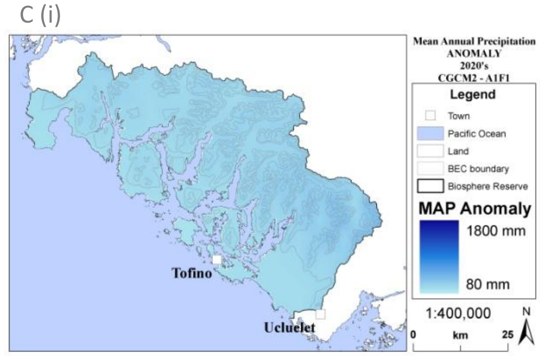


Figure 5. A series of maps showing the mean annual precipitation anomalies projected for the biosphere reserve for the following periods and scenario:

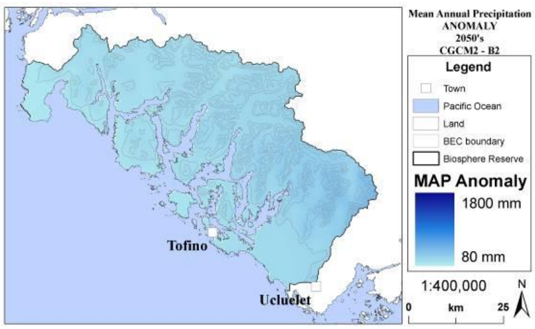
A. 1961 – 2000;

B. B2 carbon emission scenario for (i) 2020's, (ii) 2050's, (iii) 2080's;

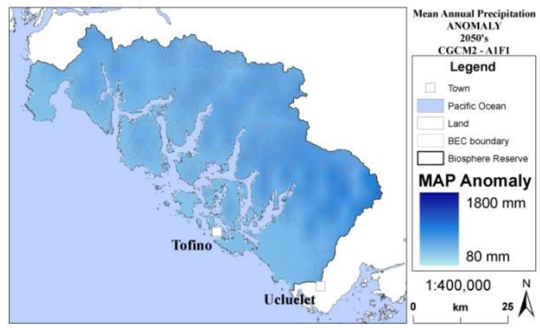
C. A1F1 carbon emission scenario for (i) 2020's, (ii) 2050's, and (iii) 2080's.

Figure 5 is continued on the next page

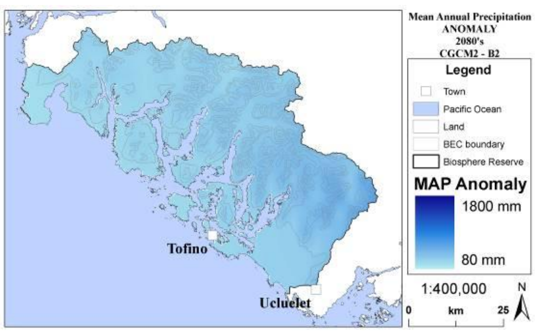
C.(ii)



C.(ii)



C. (iii)



C.(iii)

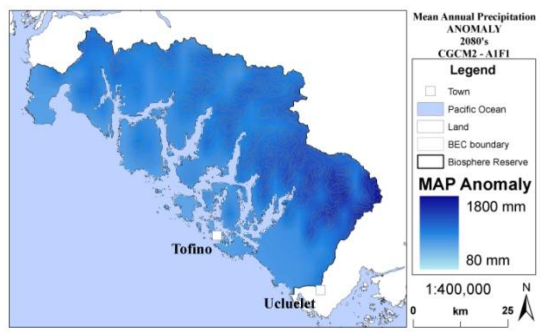


Figure 5. *(continued from previous page)*. **A series of maps showing the mean annual precipitation anomalies projected for the biosphere reserve for the following periods and scenario:**

> **A. 1961 – 2000;**
> **B. B2 carbon emission scenario for (i) 2020's, (ii) 2050's, (iii) 2080's;**
> **C. A1F1 carbon emission scenario for (i) 2020's, (ii) 2050's, and (iii) 2080's.**

Table 8. 19 climatic variables predicted for the biosphere reserve for the 2020's, 2050's, and 2080's for the A1F1 and B2 carbon emission scenarios. Future projections are tabulated against average values from 1961 – 2000 for comparison.

	ELE.	MAT	MWMT	MCMT	TD	MAP	MSP	AHM	SHM	DD<0
1961-2000	430	7.81	15.37	1.69	13.68	4079	712	4.49	21.88	85
A1F1 - 2020	430	8.69	16.19	2.42	13.77	4331	692	4.44	23.71	58
A1F1 - 2050	430	10.13	17.57	3.65	13.92	4660	655	4.45	27.21	31
A1F1 - 2080	430	11.76	19.17	5.07	14.11	5045	610	4.44	31.88	13
B2 – 2020	430	8.63	16.17	2.31	13.86	4223	695	4.54	23.57	62
B2 – 2050	430	9.29	16.81	2.89	13.92	4316	677	4.60	25.18	46
B2 – 2080	430	9.91	17.45	3.38	14.07	4407	662	4.65	26.75	35

Table 8 part 2

	DD>5	DD<18	DD>18	NFFD	BFFP	EFFP	FFP	PAS	DD5_100	EMT
1961-2000	1538	3548	19	271	122	290	167	434	119	-18.0
A1F1 - 2020	1771	3230	35	289	106	299	193	344	104	-16.4
A1F1 - 2050	2207	2718	83	315	73	317	243	231	73	-14.2
A1F1 - 2080	2755	2192	184	338	43	334	291	148	43	-11.8
B2 - 2020	1755	3255	35	288	108	298	190	346	105	-16.6
B2 - 2050	1948	3016	54	300	92	305	212	284	91	-15.6
B2 - 2080	2140	2796	78	310	79	312	233	237	78	-14.7

Table 9 - 19 climatic variables predicted for the BEC regions in the biosphere reserve for the 2020's, 2050's, and 2080's for the A1F1 and B2 carbon emission scenarios. Future predictions are tabulated against average values from 1961 – 2000 for comparison.

		ELE.	MAT	MWMT	MCMT	TD	MAP	MSP	AHM	SHM	DD<0	DD>5	DD<18	DD>18	NFFD	BFFP	EFFP	FFP	PAS	DD5_100	EMT
1961-2000	CMAunp	1404	4.24	13.86	-3.14	17.00	4448	747	3.23	18.81	444	968	4833	3	178	165	258	93	1575	157	-28.2
	CWHmm2	908	6.01	15.46	-1.19	16.65	3842	600	4.17	25.76	236	1277	4189	12	224	143	274	130	820	141	-23.2
	CWHvh1	42	9.15	15.23	4.16	11.07	3393	619	5.67	24.70	9	1730	3068	17	318	96	310	213	119	98	-13.0
	CWHvm1	334	8.15	15.77	1.91	13.85	4155	725	4.42	21.88	53	1609	3425	26	277	122	290	168	320	118	-17.3
	CWHvm2	763	6.70	15.13	-0.05	15.18	4540	772	3.72	19.77	135	1353	3948	14	235	139	276	136	682	133	-21.7
	MHmm1	1082	5.49	14.56	-1.62	16.18	4577	774	3.43	19.05	273	1160	4380	7	204	152	266	114	1110	146	-25.0
A1F1 2020	CMAunp	1404	5.13	14.68	-2.40	17.08	4730	726	3.23	20.50	346	1128	4513	7	196	157	266	108	1374	150	-26.6
	CWHmm2	908	6.92	16.26	-0.46	16.72	4099	585	4.12	27.84	169	1458	3869	24	244	137	281	144	664	133	-21.7
	CWHvh1	42	10.03	16.06	4.89	11.17	3594	602	5.60	26.76	2	2028	2751	32	334	61	322	261	92	73	-11.5
	CWHvm1	334	9.04	16.60	2.65	13.95	4411	705	4.37	23.69	37	1837	3107	46	297	111	299	189	246	104	-15.8
	CWHvm2	763	7.58	15.96	0.68	15.27	4825	750	3.69	21.44	90	1549	3629	26	255	132	284	151	535	124	-20.1
	MHmm1	1082	6.38	15.39	-0.88	16.27	4866	752	3.41	20.71	199	1337	4061	15	224	145	274	129	911	137	-23.4
A1F1 2050	CMAunp	1404	6.57	16.03	-1.18	17.22	5104	687	3.28	23.65	224	1420	3993	22	225	144	275	131	1015	134	-24.2
	CWHmm2	908	8.34	17.62	0.77	16.85	4440	555	4.13	31.76	73	1789	3349	60	274	123	292	169	449	118	-19.4
	CWHvh1	42	11.46	17.45	6.12	11.33	3855	569	5.60	30.79	0	2572	2235	77	352	11	354	343	64	25	-9.5
	CWHvm1	334	10.47	17.98	3.88	14.11	4747	667	4.37	27.13	16	2273	2601	105	323	76	314	237	161	75	-13.5
	CWHvm2	763	9.03	17.32	1.91	15.41	5201	710	3.70	24.59	51	1906	3110	65	286	116	295	179	352	102	-17.7
	MHmm1	1082	7.82	16.74	0.34	16.40	5247	712	3.44	23.80	107	1661	3541	41	254	131	284	153	625	120	-21.0
A1F1 2080	CMAunp	1404	8.21	17.61	0.22	17.39	5543	642	3.32	27.83	115	1802	3405	64	259	127	286	158	678	112	-21.6
	CWHmm2	908	10.00	19.19	2.17	17.03	4840	520	4.12	36.92	46	2230	2809	147	305	94	305	211	282	86	-16.9
	CWHvh1	42	13.09	19.06	7.55	11.51	4158	528	5.58	36.21	0	3204	1709	179	365	0	365	365	45	0	-7.4
	CWHvm1	334	12.10	19.59	5.29	14.30	5140	622	4.35	31.73	3	2839	2095	221	345	33	337	304	104	40	-11.1
	CWHvm2	763	10.66	18.91	3.32	15.59	5640	663	3.71	28.77	24	2381	2568	155	316	80	308	228	220	74	-15.1
	MHmm1	1082	9.46	18.33	1.75	16.58	5695	664	3.46	27.92	55	2084	2968	107	288	111	296	185	396	92	-18.4

Table 9 - part 2

		ELE.	MAT	MWMT	MCMT	TD	MAP	MSP	AHM	SHM	DD<0	DD>5	DD<18	DD>18	NFFD	BFFP	EFFP	FFP	PAS	DD5_100	EMT
B2 2020	CMAunp	1404	5.06	14.65	-2.53	17.18	4607	729	3.30	20.39	356	1121	4538	7	194	158	266	107	1371	151	-26.8
	CWHmm2	908	6.84	16.26	-0.58	16.82	3983	587	4.22	27.68	175	1448	3893	24	241	138	280	143	665	134	-21.9
	CWHvh1	42	9.96	16.04	4.78	11.26	3510	605	5.71	26.61	2	2004	2776	31	332	65	320	255	93	75	-11.7
	CWHvm1	334	8.97	16.57	2.53	14.04	4300	708	4.46	23.55	39	1822	3132	45	295	112	298	186	248	105	-16.0
	CWHvm2	763	7.52	15.93	0.56	15.37	4704	753	3.77	21.32	95	1538	3653	26	253	133	283	150	538	125	-20.3
	MHmm1	1082	6.31	15.36	-1.00	16.36	4742	755	3.48	20.59	207	1328	4085	15	222	146	274	128	914	138	-23.6
B2 2050	CMAunp	1404	5.73	15.30	-1.96	17.26	4711	710	3.37	21.84	293	1251	4296	13	207	152	270	118	1186	144	-25.7
	CWHmm2	908	7.53	16.90	-0.01	16.92	4075	574	4.31	29.47	112	1601	3651	38	255	132	285	153	548	126	-20.8
	CWHvh1	42	10.62	16.67	5.36	11.31	3585	588	5.78	28.45	0	2248	2538	49	342	34	332	298	77	54	-10.7
	CWHvm1	334	9.63	17.22	3.11	14.10	4393	690	4.52	25.13	28	2013	2893	69	307	99	303	205	200	92	-14.9
	CWHvm2	763	8.18	16.58	1.14	15.44	4811	734	3.83	22.76	71	1696	3412	41	267	126	287	161	438	117	-19.2
	MHmm1	1082	6.99	16.00	-0.43	16.44	4850	736	3.55	22.01	158	1474	3844	25	235	140	278	138	760	130	-22.5
B2 2080	CMAunp	1404	6.36	15.94	-1.47	17.42	4814	695	3.43	23.26	243	1382	4070	21	219	147	274	127	1026	137	-24.7
	CWHmm2	908	8.14	17.55	0.47	17.07	4166	562	4.36	31.20	84	1747	3425	58	268	126	289	163	457	120	-20.0
	CWHvh1	42	11.24	17.31	5.86	11.45	3658	574	5.83	30.26	0	2484	2317	72	349	16	346	330	66	33	-9.9
	CWHvm1	334	10.25	17.86	3.61	14.25	4485	674	4.57	26.67	20	2204	2678	99	318	82	309	226	166	79	-14.0
	CWHvm2	763	8.81	17.22	1.62	15.59	4916	718	3.87	24.18	58	1856	3189	62	280	119	292	173	363	106	-18.2
	MHmm1	1082	7.61	16.65	0.05	16.59	4957	720	3.60	23.41	122	1619	3619	39	248	134	282	148	639	123	-21.5

Table 10 - Seasonal climatic variables projected for winter(wt), spring(sp), summer(sm), and autumn(at). Variables are projected for the biosphere reserve for the 2020's, 2050's, and 2080's for the A1F1 and B2 carbon emission scenarios. Future predictions are tabulated against average values from 1961 – 2000 for comparison.

	Average Temperature (◦C)				Maximum Temperature (◦C)				Minimum Temperature (◦C)				Average Precipitation (mm)			
	wt	sp	sm	at	wt	sp	sm	at	wt	sp	sm	at	wt	sp	sm	at
1961-2000	1.94	6.74	14.22	8.35	4.71	11.14	19.20	12.25	-0.83	2.34	9.24	4.46	1601	898	352	1228
A1F1 - 2020	2.81	7.65	15.10	9.22	5.56	12.06	20.13	13.05	0.06	3.24	10.06	5.39	1783	901	339	1308
A1F1 - 2050	4.19	9.24	16.53	10.57	7.02	13.70	21.66	14.41	1.35	4.79	11.40	6.73	2051	891	330	1388
A1F1 - 2080	5.77	11.03	18.17	12.06	8.69	15.55	23.41	15.91	2.84	6.52	12.94	8.21	2365	882	319	1479
B2 - 2020	2.73	7.58	15.05	9.15	5.48	12.00	20.11	12.96	-0.02	3.15	9.98	5.33	1726	923	337	1237
B2 - 2050	3.39	8.32	15.72	9.73	6.18	12.78	20.84	13.54	0.61	3.87	10.60	5.92	1823	931	330	1231
B2 - 2080	3.99	9.00	16.35	10.30	6.82	13.50	21.52	14.10	1.15	4.51	11.18	6.50	1915	942	325	1225

Table 11 - Seasonal climatic variables projected for winter(wt), spring(sp), summer(sm), and autumn(at). Variables are projected for each BEC region in the biosphere reserve for the 2020's, 2050's, and 2080's for the A1F1 and B2 carbon emission scenarios. Future predictions are tabulated against average values from 1961 – 2000 for comparison.

		Average Temperature (◦C)				Maximum Temperature (◦C)				Minimum Temperature (◦C)				Average Precipitation (mm)			
		wt	sp	sm	at	wt	sp	sm	at	wt	sp	sm	at	wt	sp	sm	at
1961-2000	CMAunp	-3.10	3.09	12.09	4.88	-0.20	7.95	17.81	8.88	-5.99	-1.77	6.36	0.89	1760	958	358	1370
	CWHmm2	-1.11	4.78	13.72	6.71	1.33	9.19	18.97	10.35	-3.56	0.37	8.46	3.07	1572	759	277	1233
	CWHvh1	4.45	8.06	14.32	9.77	7.19	11.79	18.31	13.35	1.71	4.34	10.32	6.18	1305	772	309	1006
	CWHvm1	2.20	7.11	14.67	8.64	4.92	11.61	19.81	12.61	-0.53	2.60	9.53	4.67	1632	909	359	1253
	CWHvm2	0.16	5.61	13.80	7.23	3.00	10.38	19.31	11.28	-2.68	0.84	8.29	3.17	1801	987	379	1372
	MHmm1	-1.48	4.37	13.02	6.08	1.41	9.25	18.69	10.13	-4.37	-0.51	7.35	2.04	1814	993	376	1393
A1F1 2020	CMAunp	-2.23	4.03	12.96	5.74	0.66	8.93	18.75	9.67	-5.12	-0.87	7.17	1.81	1961	962	344	1463
	CWHmm2	-0.24	5.73	14.59	7.57	2.21	10.19	19.92	11.15	-2.69	1.28	9.27	3.99	1753	763	265	1318
	CWHvh1	5.32	8.96	15.19	10.64	8.03	12.69	19.23	14.16	2.60	5.24	11.15	7.12	1453	774	298	1070
	CWHvm1	3.06	8.02	15.55	9.51	5.76	12.53	20.74	13.41	0.36	3.51	10.37	5.61	1819	912	346	1334
	CWHvm2	1.03	6.54	14.68	8.09	3.86	11.33	20.24	12.08	-1.81	1.75	9.11	4.10	2004	992	365	1464
	MHmm1	-0.61	5.30	13.89	6.94	2.28	10.21	19.63	10.93	-3.49	0.39	8.16	2.96	2020	998	362	1487
A1F1 2050	CMAunp	-0.84	5.64	14.39	7.09	2.15	10.61	20.29	11.03	-3.84	0.67	8.49	3.14	2256	956	336	1556
	CWHmm2	1.14	7.36	16.01	8.91	3.70	11.90	21.46	12.50	-1.42	2.82	10.57	5.32	2018	760	259	1403
	CWHvh1	6.69	10.55	16.63	11.99	9.48	14.31	20.76	15.52	3.90	6.78	12.50	8.46	1670	762	290	1133
	CWHvm1	4.44	9.60	16.99	10.85	7.22	14.16	22.27	14.76	1.66	5.05	11.71	6.94	2094	902	337	1413
	CWHvm2	2.41	8.14	16.11	9.44	5.34	13.00	21.78	13.44	-0.52	3.29	10.43	5.43	2305	984	356	1556
	MHmm1	0.78	6.91	15.32	8.29	3.76	11.89	21.17	12.28	-2.21	1.94	9.48	4.29	2323	991	352	1581
A1F1 2080	CMAunp	0.74	7.47	16.03	8.58	3.86	12.53	22.05	12.54	-2.37	2.41	10.00	4.62	2602	951	325	1665
	CWHmm2	2.73	9.20	17.65	10.41	5.42	13.84	23.22	14.02	0.05	4.56	12.07	6.79	2328	758	250	1504
	CWHvh1	8.26	12.32	18.28	13.49	11.14	16.12	22.52	17.02	5.38	8.52	14.05	9.95	1925	750	280	1204
	CWHvm1	6.02	11.39	18.64	12.35	8.88	15.99	24.02	16.27	3.15	6.78	13.25	8.43	2416	892	325	1506
	CWHvm2	3.99	9.95	17.75	10.93	7.03	14.88	23.54	14.95	0.95	5.03	11.95	6.92	2657	976	344	1663
	MHmm1	2.36	8.73	16.96	9.78	5.46	13.79	22.93	13.79	-0.74	3.68	10.99	5.77	2678	984	341	1691

Table 11 - continued

		Average Temperature (◦C)				Maximum Temperature (◦C)				Minimum Temperature (◦C)				Average Precipitation (mm)			
		wt	sp	sm	at	wt	sp	sm	at	wt	sp	sm	at	wt	sp	sm	at
B2 2020	CMAunp	-2.30	3.95	12.92	5.66	0.59	8.87	18.75	9.58	-5.19	-0.97	7.09	1.74	1899	985	343	1382
	CWHmm2	-0.32	5.66	14.55	7.49	2.13	10.13	19.92	11.05	-2.77	1.18	9.19	3.92	1695	779	264	1244
	CWHvh1	5.24	8.89	15.14	10.57	7.95	12.62	19.21	14.08	2.52	5.15	11.07	7.07	1407	794	297	1013
	CWHvm1	2.99	7.94	15.50	9.44	5.69	12.47	20.73	13.33	0.29	3.42	10.28	5.55	1760	934	345	1261
	CWHvm2	0.95	6.46	14.63	8.02	3.79	11.27	20.24	11.99	-1.88	1.65	9.03	4.04	1942	1015	363	1383
	MHmm1	-0.68	5.23	13.85	6.86	2.20	10.15	19.62	10.83	-3.57	0.30	8.08	2.90	1957	1021	360	1404
B2 2050	CMAunp	-1.63	4.71	13.60	6.24	1.31	9.68	19.49	10.16	-4.57	-0.25	7.70	2.33	2004	995	335	1377
	CWHmm2	0.36	6.42	15.23	8.07	2.86	10.95	20.66	11.63	-2.14	1.89	9.79	4.51	1788	788	258	1240
	CWHvh1	5.89	9.63	15.81	11.15	8.64	13.39	19.94	14.65	3.14	5.87	11.68	7.65	1487	799	290	1008
	CWHvm1	3.64	8.69	16.18	10.02	6.38	13.24	21.45	13.91	0.91	4.13	10.90	6.14	1858	943	337	1255
	CWHvm2	1.62	7.22	15.30	8.60	4.50	12.07	20.97	12.57	-1.26	2.37	9.64	4.62	2051	1026	356	1379
	MHmm1	-0.01	5.99	14.52	7.45	2.92	10.96	20.36	11.41	-2.94	1.01	8.68	3.48	2066	1032	352	1400
B2 2080	CMAunp	-1.03	5.41	14.23	6.81	1.97	10.43	20.19	10.72	-4.03	0.39	8.28	2.90	2105	1007	330	1372
	CWHmm2	0.97	7.12	15.87	8.63	3.53	11.71	21.37	12.19	-1.60	2.52	10.37	5.08	1878	798	254	1236
	CWHvh1	6.48	10.30	16.44	11.73	9.27	14.09	20.61	15.22	3.69	6.51	12.27	8.24	1562	808	286	1002
	CWHvm1	4.24	9.37	16.81	10.59	7.02	13.96	22.13	14.47	1.46	4.78	11.48	6.72	1952	954	332	1247
	CWHvm2	2.22	7.91	15.94	9.16	5.15	12.80	21.66	13.13	-0.71	3.01	10.22	5.20	2155	1039	350	1373
	MHmm1	0.59	6.68	15.16	8.01	3.57	11.70	21.06	11.97	-2.40	1.66	9.26	4.06	2170	1045	347	1395

Chapter 4

Potential Ecological Impacts of Climate Change in the Clayoquot Sound: A Resilience Assessment

contents

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Resilience: a way of thinking

In nature, nothing is static. Understanding and managing natural systems is often complicated by this natural variability. Ideas of 'resilience' provide a way of thinking about ecological and social systems that fundamentally acknowledges that nothing in nature is static, but that for humans and other species, a resilient system can bounce back after it is pressured, and also can change and continue to function. In the context of climate change, because we know ecosystems are likely to change much faster than they have in the past, resilience also includes ideas about predicting and then managing, as best as possible, those changes that are coming, whether or not we like them.

This work takes a resilience approach in considering which pieces of ecosystems may change most and how they will affect other key components in the system. This work is the underpinning for reducing community vulnerabilities to the changes that will occur.

Species: coming and going

Climate change will act directly on species – which will be already adapted to the future climate, will adapt in place, will go extinct, or move somewhere else. A key question then is how will ecological communities change as individual species leave or are added to the diversity. Ecological theory predicts that natural communities with more species (higher diversity) tend to be more resilient because more than one species play similar functional roles – providing redundancy in the system. However, loss of either a larger number of species or those that play key roles (e.g. base prey, or top predators) can cause significant cascading ecological shifts. Losing species has been suggested as analagous to losing rivets from an airplane wing – losing one rivet may not be important, but losing key rivets or a large number of rivets has more serious consequences.

Naturally, over very long time periods, ecological communities rearrange themselves and species are lost and gained; the difference in this current climate change scenario is the rate and scope of the changes predicted. It is possible that as some current species in Clayoquot Sound will be lost and that others may take their place – or may fill the same niche. It is also important to consider that we are not predicting a shift in climate to a new stable state in the near future but instead a continuous shift climate over the multiple centuries. As a result, we cannot expect stable ecological communities for the foreseeable future.

The vulnerability of the ecological system to climate change depends upon the level of the exposure to climate change and ultimately upon the resilience of the ecosystem to the changes, such that it can evolve into a new form which is better suited to the new conditions[47]. What is needed for this project is to determine the measure of predicted changes and whether these changes will push individual ecosystems past thresholds,

[47] IPCC 2007, Utzig and Holt 2009

and if so consider what the new state will be like and what the result will be for the communities that have relied upon the ecosystems. Adaptive capacity of humans to respond to these changes is addressed in Section 7.

The following sections take each of three realms – and attempt to identify some of most important direct and indirect effects of climate change.

Terrestrial Forest Ecosystems

The First Nation communities within Clayoquot Sound have lived for thousands of years in a forested landscape from which they have gathered food and harvested building materials creating a society rich in culture. Although many aspects of First Nation life have changed recently, this connection to the forest still exists, but impending impacts caused by climate change have the potential to increase still further these changes.

Although climate change impacts can be observed at the local level, climate is by its nature something that acts at a bioregional scale and this assessment of the forest ecosystems of Clayoquot Sound is being considered in this context. At the sub-regional scale, Clayoquot Sound lies in the Windward Island Ecosystem of the Western Vancouver Island Ecoregion, an area with extreme maritime influence upon the weather, ecology and social adaptation. The Biogeoclimatic Ecosystem Classification (BEC) defines areas of similar climate based on vegetation, soils and topography, and this system will form the basis for the specific impact assessments for forested ecosystems in Clayoquot Sound.

The BEC system enables natural resource practitioners to understand the climax vegetation complexes which will be expressed over time in a given location based upon the interaction of the natural elements with the ecosystem. In this way, much of the coastal maritime area of BC is defined as the Coastal Western Hemlock (CWH) zone, where broadly speaking the climax forest is dominated by *Tsuga heterophylla.* Within this zone there are many sub-zones that express themselves differently based on temperature, moisture and nutrient regimes. In Clayoquot Sound the dominant subzones are the *hypermaritime* (CWH vh) and the *very wet maritime* (CWH vm).

The Campbell River Forest District, which is immediately north of Clayoquot, carried out a climate change mapping project in 2008 in which they carried out a similar process to determine BGC sub-zone changes[48]. The following summary of potential changes is based upon this work and interpreted for the specific location of Clayoquot (current conditions vary slightly warmer).

[48] CRFD, MoF 2008

Potential Climate Impacts

• Forest types

The terrestrial ecosystems of Clayoquot Sound are categorized into five subzones – Coastal Mountain Heather Alpine (CMAunp), Mountain Hemlock (MHmm1) and three variants of the Coastal Western Hemlock (CWHvh1, vm1 and vm2).

CWH vh1

The hypermaritime sub-zone located on the extreme outer coast and on the islands in the Sound, is predicted to be warmer and wetter into the future, with a large reduction in snow and an increase in frost free days. Ultimately this area is projected to become warmer and wetter than any climate currently found in BC and as such the future is not clearly understood (the closest similar climate currently is in south coastal Oregon but they have a different topography). Under the optimistic B1 scenario at 2050 approximately 90% by area of the sub-zone will remain within the range of climate variables but under the A1F1 scenario 50% of the area will have already moved into the warmer and hotter climate envelope.

The combination of increasing warmth and rainfall will create a variety of different growing conditions for the forest to adjust to. Very old stands, which dominate in Clayoquot, are likely to undergo increased mortality due to elevated rates of pathogen attack and increased storm events leading to wind throw and stem breakage. This may result in increased amounts of regeneration in the understory and better growing conditions as light levels and humus decomposition increase. For mid-aged stands the conditions are likely to result in increased growth rates with longer growing seasons and warmer temperatures. For young stands of trees the conditions should result in higher growing potential for western hemlock and western red cedar and this should not cause any major concerns. The other two species in the region, Sitka spruce and amabalis fir, would also benefit physiologically but it is likely that insects and disease will also increase with increasing temperatures - and these species tend to be more prone to this kind of issue.

In addition, in areas where growth is already restricted by excessive moisture, on flat, wet sites, sites will become wetter still and bog formation is expected to expand – restricting tree growth in these areas such as around Hesquiaht Harbour and on Flores Island.

Overall for the CWHvh1 the estimated ecological sensitivity is low, except for in wet areas, and the long term prognosis for the forest overstory to adapt is relatively good. The effect on understory species is unknown, and will depend on a species-by-species basis whether tolerances are exceeded, or whether new species move in that are better adapted and compete successfully with existing species.

CWHvm1

This sub-zone forms the majority of the land base in Clayoquot and is the most important for timber harvesting. Over the course of the period up to 2050 the climate will remain within the range of the CWHvm1 although trending to the warmer end, but beyond that and by 2080 summer temperatures will be higher than any experienced in coastal BC and once again the conditions will be unique with no existing forest zone with similar conditions. Snowpack might have shrunk by almost 70% and the frost free period increased by 80% but the similar rain pattern will likely prevent the system moving to any of the drier maritime sub-zones as seen elsewhere on the south coast. The total area of this subzone will likely increase as it ascends upslope into what is currently CWHvm2, but it will be warmer and wetter than previously.

Overall the impacts to the forest will be similar to that seen in the hypermaritime. The very old forests will likely see increased mortality from an increase in disease, insects and possibly windthrow if storms increase, followed by increased regeneration in the understory due to higher decomposition rates. The overall structure of the old forest however should remain relatively similar into the future.

In younger forests (early and mid seral), all species should increase their growth performance and the warmer temperatures again should increase rates of humus decomposition which could result in further productivity of the ecosystem. The warmer and wetter conditions should also favour red alder, and any increase in site disturbance may see an increase in this species over the period. Young and regenerating stands are very likely to increase growth with improved growing conditions, although this will depend on there not being an increase in small-scale disturbance agents such as insects and disease. As with the CWHvh1, flat low lying areas will likely see an increase in bog formation and a shift in the vegetation complexes they support as additional moisture stress occurs.

Overall the predicted sensitivity for the CWHvm1 is relatively low, except in wet areas, and again the long term prognosis for the existing forest to adapt to the changes is good.

CWHvm2

This is the montane variant, found above the CWHvm1 and is cooler and has more snowpack today than lower elevation zones. The general trend for this variant is to see a replacement by the vm1 conditions and the movement upslope into what is currently the Mountain Hemlock zone. The vm2 is characterized by more yellow cedar and amabalis fir than in the vm1 and the occurrence of mountain hemlock. As climate shifts, conditions will likely improve for red cedar, amabalis fir and western hemlock while yellow cedar will be at a competitive disadvantage and mountain hemlock is expected to disappear from the regeneration layer. It is estimated that by 2050, 60% of this sub-zone will be classified now as vm1 and by 2080 the majority will be replaced at this elevation range.

However, overall the sensitivity remains relatively low, except for very wet areas, even though increased mortality in the old stands will accelerate. The forest species are expected to shift over time but the natural resilience of the species present is likely to mean the forest will retain its essential structure and processes into the future.

MHmm1

The mountain hemlock zone is the highest elevation of closed canopy forest on the coast. It is characterized by cold and snowy winters where mountain hemlock, yellow cedar and amabalis fir dominate. This zone is going to experience more change than any other in the region, over the course of the next 70 years it is expected to virtually disappear as conditions warm up and snow pack drops considerably by up to 40% over a shorter winter season. With a longer frost free and growing season conditions will begin to favour western red cedar and western hemlock, and yellow cedar and mountain hemlock will gradually disappear from the forest. Increased mortality in the mature forest will be especially noticeable in the mountain hemlock zone and may increase the rate of change in this zone. At the same time, increased gaps in the forest will provide better growing conditions for regeneration and as time passes western hemlock and red cedar will gradually come to dominate these patches.

For the MHmm1 the overall estimated ecological sensitivity is high, since this system and its associated tree species is expected to largely disappear. However, resilience here should be relatively high as lower elevation tree species move into this zone as conditions warm. Although individual tree species will change, the dynamics of the system are expected to remain relatively similar – though disturbance rates may increase they are likely to remain operational at relatively small scales. Other functions of this zone (e.g. maintaining hydrology) should also therefore remain relatively stable into the future.

- ## Landslides and windthrow

If rainfall and storms increase into the future, both landslides and windthrow may increase in the region. Two of the most significant potential impacts from these events include: a) a positive effect upon regeneration rates, by increasing disturbance and allowing young trees more sunlight and better growing mediums, with the result that the forest may respond more quickly into the future; and b) increased disturbance rates may have a negative impact upon streams and rivers as material is deposited into the channels adding to sediment loads and negatively impacting spawning beds for salmon.

• Summary

Climate change is going to bring a considerable warming trend with increased rain from autumn through to spring. There will be a gradual shift of BGC subzones across elevation bands as the more productive sub montane and montane types move up the mountainsides and the region is likely to lose virtually all the Mountain Hemlock zone. The general trend for climate change impacts to subzones in the Clayoquot Region are as follows:

CMA → MHmm1 → CWHvm2 → CWHvm1 → CWH vm1-warm → CWHvm1-hot → CWHvh1 → CWHvh1-warm → CWHvh1-hot.

The qualifiers "warm" and "hot" are the unique conditions that have never yet been experienced in BC and which will gradually develop over the next 70 years. The increase in rainfall over the period, even though it is coupled with a decrease during the growing season, suggest that thresholds leading to major shifts in ecosystem are unlikely to be exceeded in the near term, and the forests in the region will predominantly remain similar in structure, dynamics, and species composition (for now), with an increase in western red cedar and red alder and a decrease in yellow cedar and mountain hemlock. Note that this analysis did not examine specific understory species – we expect these species to be buffered to some degree by the microclimate of the forest itself, but over time we expect species shifts in the understory, and in the longer term the overstory - to occur to match the considerably warmer wetter conditions that do not exist anywhere in North America today.

Below is a summary of terrestrial impacts discussed above, their timelines for beginning and their likelihood of occurring.

Table 1: Summary of Terrestrial Impacts of Climate Change in the Clayoquot Sound

Impact	Timeline*	Likelihood**
↓montane & alpine forests & understory	Long-term	Very Likely
↑red cedar/western hemlock forests & understory		
↑Mortality of old Forests		
↑Growth of young forests		
↑Landslides	Mid-term***	Likely
↑Windthrow		
↑Pest & disease		
↑Soil Erosion		

* Terms = Short-term (0-10 years), Medium-term (11-30 years), Long-term (31+ years)
** Very Likely, Likely, More Likely Than Not, Unlikely, Very Unlikely
*** Short-term for deforested slopes

The relative stability of forest dynamics here is not a pattern predicted for much of BC, and even the east coast of Vancouver Island where major changes from wet to dry and moist to very dry will occur resulting in more extreme changes in the forest.

For the forests of Clayoquot Sound this means there is a relatively low level of vulnerability in terms of the benefits that the communities rely upon directly from the forest itself, though with likely longer term effects on the understory species composition through time. Related to forested habitats however, maintaining salmon habitat in the streams and rivers of the region may be an issue into the future (see freshwater aquatic section below). Management regimes are in place that should moderate or prevent potential damage, but this should be monitored and adaption's prescribed if necessary.

Freshwater aquatic ecosystem

Hydrologic Processes

Among the many hydrologic changes that will accompany future climates, changes in three processes and/or metrics will be of particular importance: 1) a decline in snowpacks due to an overall increase in temperature (particularly in the spring and at night), 2) an increase in winter (and fall) precipitation partially at the expense of summer (and spring) precipitation, and 3) an increase in the intensity of winter rainfalls.

- ### Snowpack decline

It is well documented that western North America's snowpacks are in long-term decline[49]. These changes are documented all over British Columbia – see Table 1. The same pressures creating this decline are present in the Clayoquot Sound area. Increased temperatures in all seasons (see Section 4) will result in snow becoming viable at only higher elevations than has been the norm. The downward pressures on snowpack viability grow stronger with every year of warming. In addition, given that spring temperatures (and, in particular, springtime minimum temperatures) are projected to rise more than the other seasonal temperatures, it is expected that the snowpack that does set up over the winter, will decline earlier in the spring. Changes in temperature extremes generally follow changes in mean temperatures[50] and as a result, we further expect to see less extreme cold temperatures and, by inference, higher extreme winter temperatures that will further limit snowpack longevity.

The drainages in the Clayoquot Sound area have different amounts of high elevation terrain. Some drainages are relatively low in elevation and as a result, because snowpack development is currently not a significant factor, the loss of snow effect is largely unimportant. It is generally the larger drainages, the ones that extend well into the Vancouver Island Ranges, where snowpacks are currently significant and where important hydrologic changes related to snow will come about. Drainages intermediate in elevation will be the first to experience significant losses in their snowpacks.

- ### Increased winter precipitation

The hydrologic behaviour of the Clayoquot Sound region is highly coupled to weather, and in particular to winter rains. The scope of change associated with winter precipitation is large (see Section 4) and as a result, this effect is expected to be central to future hydrologic behaviour of Clayoquot Sound. Rain and snowfall increase will take place via a greater annual number of winter storm events and a greater frequency of high-volume precipitation associated with individual events. Whether the increased

[49] Mote 2004; Mote et al 2005
[50] Kharin *et al.* 2007 in Pike *et al.* 2010

precipitation arrives as rain or snow will depend partially on the degree of warming that has occurred. It may be that, on average, the increases in precipitation will be matched by increases in air temperature so that, overall, the increased precipitation is largely rainfall. However, the level of uncertainty around these factors is very high.

Table 2: Average change in snow water equivalent for major river basins in B.C., 1956–2005. Data from River Forecast Centre, B.C. Ministry of Environment 2007.

Basin Name	Change in snow water equivalent (%)
Upper Fraser, Thompson, Columbia, Kootenay,	–20 to -23
Nechako	–2
Middle Fraser	–47
Kettle	–32
Okanagan	–14
Similkameen	–19
South Coast/ Vancouver Isl.	**–17**
Skagit	–39
Peace	–7
Skeena	+4
Yukon/Liard	+23

- ### Increased rainfall intensity

As rainfall volume increases, so does rainfall intensity –the rate of rain falling over short periods of minutes to a few hours. In November 2006, two high-intensity rainfall events took place on the west coast of Vancouver Island, illustrating the types of frontal systems expected to more frequently occur in the Clayoquot Sound area under future climates. These are sometimes called “pineapple express” events because they are associated with warm tropical moisture-laden air moving poleward to deliver unusually high amounts of precipitation over short periods. Chapman (2006) provides an unpublished analysis of these two events (Nov 5/6, Nov 14/15). He determined 6-hour and 12-hour rainfall intensities exceeding the 50-year return period in the mountains draining into Clayoquot Sound. In addition, more extreme rainfall (exceeding 100 year return period) occurred just to the south of the Clayoquot Sound area, and including Alberni Inlet. The 100-year return period is equivalent to 135 mm in 6 hours, 217 mm in 12 hours, and 260 mm in 24 hours.

Hydrologic systems – potential impacts

The changes described above collectively translate into a new hydrologic future for the study area. Significant hydrologic adjustments are described here in terms of five general outcomes: 1) spring freshet timing, 2) winter flooding, 3) low flows, 4) slope stability, and 5) aquifer levels.

- ### Earlier spring freshet

Across British Columbia and the Pacific Northwest, the spring freshet is arriving earlier in snow-dominated watersheds[51]. Figure 1 shows the trend for the Fraser River at Hope. Of course, only some of the watersheds in Clayoquot Sound have a springtime freshet because not all of the drainages have a winter snowpack. The implications of this earlier melt for the size of the freshet flood are complex. In years where snowpacks continue to be significant through to the spring, then the earlier melt may lead to larger freshet flood peaks as similar water volumes are discharged in shorter periods. However, in future years, it is expected that snowpacks will decline so that in the spring, there is simply insufficient snow available to be melted to yield high spring flood peaks relative to the former hydrologic regime. As a result, it is possible that in the coming decade or so, spring freshet floods (where they occur) may be earlier – *and larger* - than experienced in the former hydrologic regime but that in subsequent decades, ie, once temperatures have climbed significantly more, that the spring floods will be earlier but smaller in size, eventually to the point of being relatively insignificant in many drainages. Hydrologic modeling would be required to be more specific in the relative timing of these changes.

[51] Dery *et al.* 2009, Stewart *et al.* 2005

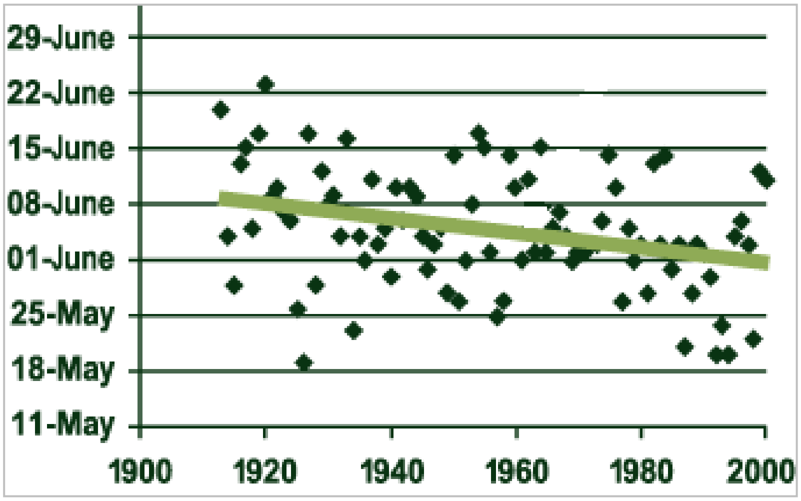

Figure 1. Calendar date (1913-1998) when one third of the Fraser River's annual flow has been discharged (analysis by the Canadian Institute for Climate Studies, 2001).

- ### Slope stability

Higher volumes of rainfall arriving in higher intensities will lead to an increase in the frequency of slope failures in steep terrain and a subsequent decline in water quality and channel stability. Guthrie *et al.* (2010) analyse the landslide patterns associated with the November 2006 frontal precipitation events described above. Based on mapping of 626 landslides, they examined relationships between rainfall intensity, air temperature, and wind speed relative to landslide incidence. They found a critical threshold of rainfall intensity between 80-100 mm in 24 hours results in a rapid increase in landslides with increasing precipitation. It was also discovered that wind was also associated with the increased occurrences of landslides and that rain on snow played an important role. This case study highlights that increases in rainfall volume and intensity will push hillslopes across stability thresholds resulting in a high likelihood of significant increases in sedimentation.

- ### Winter flooding

A direct consequence of increased frequency of winter rainfall will be an increase in flood frequency. The higher volume and intensity of rainfall, coupled with a warmer wetter snowpack, will together yield yet higher runoff and larger downstream floods as the air temperatures climb in the coming decades. These events will likely accompany a greater degree of sedimentation and hence aggradation (build up of sediment in rivers) leading to a loss of habitat and a decline in channel stability. Given that the capacity of some channels may become reduced due to accelerated sedimentation (see previous section on slope stability), the damage from increased flood flows could be higher than would be expected today.

- **Aquifer levels**

The warmer wetter winters followed by warmer (and drier) summers suggest changes to how aquifers will be recharged. While abundance of winter precipitation will enhance recharge, additional precipitation is prone to running of quickly due to the warmer temperatures and the general decline in snowpack. Similarly, the early freshet and warmer and drier summer conditions will tend to further accelerate aquifer discharge earlier in the dry season. Although limited mapping is available for the Clayoquot Sound groundwater resources, Observation Well 329 (located in BC Aquifer 159, Ucluelet area) illustrates that levels in this nearby sand and gravel aquifer fluctuate seasonally and across years in response to shifts in climate and regional weather patterns (Kevin Ronnesseth personal communication). It is reasonable to assume that similar aquifers in the Clayoquot Sound area will fluctuate seasonally and across years similarly in response to future climates. Eventually (perhaps in the 2050s and beyond), saltwater intrusion may also become a significant concern as sea level rises. See Rivera *et al.* (2004) for a wider discussion of groundwater change.

- **Low flows**

While the winter period will experience a great number of flood peaks, the late summer period will experience an increase in the number and magnitude of low flow days[52]. The earlier freshet, the decline in winter snowpack/storage, the hotter temperatures, and a potential decline in warm-season precipitation all point to longer dry periods and lower flows during the late summer period. Initially, small drainages currently with limited or no snowpack potential are the most vulnerable. As the hydrologic changes take effect, the larger drainages will become susceptible.

Summary

Table 3 summarizes the freshwater aquatic impacts discussed above along with their timelines for beginning and their likelihood of occurring.

[52] Pike *et al.* 2010

Table 3: Summary Impacts on Freshwater Aquatic Ecosystem in Clayoquot Sound

Impact	Timeline*	Likelihood**
↑ Rain intensity and volume	Short-term	Very Likely
↓ Snow levels & snowpack during year		
Earlier spring freshet		
↑Water temp in streams/lakes		
↑ Sedimentation of creeks and rivers and ↑ water turbidity		
↑ Streamflow and flooding of riparian areas in winter and fall		
Lower and longer low flow stream periods in summer		
↑ Aquifer re-charge in winter/fall		
↑ Aquifer discharge in summer		
↑ Saltwater intrusion to aquifers (with sea level rise/storm surges)	Long-term	More Likely Than Not

* Time Scale = Short-term (0-10 years), Medium-term (11-30 years), Long-term (31+ years)
** Likelihood Scale = Very Likely, Likely, More Likely Than Not, Unlikely, Very Unlikely

Overall, the hydrologic systems of Clayoquot Sound are naturally resilient. They are designed to function within a broad range of conditions, and the forested landscape acts to buffer the effects of large-scale storm and high intensity rainfall events. As climate alters the frequency and intensity of such events, changes in each of the processes outlined above will occur. Two thresholds may be particularly important – disturbance thresholds that lead to slope failure and excessive sedimentation, and very low flow levels in creeks that result in loss of highly valuable aquatic / riparian habitats. Notwithstanding these two potentially significant effects, the system is relatively insensitive to broader changes, and the system is expected to be reasonably resilient into the future. On a watershed by watershed basis however, very significant impacts to values and resources can occur in single storm events that fundamentally alter the values produced - fish habitat, water supplies, riparian habitat, movement of whole channels etc. These single high intensity events are very hard to model, predict and manage for into the future, and may be the cause of decreased resilience into the future if the rate of occurrence significantly increases.

Marine Ecosystem

As already noted, climate change acts on a global scale, but its effects can vary considerably among locations and ecological contexts. Thus, the various effects of climate change on the marine ecosystem of Clayoquot Sound are unique because of the uniqueness of this setting in the region and the world. Clayoquot Sound is well defined biogeographically as a series of relatively independent coastal fjord estuaries (inlets) in which the runoff is predominantly from rainfall in a relatively localized coastal rainforest watershed. It is different from the coastal fjord estuaries of mainland British Columbia many of which receive much of their runoff primarily from snowmelt.

There is minimal direct information about climate change effects on Clayoquot Sound marine ecosystems. Most available information relates to nearby or similar areas, offshore areas, or elsewhere throughout the world. Nevertheless, various kinds of biological changes can be expected or inferred based on literature reviews from these other settings. Some useful reviews exist in the scientific literature[53].

The present biophysical assessment of marine ecosystem impacts relies on inference from general existing knowledge of these marine ecosystems and the associated literature. We have taken a general descriptive approach to identifying potential effects, rather than to make quantitative projections of biological and ecological effects. This approach reduces this complex ecosystem to a small number of pieces, but the hope is that the presence and health of these species provides some insight into the health of broader aspects of the system.

System Dynamics

Marine ecosystems in general are highly dynamic—much more so than terrestrial ecosystems, which often appear ‘stable’ on human timeframes (resulting in our use of the terms ‘balance’ or ‘equilibrium’).

For terrestrial systems, air temperature and precipitation tend to be strong controlling variables, but a much wider array of physical and chemical (oceanographic) variables shape marine ecosystems, including temperature, salinity, nutrients, dissolved oxygen and light transparency (Table 4), and all of these vary at both broad and fine scales. Both fast and slow marine life is sensitive to these variables, and changes in these variables influence the productivity and the structure of the system’s biological components. These variables shape the system largely from the bottom of the food web, but they also directly influence organisms throughout food web.

All these factors vary across time and space at different scales, and the oceanography adjacent to and within Clayoquot Sound has a notably high degree of texture, or

[53] IPCC 2007, Poloczanska et al. 2007

'heterogeneity', as do the marine areas of northern British Columbia[54]. The West Coast of Vancouver Island, including Clayoquot Sound, features unique oceanographic characteristics (Okey and Dallimore in prep.) that lead to high productivity and a unique biodiversity. One example of this texture (heterogeneity) and these unique productive features is shown in Figure 2.

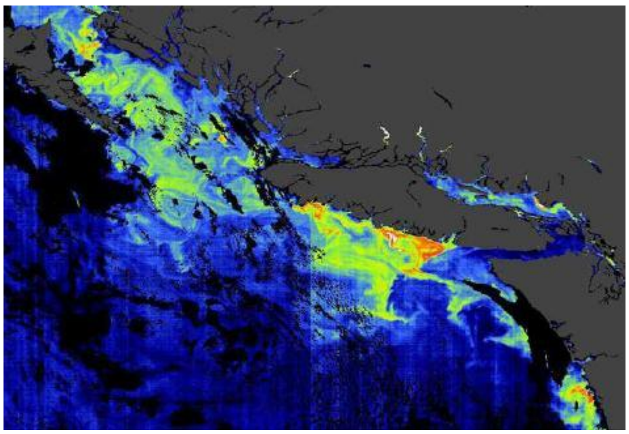

Figure 2. Chlorophyll florescence in most of British Columbia's marine areas and part of the US coast during 28 August 2010 (Gower and King 2010).

In addition, individual species can strongly structure, or control, marine communities - these are often apex predators with strong overall interaction strengths in the system. If these strongly interacting or keystone species are directly affected by physical aspects of the ocean, then cascading impacts can occur. Marine communities therefore can be influenced from the 'bottom-up' or the 'top-down' with changes occurring over short periods of time (at least in comparison to terrestrial systems).

Natural disturbances in marine ecosystems are typically understood as discrete events that disrupt or remove fauna from particular areas or 'patches', which are then re-colonized in successional stages, such as when a storm removes kelp canopies that have formed over the calm summer months.

Natural variability in 'bottom up' forces, 'top down' forces, and natural disturbance regimes can be thought of as "healthy" for the ecosystem, the component biota, and the resident human communities. This ecological texture (variability and complexity) nurtured the evolution, adaptation, and colonization of a broad diversity of organisms that inhabit the complex array of spatial, temporal, and functional niches resulting from these forces and the diversity of habitats.

[54] Okey et al. 2010

These system dynamics are modified by the introduction of new types of pressures and stressors by humans throughout the last 10,000 years or so of human habitation of the area. These pressures and stressors have changed, and very recently have hugely increased - leading to the observed degradation of the system. This ecosystem degradation has manifested by changing the 'bottom up' forces, 'top down' forces, and natural disturbance regimes in addition to direct effects on valuable ecosystem components. Climate change is the latest stressor category, and the most worrisome in the long-term because of the expected increases in the relative importance its effects, but also because local climate change impacts are a manifestation of global scale changes that cannot be managed locally.

Differential effects of climate change on Clayoquot Sound marine biota will lead to widespread mis-matches of co-dependent species and changes in the assemblages of species. These structural changes will lead to unknown but potentially large effects on the function of biological communities. From an equilibrium perspective, these changes could push marine ecosystems toward or beyond tipping points and into degraded stable states from which recovery would be extremely unlikely. Even without sudden shifts from equilibrium points, such changes would considerably change the services that the stability of the system and the services it provides to humans.

Climate change manifests as a wide variety of physical and chemical changes, and biological impacts. Examples of these are listed in Table 4 with reference to the North-eastern Pacific Ocean.

Table 4: Aspects of physical, chemical, and biological changes in the Northeastern Pacific Ocean based on literature reviews by Tom Okey.

Physical and chemical changes	Biological changes
• Temperature (+) • pH (-) • Precipitation (+) • Snowpack (-) • Salinity (-) • Stratification (+) • Dissolved oxygen (-) • Sea level (+) • Storminess (+) • North Pacific current (+) • Upwelling (+) • ENSO (increased frequency)	• Poleward shift of species ranges • Changes in phenology, or timing of life stages and migration • Mis-matches and re-assembly of communities • Increased extinction risk • Physiological stress • Invasive species and disease • Effects of exposure to toxins • Nutrient enrichment and algal blooms • Increased vulnerability to other anthropogenic stressors

Direction of change is indicated in parentheses (+ is up, - is down).

Perceptions of current state

In an attempt to understand the relative importance of these different aspects of climate change, nine aspect categories of climate change were rated during the West Coast Aquatic survey by degree of stress (Figure 3). Deoxygenation was ranked as the aspect exerting the highest stress, whereas sea level rise was rated lowest, but all categories were considered to exert more than medium levels of stress.

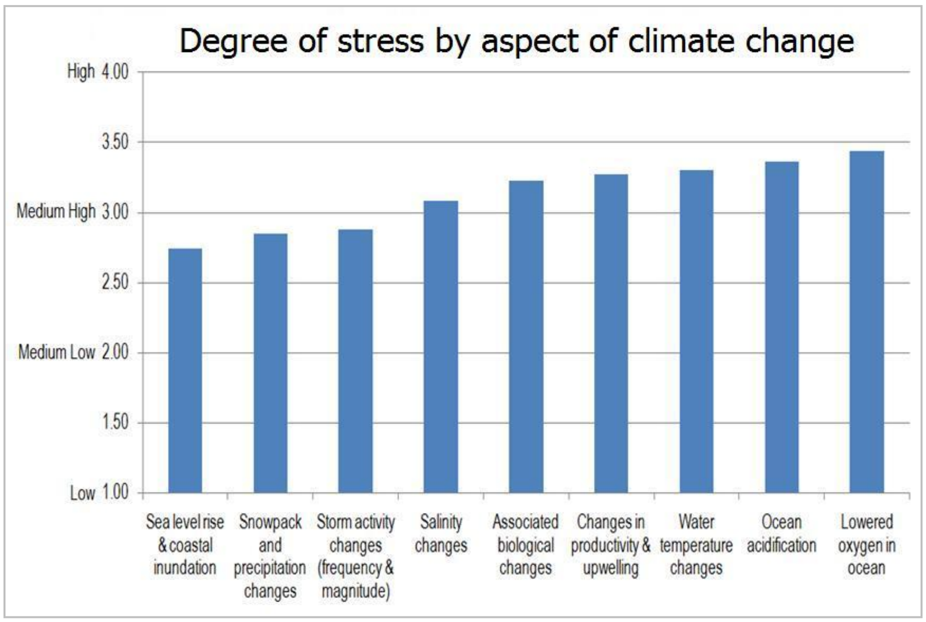

Figure 3. Degree of stress exerted by different aspects of climate change impacts to the West Coast Vancouver Island marine ecosystem as rated by expert survey respondents (n=48).

The overall ecological health of Clayoquot Sound was evaluated by these 48 knowledge holders in relation to the other sounds and marine ecosystems on the West Coast of Vancouver Island (Figure 4). The Clayoquot Sound ecosystem was ranked as moderately healthy, with Kyuquot Sound being ranked healthiest and the Alberni Inlet being ranked as least healthy.

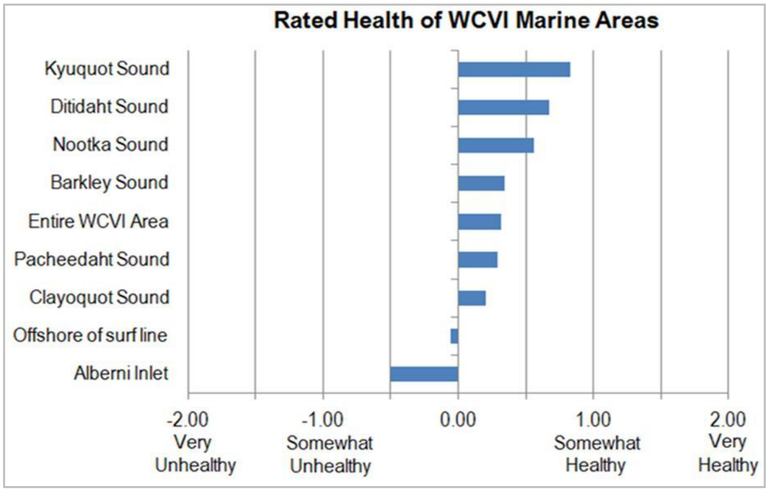

Figure 4. Perceptions of relative health of the various marine ecosystems of the West Coast of Vancouver Island, with Clayoquot Sound ranking as moderately healthy (n=48).

However, these knowledge holders considered the health of the Clayoquot Sound ecosystem to be declining to a relatively large degree (Figure 5), and that this change is happening relatively rapidly (Figure 6).

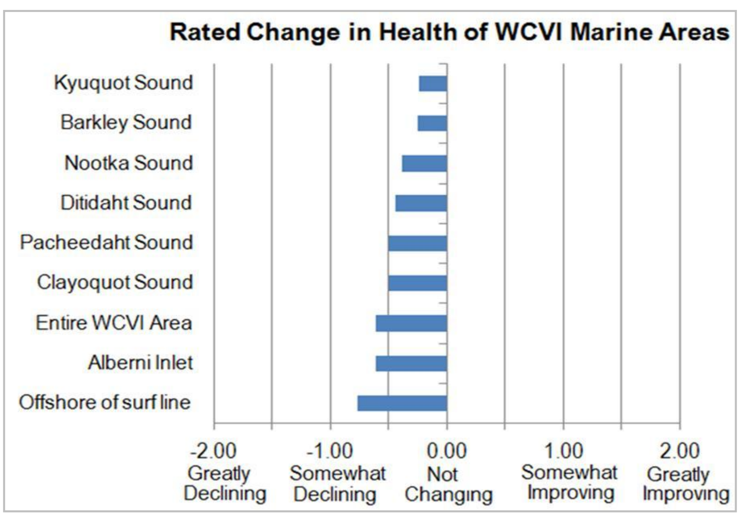

Figure 5. Perceptions of how the health of West Coast Vancouver Island marine ecosystems is changing, indicating that the ecological health of Clayoquot sound is declining to a relatively large extent (n=48).

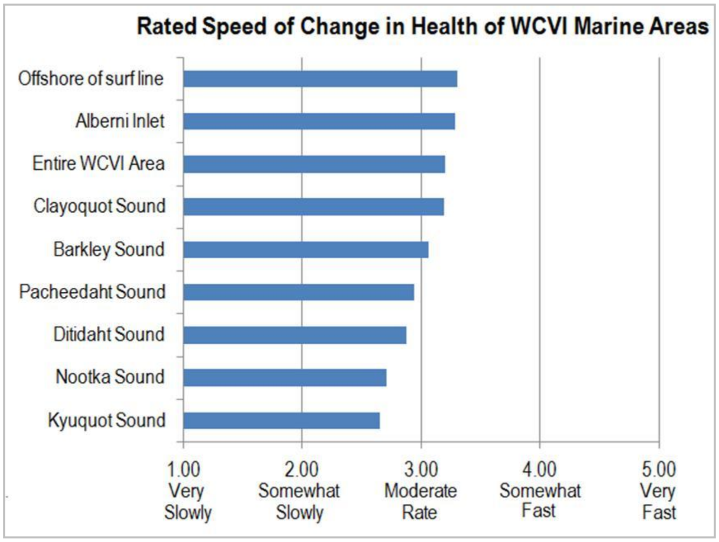

Figure 6. Rated speed in the change in the health of the marine areas on the WCVI (n=48).

These results are one form of evidence—perception of knowledge holders—that the Clayoquot Sound marine ecosystem is functionally degraded. These general ratings of perceived ecosystem health, relative health, and the direction and rate of change in health resulting from this online survey of 48 knowledge holders was consistent with the results of 28 key informant interviews of Clayoquot Sound community members (mean age 50 years) conducted during Phase 1 of the present project on *Climate Change in Clayoquot*. These key informants generally highlighted observations of changes that have occurred across a wide variety of biophysical components of Clayoquot Sound's marine ecosystem.

Observed changes to date include increased air temperatures, less frequent rain but heavier showers and less lightning in summer, lower lake water levels in summer, less ice and snow but more rain in the winter, less frequent storms but stronger winds in winter. Observations also included some hints of perceived sea level rise and coastal erosion, perceived increases in water temperatures and more red tide and algae blooms, and perceived changes to a wide variety marine life including marine mammals, fishes, invertebrates, and seaweeds that are culturally important. The conclusion that the Clayoquot Sound ecosystem has changed considerably is further supported by the history and variety of human activities and stressors[55] and the observed biological and economic changes in general.

[55] Mak et al. in review

Not surprisingly, the perceived attribution of causes of these observed changes was a mixture for each marine life category, including direct resource utilization, water pollution, habitat degradation, climate change impacts, and mismanagement.

This traditional ecological knowledge stands out as an essential for highlighting some culturally important changes in the ecosystem and for generally indicating the degree change that has occurred. In the distant past, such information could be used as the basis for effective management of human activities and important uses, but the qualitative nature of this information is not adequately matched to contemporary problems because it cannot be easily used to distinguish relative importance of the causes of change, given the much wider variety of human pressures that exist today.

A more quantitative assessment of Clayoquot marine ecosystem change is needed, in terms of how various specific values have been reduced or changed for the present and the future, and in terms of the relative contributions of the different human stressors to changes in each group. The selection and use of ecological indicators is the next practical step toward evaluating Clayoquot Sound ecosystem health. These indicators can be used to evaluate the state of the system and they can be tracked over time to evaluate trends. Changes in climate-related physical and chemical indicators of environmental quality are examined below, followed by a summary of expected changes in some biological indicators of productivity and biodiversity.

Trends in oceanographic variables

• Deoxygenation

Dissolved oxygen is expected to decrease in the global ocean by 1 to 7% this century[56], but these changes are occurring much more rapidly in the North Pacific Ocean where oxygen has already decreased by 22% during the last 50 years at depths of between 100 m and 400 m[57] (Figure 7).

[56] Sarmiento et al. 1998, Keeling et al. 2010, Rabalais et al. 2010
[57] Whitney et al. 2007

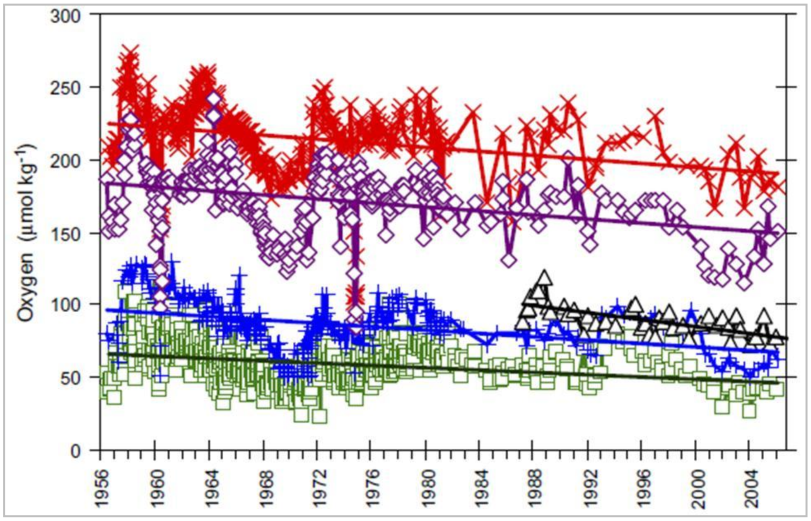

Figure 7. Declines in dissolved oxygen at different isopycnal surfaces (between 100 m and 400 m) and stations along Line P off the West Coast of Vancouver Island (Whitney et al. 2007).

This rapid deoxygenation is occurring in the North Pacific due to increased water temperatures and increased rainfall in the region and freshening of the surface waters, which is stratifying the upper water column and reducing the ventilation of seawater with the atmosphere. This stratification also reduces the nutrient supply to the photic zone, thus reducing photosynthesis and productivity. Similar oxygen minimum zones (OMZs) are expanding all over the world, and these low oxygen conditions can impinge on coastlines such as along the West Coast of North America where it has affected marine life considerably in recent years[58].

The effects of deoxygenation vary greatly among different forms of marine life[59]. Many sublethal effects change distributions and behaviour considerably before lethal effects occur. Ocean warming and ocean acidification interact in a variety of ways with deoxygenation[60] . Deoxygenation effects can, thus, be extremely complex and difficult to estimate.

Dissolved oxygen is typically naturally low or absent in the deeper water within coastal fjords (inlets) because (1) the glaciers that carved the fjords usually leave shallow sills of glacial moraine at their mouths which prevent mixing of waters in the deep basins of these fjords with more oxygenated offshore waters, (2) the high input of nutrients and

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[58] Grantham et al. 2004, Dybas 2005, Chan et al. 2008
[59] Vaquer-Sunyer and Duarte 2008, Levin et al. 2009, Rabalais et al. 2010
[60] Oschlies et al. 2008, Portner 2010

organic material and the high primary productivity of these inlets lead to high rates of microbial decomposition in these deeper layers, which uses up oxygen[61]. The basin of Inner Tofino Inlet, for example, is permanently anoxic and that of outer Tofino Inlet is seasonally anoxic.

Oxygen is as essential to marine life as it is to terrestrial life. The changes in the oxygen minimum zones in BC fjords (inlets) are already known to have a large effect on marine life in these special environments.[62] Making specific projections of these effects in Clayoquot Sound would be challenging, but worthwhile given the importance of oxygen.

- ## Salinity

Surface salinity[63] has generally declined since 1955 (Figure 8), meaning a general freshening of surface waters further out to sea. This is consistent with trends from the Alaskan coast and Bering Sea indicating a general freshening of surface waters due to enhanced precipitation in northern areas, and it is also consistent with the decreased oxygen concentrations in the Northeast Pacific Ocean discussed in the previous section.

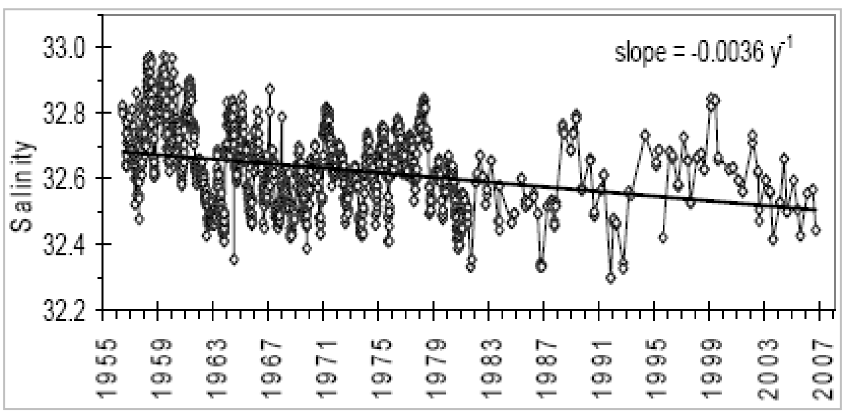

Figure 8. Surface salinity at Ocean Station P (50 N, 145 W) from 1956 to present (taken from Whitney and Robert 2007)

In addition, the frequency of very low salinity events at Amphitrite Point Lighthouse at Ucluelet and at Bamfield Marine Sciences Centre has decreased since the mid-1970s (Figure 9), and this may reflect decreases in winter freshwater runoff in these coastal systems.

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[61] (Dallimore et al. 2005, Hay et al. 2009, Dallimore and Jmieff 2010

[62] Timothy and Soon 2001, Devol 2004

[63] Based on data from an oceanographic sampling station 20 degrees of longitude west of Vancouver Island

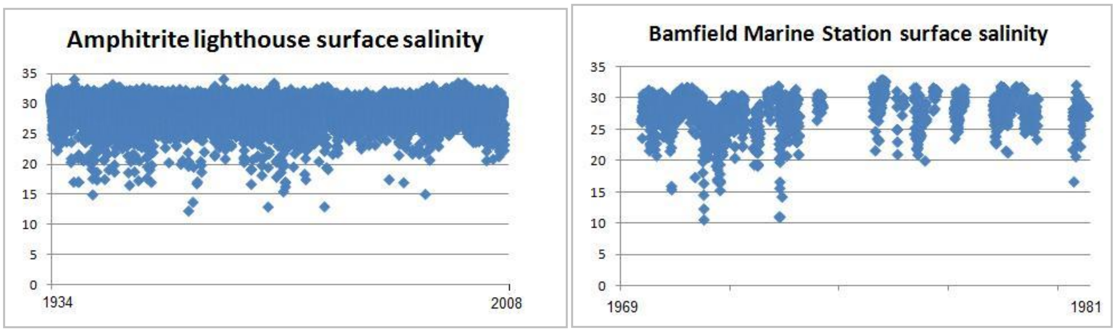

Figure 9. Surface Salinity Measurements from Amphitrite Lighthouse and Bamfield Marine Sciences Centre both showing decreases in very low salinity events in the mid-1970s.

The contrast of these decreases in winter runoff events and general increases in freshwater runoff in the greater Gulf of Alaska may be explained by the location of Clayoquot Sound at the southern edge of the predicted increases in rainfall. Winter precipitation has indeed apparently decreased in the Clayoquot Sound area during the preceding century[64] but winter precipitation in Clayoquot Sound is projected to increase over the coming century (see Section 4).

Future changes in patterns of runoff and salinity in the Clayoquot Sound marine ecosystem will have important implications for the area's ecology and economies, since the Clayoquot Sound's estuarine characteristics strongly influence the productivity and distributions of the species in this area.

- ## Temperature

A considerable increase in the global annual heat content of the ocean in the layer between 0 and 700 m has been observed over the last 50 years65 and so ocean temperature is increasing at every scale. For example, increases in the greater north-eastern Pacific have been highlighted by (Figure 10)[66].

[64] BCME 2007
[65] IPCC 2007
[66] Whitney et al. 2007

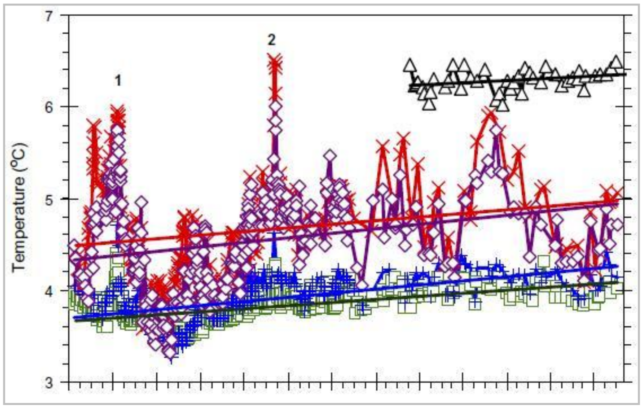

Figure 10. Increases in temperature at different isopycnal surfaces (between 100 m and 400 m) and stations along Line P off the West Coast of Vancouver Island (Whitney et al. 2007).

Sea surface temperature at stations around southern coastal British Columbia has increased by about 0.5°C on average during the last 50 years (Figure 11).

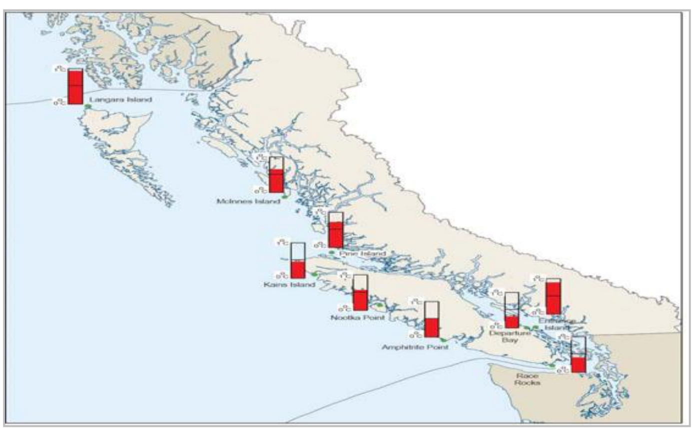

Figure 11. Rate of change in sea-surface temperature (ºC/50 years) at nine lighthouse stations on the B.C. coast, Fisheries and Oceans Canada ***www.pac.dfo-mpo.gc.ca/sci/osap/data*****. Each full bar is 1°C. (Figure modified from BCME 2007).**

The measured surface sea temperature at Amphitrite Point Lighthouse, the station nearest Clayoquot Sound, has increased ~0.5°C during the last 50 years. Higher than average temperatures have predominated there since the late 1970s (Figure 12).

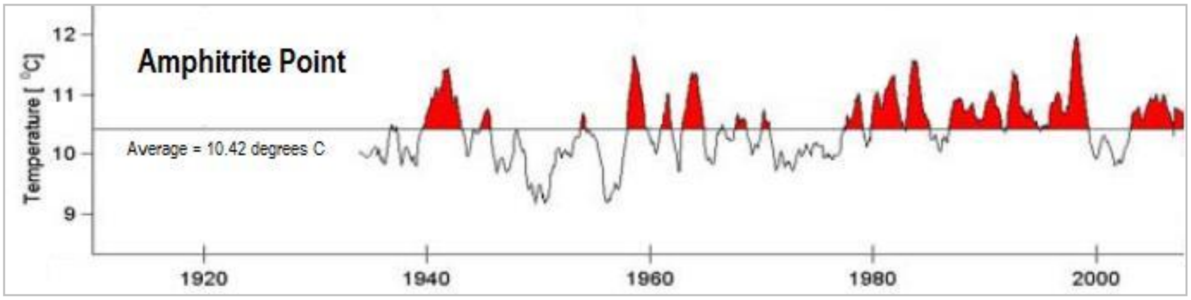

Figure 12. Long-term time series of annual-average sea surface temperature at Amphitrite Point Lighthouse located at Ucluelet, between Clayoquot and Barkley Sounds showing predominantly higher than average temperatures since the late 1970s (modified from Chandler 2007)

Model projections for the adjacent ocean region indicate that this rate of surface sea temperature increase will accelerate to between 1 and 2°C per century for the decade centered at 2055[67]. These increases are expected to have significant impacts since temperature is another variable that, in general, strongly influences the physiology, distribution, and abundance of marine life.

• Acidification

Increases in atmospheric CO_2 concentrations increases carbonate ions in the oceans thus lowering pH and acidifying the oceans[68]. Anthropogenic releases of CO_2 during the last 250 years have led to the lowest ocean pH levels (most acidic) in 20 million years[69]. This is causing considerable changes to marine life because acidity level influences a variety of physiological processes. For example, the calcium carbonate shells or structures of a broad spectrum of marine animals, dissolve or cannot form when seawater becomes undersaturated with calcium carbonate compounds[70]. Acidification of ocean waters is thus poised to fundamentally change the character of marine ecosystems by adversely affecting organisms that rely on calcium carbonate for their skeletal structures, including plankton and many other types of organisms.

The North-eastern Pacific Ocean naturally has some of the lowest pH waters in the world because it is at the end of the ocean conveyer belt, and CO_2 has built up from

[67] IPCC 2007
[68] Raven et al. 2005
[69] Feely et al. 2004, Sabine et al. 2004, Caldeira and Wickett 2005, Orr et al. 2005, Hauri et al. 2009
[70] Feely et al. 2004, Feely et al. 2008

respiration in these old waters that upwell along this coastline[71]. Marine organisms of the area have thus adapted to these marginal pH conditions, but the pH of these waters is declining further due to temperature effects increasing rates of acidification[72] and this may lead to severe ecological impacts and considerable change. There are already some examples of rapid ecological change in nearby marine intertidal habitats associated with these decreasing trends in pH[73].

- ## Sea level rise and storm surge

Global sea level is expected to rise by 10-22 cm by 2050 and by 21-44 cm by 2100 (Figure 13)[74], and it is expected to continue rising for millennia due to anthropogenic sea level rise. The two global causes of sea level rise are (1) changes in volume due to thermal expansion and salinity effects, and (2) changes in volume due to melting of glaciers, ice caps, and other ice and snow[75].

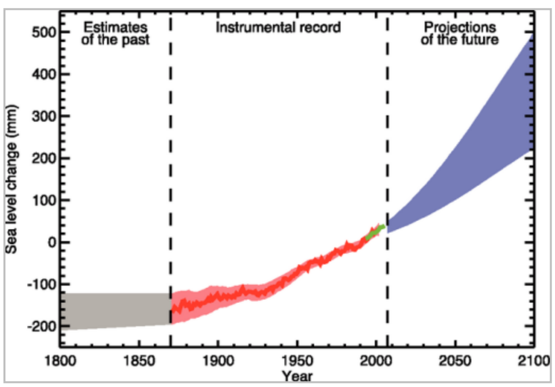

Figure 13. Measurements and projections of global mean sea level (deviation from the 1980-1999 mean) (IPCC 2007).

However, sea level rise is far from uniform along shorelines because it is strongly influenced by local processes such as the speed at which the land is rising and falling, and this varies considerably on small scales due to particular geological and geomorphological histories (e.g. uplift and subsidence).[76] Other regional factors that influence the variability of sea level rise include variations in ocean temperature,

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[71] Feely et al. 2008, Hauri et al. 2009

[72] Orr et al. 2005, Byrne et al. 2010
[73] Wootton et al. 2008
[74] IPCC 2007
[75] IPCC 2007, Thomson et al. 2008
[76] Thomson and Crawford 1997

salinity, winds, tidal characteristics, wave exposure, and ocean circulation.[77] El Niño events, such as the 1997-1998 event, can increase sea level by 10-40 cm for months at a time causing coastal inundation.[78]

Some estimations of sensitivity to sea level rise have been made for British Columbia[79], but these are relatively rough and on a relatively broad scale (Figure 14)[80]. There are various options for increasing the accuracy and precision of sea level rise impacts locally for Clayoquot Sound communities, but each will require additional data layers before these predictions become locally more useful.

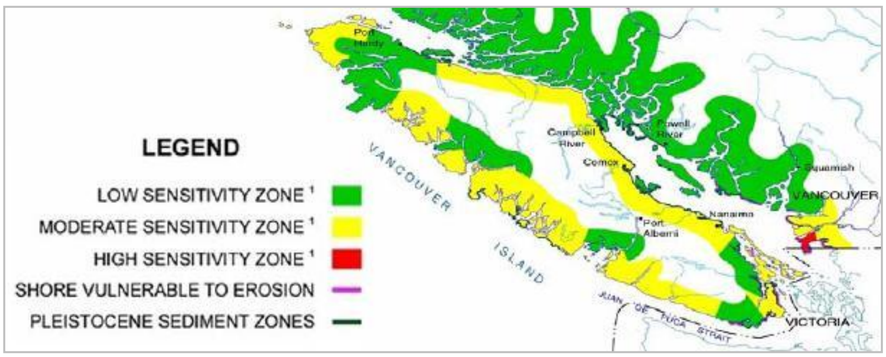

Figure 14. Sensitivity of Vancouver Island and the Southern BC coastline to sea level rise and erosion. Modified from Hay & Co. Consultants 2004 (Cited in BCME 2007). The resolution on this map is similar to that by Shaw (1998a) on the Atlas of Canada by Natural Resources Canada.

• Changes in storm frequency and wave heights

Extreme precipitation, wind, and wave heights may increase in Clayoquot Sound and the surrounding region, but the uncertainty in the science behind these projections is still high.

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[77] IPCC 2007, Thomson et al. 2008

[78] Barrie and Conway 2002, Cherniawsky et al. 2004

[79] See Shaw et al. 1998a, Shaw et al. 1998b, BCME 2007

[80] Shaw's (1998a) data are used on the Atlas of Canada by Natural Resources Canada[80]. Currently, sea level rise sensitivity of specific coastal estuaries in British Columbia is being estimated using the ShoreZone dataset (http://www.coastalandoceans.com/shorezone.html), and the a five colour ratings are being expressed at a much finer scale on Goggle Earth compatible files (D. Biffard, BC Ministry of Environment, Pers. Comm., 10 November 2010)

Extreme precipitation events are expected to increase during the coming century in most regions of the world,[81] as well as in British Columbia during some seasons and in some areas.[82] Salinity measurements from Amphitrite Point Lighthouse and Bamfield Marine Sciences Centre suggest that very extreme precipitation events might have declined since the middle 1970s, but this could be due to short-term cycles.

There is relatively good agreement that storm activity is generally shifting poleward globally, meaning increases in high latitudes and decreases on low latitudes, but there is considerable uncertainty about mid-latitude storms.[83] The Eastern Pacific is highlighted as a unique area with a possible strengthening and equator ward shift of storms, but not increases in frequency.[84] A recent ensemble analysis of IPCC global climate models (Ulbrich et al. 2008) also indicated a poleward shift in storm activity in general globally including a 7% increase in storms near the Aleutian Islands by 2100 but this analysis indicated no change or less than a 1% increase off the coast of British Columbia. The present author assumes that modelling projections of trends in storms, especially in mid-latitudes and in the Eastern Pacific, although the result of rigorous analyses, remains uncertain.

In contrast to these uncertain projections for storms in the vicinity of Clayoquot Sound, new research[85] suggests that Significant Wave Heights (the average wave heights of the one third largest waves) have increased by more than half a meter since the mid-1970s at buoys offshore from Oregon, and that the very largest waves have increased by about 2.5 meters during that same period. These observed increases in large ocean waves off Oregon are consistent with general predictions of the U.S. Climate Change Science Program that increased ocean temperatures will lead to increased intensities of hurricanes and extra-tropical storms, which will increase wave activity, including the sizes of the largest waves.[86]

This rate of increase in the height of the largest waves is particularly concerning because these strongly effect the rates of coastal erosion and the frequency of coastal flooding, which also are known to have increased in the region. It is likely that these trends in wave heights are the result of changes in storm tracks, higher winds, and more intense winter storms related to global climate change, but it could also have resulted from changes in ocean cycles such as the Pacific Decadal Oscillation and the El Niño–Southern Oscillation, which are not necessarily independent of global climate changes.

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[81] Kharin et al. 2007
[82] Pike et al. 2008
[83] Easterling et al. 2000
[84] Bengtsson et al. 2006
[85] Ruggiero et al. 2010
[86] Karl et al. 2008

The character of El Niño events, and other aspects of the El Niño-Southern Oscillation, may change with global warming.[87] Extreme weather events associated with potential increases in El Niño amplitude, frequency, or duration will likely cause considerable coastal inundation and erosion, especially when combined with future sea level rise[88] and high tides.[89]

Changes in the character of storms, the heights of the largest waves, and other factors that combine to affect shorelines may have severe effects on low-lying coastal communities of the region and their infrastructure, as well as the coastal ecologies of the area. Given the uncertainty in the projections surrounding these variables, any planning should assume that storms and wave heights will increase considerably during the coming century.

- **Oceanographic currents**

Two major currents in the region may intensify with global climate change: The North Pacific Current, which brings warm waters from the central Pacific, and the California Current, which flows southward from British Columbia to Mexico.[90] Increases in the North Pacific Current may bring more warm water and heat to the West Coast of Vancouver Island. However, a northward shift and an increase in the intensity of upwelling along the California current have also been observed and is expected to continue with climate change.[91] This could bring cold water from depth during upwelling seasons, thus partially counteracting the heating. Although rich in nutrients, these upwelled waters are ever lower in dissolved oxygen and pH, making them "corrosive," as discussed in the previous deoxygenation and acidification sections. This increased upwelling of corrosive waters may lead to severe consequences to the flora and fauna of the West Coast of Vancouver Island, including Clayoquot Sound, despite increases in upwelled nutrients. In addition to global climate change, other cycles including El Niño–Southern Oscillation and the Pacific Decadal Oscillation influence these regional currents, upwelling, and associated processes.

Marine Life – potential impacts

As discussed above, climate change is having a significant impact on the physical characteristics of the marine ecosystem. This will have significant impacts on a wide array of individual species – a few of these are discussed below.

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[87] Trenberth et al. 2002, Merryfield 2006
[88] Abeysirigunawardena and Walker 2008b, Abeysirigunawardena et al. 2009
[89] Thomson et al. 2008
[90] IPCC 2007
[91] Snyder et al. 2003

Clayoquot Sound marine ecosystems are in constant flux, and so the plants and animals within them are adapted to survive within a 'background' range of environmental conditions. Conditions can be pushed outside of that normal range of conditions for some organisms when too many human-induced changes are introduced.

These new environmental changes may cause changes in species composition, affecting the structure and function of these ecosystems and the human communities that depend upon these and related, natural resources.

There are key organisms in Clayoquot Sound that local society has interests in maintaining, and in some cases adaptive strategies may be necessary to support the survival of these organisms. In many other cases, global environmental changes (i.e., climate change) will combine with other human-induced stressors to make Clayoquot Sound less hospitable to some familiar organisms and more hospitable to some unfamiliar organisms. This is illustrated by projections of poleward range expansions of fish species globally[92] and in this region.[93] In Clayoquot Sound, this will eventually lead to a change in the species assemblage and the structure and function of the marine ecosystem. Adaptation approaches should consider these potential changes.

The potential climate change induced biological impacts to Clayoquot Sound will be felt along a spectrum of scales, ranging from global to local. The present assessment is focused on the local effects of global change, and these effects will also be influenced by local stressors that are unrelated to climate change.

In this section, a group of organisms are selected as indicators of potential climate change impacts on the broader suite of biological organisms of the Clayoquot Sound marine ecosystem.

• What is the state of the ecosystem today?

Many marine organisms that human communities in Clayoquot Sound have depended on historically are currently in decline. For instance, most of the key indicators discussed in this section are thought to be declining locally, affecting all other species in the Clayoquot marine environment. All species of salmon and many species of rockfish and forage fish as well as Cassin's auklets are at an all-time low; oysters, manila clams, geoduck, rockweed and euphausiids (krill) are all experiencing a drop in population numbers. It can be difficult to pinpoint the exact causes for these declines, especially since most organisms are affected by combinations of overharvest, predation, loss of key habitat, competition with invasive species, natural climatic changes (i.e., Pacific Decadal Oscillation, El Nino/La Nina), and changes to their environment brought on by climate change.

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[92] Cheung et al. 2009
[93] Cheung et al. Submitted

However, some important marine species are increasing in abundance for reasons that are independent from climate change impact (i.e., Grey whales, Steller sea lions, sea otters, eelgrass, and giant kelp). Many of these species are rebounding from past all-time lows because harvest pressures (by humans and predators) have decreased.

This assessment is focused on the taxa listed below (Table 5) as indicators of ecosystem integrity from a human interest perspective.

Table 5. Indicator Species in the Clayoquot Sound

Group	Species
Marine Mammals	Grey whale (Eschrichtius robustus) Steller sea lion (Eumetopias jubatus) Sea otter (Enhydra lutris)
Finfish:	Salmon (Salmonidae) Rockfish (Sebastes) Pacific sandlance (Ammodytes hexapterus)
Bivalves	Pacific/Japanese Oyster (Crassosrea gigas) Manila clam (Venerupis philippinarum) Geoduck (Panopea generosa)
Marine birds	Cassin’s Auklet (Ptychoramphus aleuticus) Marbeled Murrelet (Brachyramphus marmoratus)
Marine macrophytes:	Eelgrass (Zostera marina) Giant Kelp (Macrocystis pyrifera) Pacific Rockweed (Fucus gardneri)
Zooplankton:	Euphausiids (krill) (Euphausiacea) Mysids (Mysidacea)
New species	Brown pelican (Pelecanus occidentalis) Feather Boa Kelp (Egregia menziesii) Humboldt squid (Dosidicus gigas)

While some climate and oceanographic variations remain within ‘normal’ bounds, the longer term trends of increasing temperature, and decreasing salinity, oxygen and pH do not bode well for many of the marine organisms that Clayoquot communities depend upon. If current trends continue, the structure and function of Clayoquot marine ecosystems will change. As these changes accumulate, thresholds may be crossed, causing the systems to shift rapidly or collapse, thereby having severe impacts on fisheries, tourism, and various other assets of Clayoquot Sound human communities.

System Dynamics

The main variables controlling the Clayoquot Sound marine community are food, ocean pH, oxygen, temperature, nutrients, and the integrity of important habitat. All of these vary on time scales including millennial, centennial, decadal, annual, seasonal, and daily, as well as across the space of the WCVI marine area. The inferences we make about the biological effects of climate change impacts are based on observations of the effects of climate variability on these scales, and on other knowledge of how ecosystems work. Some examples are provided here:

- Declines in key prey species, such as euphausiids, mysids, and sand lance, can severely affect culturally key organisms such as whales, sea lions, rockfish, salmon, and marine birds. These food, or forage, organisms are affected by changes in all of these physical and chemical variables.
- In contrast, water temperature along this coastline is often singled out as having a strong influence on salmon populations. For instance, Clayoquot Sound is at the southern distribution limits of most Pacific salmon species. Azumaya *et al* (2007) found that the upper thermal limit was 13.3˚C for sockeye, 15.6˚C for chum, 16.6˚C for pink, 15.7˚C for coho and 13.4˚C for chinook. The projected 4˚C air temperature change could increase sea water temperatures too much for the more temperature sensitive salmon, such as sockeye and chinook. However, food, oxygen, nutrients, and habitat integrity strongly influence early life stages of outmigrating salmon, and these variables influence adult salmon out at sea. Salmon will also be limited by temporal mismatch of prey (e.g. euphausiids) at early life stages, changes in predation and competition, and exposure to disease and viruses (which may thrive in warmer sea temperatures).
- Variations in ocean pH also affect the composition of marine organisms along this coastline and acidification (decreased pH) is generally expected to affect organisms that have calcium carbonate structures, such as bivalves. But the bivalve species considered during this analysis will also be impacted by predation, harvest, temperature and the availability of marine nutrients, and acidification will also affect the basic physiology of organisms that don't rely on calcium carbonate structures.
- The biomasses of some marine macrophytes (e.g., eelgrass, giant kelp) appear to be increasing, in part because of reductions in herbivores through predation by sea otters. The number of species of mactophytes may also be increasing in this system due to introductions, invasions, and other arrivals. Forecasted climate

changes may impact these organisms (e.g., larger storm waves may more frequently remove plants and their attachments and warmer water temperatures will allow additional southern species such as the feather boa kelp to move in), but it is not expected that these changes will severely deplete the populations.[94] The increased biomass of marine macrophytes should also increase the overall resilience of the nearshore marine ecosystems as they will provide storm surge buffers and protective habitat for young fin-fishes.

Specific Impacts

The worst-case scenario of the climate projections considered in this analysis includes an average temperature increase of 4˚C, and an average precipitation increase of 764 mm by the 2080s (Chapter 3). If these projections are realized, the marine communities in Clayoquot Sound will likely look very different than they do today.

Projected changes on chosen indicator groups are discussed here:

Marine Mammals:

Although most marine mammal numbers are increasing in Clayoquot Sound, those increases are generally attributed to recovery after over-exploitation. The changes to the marine environment brought on by climate change are expected to negatively impact all three of the focal species (grey whale, Steller sea lion, and sea otter). The temperature changes and acidification associated with climate change will cause declines in key food species (mysids and forage fishes) for the grey whale and the Steller sea lion. This loss of food may cause these species to leave the local area. Increased temperature, acidification, and increased precipitation will also likely impact the main food sources of sea otters (and thus sea otters themselves), as will increases in invasive species that are better able to survive in warmer waters. Bivalves such as clams, a key food source for sea otters in Clayoquot Sound, are already being threatened by invasive European green crabs, as well as by more dramatic winter temperature fluxes (especially freezing).

Fin-fish:

The projected temperature increase is expected to adversely affect salmon growth, survival, and reproduction. As mentioned previously, continued increases in seawater and freshwater temperatures associated with a 4˚C air temperature change may impact sockeye and Chinook strongly. Salmon live within a wide range of salinities; therefore projected salinity declines associated with increased precipitation may not directly affect these species. Any decreases in upwelling associated with climate change would affect general productivity, resulting in less available food for various life stages of

[94] Druehl 2003, Grove et al 2002

salmon, but seasonal upwelling is projected to increase along the West Coast of North America[95], so the resulting increased nutrients might buffer some of the negative effects on salmon and other fin fishes. With that increased upwelling, however, might come the impingement of more corrosive (acidic) and deoxygenated waters on the shelves and nearshore environments, and this may, in turn, adversely affect finfish. Fish larvae, such as rockfish larvae will also be affected in these different ways by changes in upwelling, productivity, and water chemistry. Rockfish Conservation Areas will preserve at least some important adult habitat, and may be vital to rockfish survival in the context of these changes. Forage fishes such as sand lance are already thought to have been impacted by climate changes (www.foragefish.org); Sand lance spawn on lower intertidal beaches – and this habitat is expected to be negatively impacted by temperature changes (i.e., winter freezing kills eggs and dry hot summers will boil them) and by salinity changes due to increased precipitation, etc. Maintaining an intact nearshore environment, especially where forage fish are known to spawn, and habitats where other fishes take refuge, will help increase the resiliency of fin fishes to future climate changes.

Bivalves:

The projected changes in temperature, acidification, oxygen, and productivity will affect Clayoquot bivalve communities. Warmer temperatures may increase both beneficial and harmful plankton growth, which will influence area oyster farms in unpredictable ways. Acidification and deoxygenating will limit oyster growth, but it is possible that increased seasonal upwelling may offset some of the negative effects. Clams will also be impacted by extremes in temperature, but will also be limited by predation by the invasive European green crab, and by an increasing sea otter population. Geoduck may thrive under warmer sea temperatures, especially those deep enough to avoid sea otter predation.[96]

Marine macrophytes:

Eelgrass growth seems to increase when seasonal temperature variation moderates, i.e. cooler summers and warmer winters[97] (Tom *et al* 2003). However, greater rainfall may affect water transparency and light penetration in shallow coastal areas, thus reducing seagrass growth[98] . The projected warmer and dryer conditions could mean lower growth overall, even though we are currently experiencing increased growth. Giant kelp populations are increasing in Clayoquot Sound due to the presence of sea otters and the resultant reduced predation by sea urchins. Warmer temperatures will be beneficial for growth but only up to a certain point as Grove *et al* (2002) reported that extended

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[95] Snyder et al. 2003
[96] Noakes and Jamieson 1990, Ianson and Flostrand
[97] Tom *et al* 2003
[98] Hauxwell, J., Cebrian, J., Valiela, I., 2003.

periods of higher than normal temperatures and precipitation resulted in lower densities of kelp.

As an example of the complexity in predicting changes in the Clayoquot area, although the Ignace family in Hesquiaht Harbour has noted a disappearance of nearshore organisms, including Pacific rockweed and limpets, Pacific rockweed reductions have not yet been noted in other parts of Clayoquot Sound (though studies have not been conducted to measure change). This is interesting because the small changes in ocean acidification expected for the region will be locally buffered in front of the Ignace house at the old Hesquiaht village site by the presence of a limestone shelf.

Zooplankton:

Euphausiid (krill) populations have generally declined to low levels in Barkley Sound during the past two decades.[99] Although no parallel monitoring has been conducted in Clayoquot Sound, similar trends may be occurring there, and such indications of food declines may account for some of the finfish declines (such as salmon and herring) that have recently been observed. One explanation for these declines may be ocean acidification caused by climate change.[100] Due to their similarities, it is also plausible that changes in mysid production may somewhat parallel that of euphausiids, but parallel monitoring would be required to determine this.

Marine Birds:

Although not commercially important, marine birds are good indicators of ecological change. Cassin's Auklets are zooplanktivorous feeders (low on the trophic level) and have a small body size. Studies have shown that climate variations seem to have stronger effects on the survival rates of seabirds that feed at a low trophic level, have small body size, and a short lifespan.[101] Adult survival of female Cassin's Auklets was halved during extreme climate events between 1994 and 2008, showing their susceptibility to oceanographic variability that may be associated with climate change. On the other hand for Marbled Murrelets (a similar sized diving bird), recent studies[102] suggest a stable population in Clayoquot Sound and consistent use of nesting habitat within relatively undisturbed watersheds, despite changes in the marine ecosystem attributed to El Niño events and changes in prey stocks.

[99] Tanasichuk, 2002
[100] R. Tanasichuk, pers. comm, April 2010
[101] Morrison et al, in press
[102] Cragg and Burger, in press

New Species:

With changes in local climate and ocean conditions and biological community structure in Clayoquot Sound due to climate change, new species will arrive. These species will not necessarily have negative impacts, though they do show change. Rare or novel species observed recently include the Brown Pelican, feather boa kelp, Humboldt squid, Pacific mackerel, salmon shark, ocean sunfish, pacific butterfish, pacific pomfret, yellowtail and opah.[103] The extent to which these new species occupy niches left by species moving north, or compete with species still in the region is unknown.

Summary

The very nature of the oceans are changing – and rapidly. The influence on species distribution, population sizes and interactions is very likely to be massive. Table 6 summarizes the oceanographic impacts of climate change discussed above, their timelines and likelihoods of occurring.

Table 6: Oceanographic Impacts of Climate Change in the Clayoquot Sound

Impact	Timeline*	Likelihood**
↑ Deoxygenation	Short-term (already Observed)	Very Likely (to continue)
↓ Salinity		
↑ Sea Temp		
↑ Acidification		
↑ Sea level Rise		
↑ Storms, Storm Surge & Wave Heights		
Change in Currents		

* Time Scale = Short-term (0-10 years), Medium-term (11-30 years), Long-term (31+ years)
** Likelihood Scale = Very Likely, Likely, More Likely Than Not, Unlikely, Very Unlikely

Direct impacts of physical ocean changes on individual species may be significant in itself. Table 7 summarizes potential species impacts from climate change discussed above, their timelines and likelihoods of occurring.

[103] Okey and Wing 2010

Table 7: Species Impacts from Climate Change in the Clayoquot Sound

Impact	Timeline*	Likelihood**
Marine Mammals ↓Grey whales, ↓Stellar Sea lions, ? Sea Otters	Short-term	Likely
Finfish ↓Sockeye & Chinook, ↓Rockfish, ↓Sandlance		Very Likely
Shellfish ↓Pacific Oyster & Manila Clam, ↑Geoduck		Likely
Marine Plants ↑Eel grass & Kelp (large forests only), ? Rockweed		Likely
Zooplankton ↓Krill		Likely
Marine Birds ↓Cassin's Auklet, ? Marbled Murrelet		Likely
Novel Species ↑ Brown Pelican, ↑Feather Boa Kelp, ↑Humbolt Squid, Pacific Mackerel, Salmon Shark, Ocean Sunfish, Pacific Butterfish, Pacific Pomfret, Yellowtail, Opah		More Likely than not (to continue to change)

* Time Scale = Short-term (0-10 years), Medium-term (11-30 years), Long-term (31+ years)
** Likelihood Scale = Very Likely, Likely, More Likely Than Not, Unlikely, Very Unlikely

Species are expected to move into, and out of the region in response to changing physical conditions – and novel species are already observed in the Clayoquot Sound area, and their interactions with existing species populations is yet to be played out. Some important functional species - whales, sea otters, seals – are currently bouncing back from historic lows due to hunting pressure, however all these species are likely to be negatively impacted by climate change. Impacts on species at the base of the food chain – such as krill – are likely to be negative, but difficult to predict due to the large number of interacting factors. The potential for such changes to cascade through the marine ecosystem are very large and highly uncertain. As a result, key organising processes are likely to change, and could cause significant changes – affecting overall resilience of this ecosystem in the short to mid-term.

Climate Change and Ecosystems – A Resilience Summary

Ecosystems are already showing changes that appear related to climate change, and we know with a high likelihood that the rate and magnitude of change will increase into the future.

In Clayoquot Sound, marine systems will change fastest because they are more 'fluid' and some species can move more easily. Temperature changes will affect all systems – but the physical changes in the ocean are expected to be dramatic, and cause severe changes to marine biodiversity. Humans will need to alter their management regimes to take this into account – changing expectations about what the ocean will offer, and how certain this will be, will be a key part of managing for uncertainty in the future. The ocean system has the potential to quite radically change its state and dynamic processes, and may therefore not be resilient into the near future as feedback loops alter key processes dynamically within this system. There is high certainty that the marine systems will change significantly from their current patterns, and that this will affect the abundance and distribution of specific species important for the First Nations in Clayoquot Sound. Novel species have already arrived in this system – and we do not know how they are interacting with species already in this environment. Some may fill niches left by species moving further north, while others will likely compete with existing species – perhaps increasing the rate of decline for maladapted species less able to move. There is however high uncertainty as to the future nature of the marine ecosystem – because of the high level of complexity and potential for cross-scale interactions and multiple thresholds being crossed – the potential results of which are largely unknown today.

The forested ecosystems of Clayoquot Sound, in contrast, are likely relatively resilient naturally because of the predominance of slow disturbance factors and because they create and maintain their own micro-climate and internal processes. In addition, these terrestrial forests are likely to be buffered from some of the more significant climate changes predicted elsewhere. The cool wet climate will become warmer and wetter still – but is unlikely to exceed ecological tolerances for many forested species within the next few decades, though in the longer term the understory of the forest and the values that come from there are likely to shift to species more adapted to warmer climate. The current relatively intact condition of the forests of Clayoquot Sound further buffers the effects of climate change - future land management decisions will be important in maintaining these values. There is reasonable likelihood however that the forested systems will remain resilient over the next century, assuming that management practices continue to be precautionary, and become more so as required.

The freshwater aquatic system links terrestrial ecosystems to the marine – providing crucial ecosystem services including fresh water and salmon spawning habitat, as well as high biological diversity in the hydroriparian zones. This system has a natural resilience – historically adapted to respond to naturally highly variable seasonal conditions. With climate change particular processes may change sufficiently to cause threshold effects for some key species. Likely most important to First Nations may be the potential impacts to spawning salmon as temperatures exceed thermal tolerances particularly for sockeye. However, the potential for increased sedimentation may have a significant interaction with light levels and benthic primary productivity in the near-shore zone which could have significant impacts at multiple scales throughout the marine environment. This type of cross-scale and cross-realm impact is very hard to predict or to manage.

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Chapter 5

Potential Socio-Economic Impacts of Climate Change in the Clayoquot Sound: A Vulnerability Assessment

contents

Introduction

Climate vulnerability can be described as the degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes.[104] The following section is an assessment of the vulnerability of Ahousaht, Hesquiaht and Tla-o-qui-aht First Nations to potential climate changes and its biophysical impacts to 2080.

The Clayoquot communities, like many First Nations, have seen an extraordinary amount of change to their way of life over the last century. They have experienced colonization, epidemics, the imposition of the reserve and the residential school systems, continued encroachment by outside interests intent on carving up their traditional territory and resources, and the decline of the fishery and the forest sectors. They have also experienced numerous climate cycles, ecological cycles and natural disasters.

Despite these changes or disturbances, the Clayoquot communities have survived and are increasingly thriving. The people continue to fish, hunt and collect for food, they increasingly have control in managing their territorial resources and the community is actively engaged in political and cultural affairs. They have also managed to preserve large tracts of traditional territory, providing relatively intact ecosystems, abundant with old growth forests, clean water, and plentiful fish and wildlife. And they continue to rebuild their communities, with new schools, new infrastructure and new services, while reviving important cultural practices.

It is a credit to the communities' adaptability and persistence that they have survived these changes but now the communities face a new challenge in the form of climate change that will again impact many aspects of their lives. As is indicated in Cahpter 4, the ocean and, to a lesser extent, the land are likely to undergo significant changes in the very near term, which will impact marine species, shorelines, freshwater flows and the communities which depend on these natural assets. Because the Clayoquot communities are so closely tied to the land and the ocean, they are particularly vulnerable. Chief among these vulnerabilities are threats to health and safety, food supply, livelihoods, infrastructure and shelter and various cultural, social and political resources. Past adaptation successes would suggest that the communities will adapt to these changes but how well they adapt depends on how well they are prepared.

Below is a climate vulnerability assessment, which evaluates the state of preparedness for climate change among the Ahousaht, Hesquiaht and Tla-o-qui-aht communities. The methodology used is based loosely on the WEHAB+ framework developed by the Tyndall

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[104] IPCC². Intergovernmental Panel on Climate Change. Climate Change 2007. Synthesis Report.

Group for Climate Change Research[105] whichich looks at how key community supports or assets are impacted by climate change. The key assets in this case include:

- Health and Safety
- Food Supply
- Livelihood/Economy
- Infrastructure and Shelter
- Cultural, Social and Political Resources

Ecological health, which is also an important asset to evaluate in climate vulnerability, is not discussed here, because it has already been thoroughly discussed in Chapter 4).

Health and Safety - *Moderate Vulnerability*

Climate change is likely to stress what might be described as an already vulnerable state of health in the Clayoquot communities; however, the communities appear to be well prepared for occasional natural disasters through their emergency preparedness programs and strong family support network, perhaps less so if these events reccur regularly.

As mentioned in Chapter 2, all three of the communities face health challenges related to asthma, diabetes, heart disease and depression but increasingly the communities are addressing the causes of these illne (dietary changes, new house construction and house renovations, traditional healing and employment development). Emergency preparedness skills and awareness in the communities are also relatively strong, with the communities well organized to deal with occasional fires, storms, tsunamis, earthquakes and epidemics. Indeed, theAhousaht in particular are known around the province for their well educated and well prepared volunteers.

The expected climate changes are chiefly a threat to health and safety from increased storm severity and rain-induced flooding (Table 2). The most likely short-term vulnerabilities are those related to stress or harm from infrastructure failure, particularly in the low lying areas (below 5m). More likely than not, there are also risks associated with boating and more severe storm activity in the short-term. In the mid-term, potential impacts include mild health risks related to exposure to new pests and diseases as temperatures increase.

A primary consideration should be the large amount of new housing to be built in the next few years and a need to be proactive about using the best designs and available features to deal with air circulation and mould as a warming, precipitation and possibly windsincrease.

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[105] Emma L. Tompkins . Emma L. Tompkins, et al. *Surviving Climate Change in Small Islands – A Guidebook*

At this time, although the communities are very resourceful, there is no real strategy for dealing with more severe storm and rain conditions or increases of pest and disease, if they arise on a wide scale or in a recurrent manner. This situation could leave the communities' health and safety moderately vulnerable.

Table 2: Health and Safety Vulnerabilities in the Clayoquot Communities

Climate Vulnerability	Timeline*	Likelihood**
Health		
• Increased in respiratory stress (↑rain & household mould)	Short-term	Very likely
• Increased discomfort or stress due to infrastructure failure or household displacement (↑storm & rain severity)	Short-term	Very likely (power)/ Likely (other infra)
• Increased occurrence of new pests and diseases (↑temperatures)	Mid-term	Likely
• Increased health issues due to dietary changes (↓sea water quality, ↓salmon/shellfish)	short-term	More likely than not
Safety		
• Increased physical boating danger (↑storm severity)	Short-term	More likely than not
• Increased physical harm from landslides (↑rain severity)	Short-term	Very unlikely

* Time Scale = Short-term (0-10 years), Medium-term (11-30 years), Long-term (31+ years)
** Likelihood Scale = Very Likely, Likely, More Likely Than Not, Unlikely, Very Unlikely
Source: Interviews with community leaders.

Food Supply - *Moderate Vulnerability*

Climate change is likely to cause gaps in traditional seafood supplies in the Clayoquot Sound. This may be offset to some degree by new seafood species moving into the area and by the relatively benign effects on the terrestrial environment but overall the effects of climate change will likely result in food supply uncertainty.

The Clayoquot communities depend heavily on seafood for their diet, with approximately 60% of the Nations' annual protein derived from wild marine sources (fish, clams, oysters, sea urchin etc.). Much of this seafood is provided on a relatively regular basis through household fishing and collecting activities as well as through the community food fish program, household smoking and canning and community bartering. Hunting for deer, ducks or geese as well as collecting and preserving wild plants and berries supplement the largely seafood diet for at least part of the year. Fresh produce, dry goods and non-wild meats are obtained mainly off reserve.

As is indicated in Chapter 4, climate change will soon likely have a significant impact on many marine species, many of which the Clayoquot Nations depend on for food. Some important species such as Sockeye and Chinook salmon, Manila clams and Pacific Oysters will likely diminish significantly as temperatures and/or acidity levels rise (Table 3). Other species such as Coho salmon and Chum (Dog) salmon and Geoduck will likely continue to survive under new oceanic conditions. This means that some traditional seafoods will still be available but seasonal gaps may arise.

Table 3: Food Supply Vulnerabilities in the Clayoquot Communities

Climate Vulnerability	**Timeline***	**Likelihood****
Seafood		
• Decline in some traditional seafoods (sockeye, chinook, rockfish, clams & oysters)	Short-term	Very Likely
• Some traditional seafoods may survive (coho, chum, geoduck)	Short-term	More likely than not
• Increase in new marine species (squid, mackerel, southern rockfish, etc.)	Mid-term	Very Likely
Traditional Plant Foods/Wildife		
• Decline in Montane and Alpine dependent species	Mid to Long-term	Likely
• Increase in red cedar/western hemlock dependent species	Mid to Long-term	Likely
Agriculture		
• Increase in growing season and productivity	Short-term	Very likely

* Time Scale = Short-term (0-10 years), Medium-term (11-30 years), Long-term (31+ years)
** Likelihood Scale = Very Likely, Likely, More Likely Than Not, Unlikely, Very Unlikely
Source: Discussions with Katie Beech, Neil Hughes, Tom Okey and Rachel Holt

At the same time, new marine food species such as mackerel, squid and other finfish may emerge in the Clayoquot Sound, which may substitute for lost food species. Exactly when this shift in species will begin and whether it will occur concurrently to offset the loss of the other species or compete with them is uncertain. What is clear is that chemical and physical changes to the ocean are already beginning and that this trend together with past over-fishing and habitat loss will undoubtedly stress existing traditional food fish species further.

The terrestrial-based food supply, on the other hand, is likely to be benignly affected by the projected climate changes, with the existing hemlock/cedar forest ecosystem expected grow in area and Montane and Alpine ecosystem expected to shrink concurrently. This would suggest that food from hunting or gathering in the hemlock/cedar zones may remain relatively stable or increase. As well, the growing season is expected to expand significantly such that the entire year is likely to become frost free, which would suggest that opportunities for wild plant collection and fresh produce cultivation will expand.

Hence, while some traditional marine foods may decline with climate change, others may persist and new species may arise. Moreover, as temperatures increase, growing seasons will expand and present better opportunities for food cultivation. In the past, the Clayoquot communities have adapted their food supply to changes in ecological or regulatory conditions. When fish stocks began collapsing in the 1990s and commercial fish licenses began declining, the communities adjusted by eating less fish or depending more on the community fish program or they ate more wild meats and berries or bought more groceries. They will no doubt adjust again if fish stocks decline further or shift; however, it would perhaps be more beneficial to plan for such changes now so that there is less stress on the communities when the changes do occur and so that each one can choose the level of self-reliance they wish to have.

Presently, the Clayoquot communities are educating their people about gardening and healthy diets, with the hope of strengthening local food security and health. If this is adopted across the communities in a permanent way, this will leave them less vulnerable to shifts in the wild food supply. Presently, there is also planning taking place around fishing rights, which may secure the communities more access to existing fish stocks. There is not however, any strategizing presently about how to deal with food supply and the probable shift in marine species. This lack of planning could leave the communities moderately vulnerable as climate change impacts begin to occur.

Livelihood/Economy - *Moderate Vulnerability*

Although the economies of the Clayoquot communities may be slightly buffered from climate change due to their dependence on the public and forest sectors, they are relatively small and emerging with modest skill bases and vulnerable to fishery and tourism declines, which leaves them moderately vulnerable to climate change.

As indicated in Chapter 2, household incomes are relatively low in the three Clayoquot communities, heavily dependent on seasonal employment and social assistance. This situation leaves the communities vulnerable to climate change in the sense that it affords households and the local government little discretionary income to invest in coping with or adapting to climate impacts.

The Clayoquot economies are also relatively undiversified, which may be a mixed blessing in terms of climate change. The forest sector, despite having to deal with worsening terrain stability issues and pests, will likely benefit from the coming clmate changes, since cedar and hemlock forests are expected to grow in area (Table 4). All of the Clayoquot communities are invested in the forest sector through Iisaak Resouces Ltd. and therefore all stand to benefit.

The dependence of the communities on the fishery/aquaculture sector, however, may be risky, since this sector will likely be the most destabilized climate change. The Ahousaht are particularly vulnerable here, since they are the most heavily invested in this sector.

Table 4: Livelihood Vulnerability in the Clayoquot Communities

Climate Vulnerability	Timeline*	Likelihood**
Fishery		
• Decline in some traditional seafood (sockeye, chinook, rockfish, clams & oysters)	Mid-term	Very Likely
• Some traditional seafoods may survive (coho, chum, geoduck)	Mid-term	Very Likely
• Increase in new seafoods (squid, mackerel, southern rockfish, etc.)	Mid-term	Very Likely
• Increased vulnerability to damage of boats, equipment & habour	Short-term	More likely than not
• Increased vulnerability to conflict over fish stocks	Short-term	More likely than not
Forestry		
• Increase in area of red cedar/western hemlock growth	Mid-term	Likely
• Increased risk of vulnerability to landslides and sedimentation may further restrict logging	Mid-term	Likely

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Tourism	Timeline*	Likelihood**
• Increased uncertainty re tourist visitations (↑ beach erosion, ↓ sports fishery, ↑temperatures)	Short to Mid-term	Likely
General		
• Decline in business (↑ housing & public infrastructure failures)	Short-term	More likely than not

* Time Scale = Short-term (0-10 years), Medium-term (11-30 years), Long-term (31+ years)
** Likelihood Scale = Very Likely, Likely, More Likely Than Not, Unlikely, Very Unlikely
Source: Discussions with Katie Beech, Neil Hughes, Tom Okey, Martin Carver & Don MacKinnon.

The Tlaoquiaht are the only Clayoquot community heavily invested in the tourism sector but the other two communities have aspirations to grow this sector as well. Climate change will likely increase uncertainty in this sector, however, since it may both benefit and threaten it. Warmer and drier summers may attract greater numbers of tourists to the area but also increase the risk of water shortage. Sports fishing stocks may be put in jeopardy with ocean changes and more severe winter storms may damage important infrastructure (beaches, wharves, and resorts) which attracts or serves the tourist population.

All three of the commununities, particularly the Hesquiaht are dependent on the public sector (Band Government, education, health, and social assistance transfers) for jobs and income. And while this sector can only support a limited number of jobs or income, it is relatively insulated from the effects of natural disturbances and hence may provide a somewhat of a buffer from the economic impacts of climate change in the future.

Buffer or no buffer, however, the knowledge and technical base of a community is increasingly important to a dynamic and adaptatble economy. At present, the skill and knowledge levels in the Clayoquot communitiesis relatively low. These levels have improved over the years with increased technical and university training but they are still far below the non-First Nation levels, which leaves the Clayoquot communities vulnerable. If they are going to compete with other First Nations and the rest of the world in the future and they are going to adapt to the changing circumstances that climate change will bring, the more knowledge and training they have (traditional or otherwise), the better.

Lastly, the Clayoquot communities are hoping to strengthen their local economies by negotiating treaties and greater control over the natural resources in their traditional territories. However, little is being discussed in these negotiations regarding how climate change may affect these resources or their livelihoods. To the extent that climate change impacts are not being considered in these negotiations, the communities leave themselves vulnerable.

Infrastructure and Shelter - *High Vulnerability*

The Clayoquot First Nation communities manage a wide range of infrastructure and housing, which will likely be stressed by climate changes, particularly by increased storm severity. Given limited resources to upgrade and maintain these assets and little consideration for climate impacts on management planning and new development, the communities' infrastructure and shelter are highly vulnerable.

Infrastructure and housing are very important to the welfare and livelihood of a community. Without reliable infrastructure and housing most communities cease to function and evolve. This is particularly the case in remote communities, which have few alternatives and few resources to maintain infrastructure when it fails. The Clayoquot communities (excepting Ty'histanis & Esowista) are relatively remote, with basic but wide ranging infrastructure, modest capital and operating budgets and few skilled staff. Although each of the communities has their own particular infrastructure vulnerabilities (see Appendix 1) there are a number of important commonalities in all communities (Table 5). These vulnerabilities, which are generally related to storm damage include:

- storm water drainage challenges,
- erosion and flooding risks from storm water surges or freshwater flows,
- sewer failure due to outfall blockage or flooding,
- increased household mould and mildew risks due to increased winter precipitation, and
- increased frequency of power and telecommunication outages due to severe storms

Storm water drainage is a key vulnerability in all communities, because housing in many of the communities is located in low lying areas where water tends to collect. This is particularly the case in the older neighbourhoods of Hesquiat Harbour, Ahousaht and Opitsat. Similarly, the lower level of Esowista and the new community of Ty-histanis are also vulnerable to stormwater drainage threats due to their proximity to local bogs and streams that empty into the ocean.

Erosion and flooding from storm surges or increased winter precipitation is also a key vulnerability in all communities, risking damage to breakwaters, wharves, housing, pipe supports, pump houses, roads and solid waste sites. Again, the low lying or shoreline areas of Ahousaht, Opitsat, Esowista and Hesquiaht all face risks of inundation from severe storms. They also face flooding associated with intense precipitation. By way of example, the breakwater in Hot Springs Cove was damaged by a storm this year for the first time.

Hesquiaht, Ahousaht, Opitsat and Esowista (by way of the Tofino outfall) also face the risk of sewer failure due to outfall blockage. This blockage is a result of severe storms moving sand over the end of the outfall pipes and clogging their spouts. This recently happened to the Tofino outfall, getting buried by up to 20' in sand before a further event cleared it. There is also a risk of lift stations and septic fields/tanks being inundated by storm surges or floods, particularly in Hesquiaht, Opitsat and lower Esowista.

Table 5.
Infrastructure and Shelter Vulnerabilities in the Clayoquot Communities

Climate Vulnerability	Ahousaht	Hesquiaht	Tla-o-qui-aht		Timeline*	Likelihood**
			Opitsat	Esowista/ Ty-histanis		
Housing and Public Buildings						
• ↑ damage to low lying foundations (flooding/ storm surges)	√	√	√	√		More likely than not
• ↑ risk of roof damage (blow down, windforce)	√	√	√	√	Short-term	Likely
• ↑ risk of mould/mildew (driven rain)	√	√	√	√		Likely
Water Supply						
• ↑ flooding pump house (storm surge)	√	√	√			
• ↑ damage to pipe support (erosion)	√	√	√	√		
• ↑ pump stoppage due to power interruptions	√	√	√	√	Short-term	More likely than not
• ↑ frequency of siltation, water turbidity and boil alerts	√	√	√			
• ↑ Risk of changes to well capacity or salt-water intrusion into aquifer				√		

Table continued next page

Table 5.
Infrastructure and Shelter Vulnerabilities in the Clayoquot Communities

Climate Vulnerability	Ahousaht	Hesquiaht	Tla-o-qui-aht		Timeline*	Likelihood**
Sewer						
• ↑ risk of outfall obstructed with sand	√		√	√	Short-term	More likely than not
• ↑ risk of damage to sewer outfall lift station or sewer lines from flooding/inundation	√	√	√	√		
• ↑ risk of septic field/tanks failure from flooding/inundation	√	√	√			
• ↑ risk of exceeding sewer capacity resulting in back-up and overflow	√		√	√		
Stormwater Drainage						
• Flows from heavy rains or surge inundation could exceed drainage capacity in low-lying areas (below 5m) causing flooding and erosion	√		√	√	Short-term	Likely
• ↑Risk of exceeding capacity of stormwater detention pond		√		√ Ty-histanis		More likely than not
Wharves/ Docks						
• ↑ Damage to Government wharf or dock due to storms	√	√	√		Short-term	Likely
Breakwaters						
• ↑ Settling or movement of existing rocks near cemetery and existing beach shore protection	√	√			Short-term	Likely
• ↑ Erosion at existing timber break-water and access pathway, near cemetery and Band Office		√	√			

Table continued next page

Table 5.
Infrastructure and Shelter Vulnerabilities in the Clayoquot Communities

Climate Vulnerability	Ahousaht	Hesquiaht	Tla-o-qui-aht		Timeline*	Likelihood**
			Opitsat	Esowista/ Ty-histanis		
Telecommunications						
• ↑Service disruption from power outages, landline or microwave tower damage due to storm activity (wind & lightening)	√	√	√	√	Short-term	Very likely
Hydro						
• ↑ Power interruptions (wind)	√	√	√	√	Short-term	Very Likely
• ↑ Storm surge erosion of pole supports	√		√			More likely than not
Roads						
• ↑ Risk of road flooding and erosion below 5m (↑ rain intensity and risk of exceeding culvert capacity)	√	√	√		Short-term	Likely
• ↑Risk of erosion or slumping along steep slopes (↑ rain intensity)			√	√		More likely than not
Solid Waste						
• ↑ Slumping and leaching • from landfill (↑ erosion along slope toe due to ↑ storm surges and rain)	√		√		Short-term	More likely than not

* Time Scale = Short-term (0-10 years), Medium-term (11-30 years), Long-term (31+ years)
** Likelihood Scale = Very Likely, Likely, More Likely Than Not, Unlikely, Very Unlikely
Source: Discussions with community leaders and Don MacKinnon.

All communities also face increased risk of mould and mildew in their homes and public buildings due to increased precipitation. New home design in Ahousaht and Ty'histanis/Esowista may address this vulnerability but many older homes will likely worsen without significant improvements to rain screens and ventilation systems.

Power and telecommunication outages, which are common already in the whole Clayoquot Sound due to storm winds, windthrow and lightning strikes are likely to become more frequent in the future with more severe storms expected. Remote communities, like Ahousaht, Hequiaht and Opitsat, which are usually attended to last, are likely to suffer the most.

Many of these risks are already known but not necessarily incorporated to existing management planning and new development planning, because existing policies or standards do not require it.

Given the climate risks and the relatively modest capital and maintenance budgets, scarce staff as well as a lack asset management planning that incorporates the risks above, the communities' infrastructure and shelter are highly vulnerable to expected climate changes.

Cultural, Social and Political Resources - *Moderate Vulnerability*

While social, cultural and political resources are relatively strong in the Clayoquot First Nation communities and getting stronger, the physical impacts imposed by climate change will stress these resources, in some cases, significantly. Because there is little awareness or planning for these stresses, the communities' cultural, social and political resources are moderately vulnerable.

Despite a barrage of challenges since colonization, the Clayoquot communities have managed to survive and increasingly thrive. Much of the explanation for this incredible resilience is related to the communities' ties to its traditional culture and world view, its strong family and clan support system and its ability to make decisions as a community unit. These cultural, social and political resources will stand the community in good stead for expected climate changes.

Table 6: Cultural, Social and Political Vulnerabilities

Climate Vulnerability	Timeline*	Likelihood**
Culture		
• Decline in traditional fishery may weaken cultural practices (diet, food gathering and livelihood)	Short-term	Likely
Social		
• Decline in traditional fishery may weaken livelihoods & subsistence and family relations • Decline in traditional fishery may increase conflict with other non-First Nation fishers, which may stress relations	Short-term	Likely

Political/Administrative		
• ↑ Storm and rain damage may stress the community's funds and capacity to govern for a time	Short-term	Likely

* Time Scale = Short-term (0-10 years), Medium-term (11-30 years), Long-term (31+ years)
** Likelihood Scale = Very Likely, Likely, More Likely Than Not, Unlikely, Very Unlikely
Source: Discussions with community leaders.

Having said this, climate change and the accompanying physical and economic impacts will likely stress the cultural, social and political resources of the Clayoquot communities significantly and sooner than later (Table 6). Increased storm severity will likely flood and erode certain cultural sites (e.g. cemeteries, heritage sites) near the shore and in low lying areas. The decline in traditional fisheries will likely impact seasonal food collection, diets and possibly feasts and ceremonies, since salmon and salmon fishing are integral to the Clayoquot way of life.

Similarly, storm impacts and fishery impacts will likely weaken community livelihood opportunities, which in turn may stress family incomes and family relations. A decline in the traditional fishery may also create tensions and conflicts with non-First Nations fishers, as First Nations struggle to increase their share of a shrinking resource and non-First Nations try to maintain their share just to remain viable.

These cultural and social impacts as well as impacts on community housing and infrastructure may well stress the communities' political resources (the local Band and Hereditary governments) beyond their fiscal capacity and their ability to govern effectively at times.

Dealing with such issues as infrastructure, food supply, health and safety and livelihood vulnerabilities will largely address the resulting cultural, social and political impacts but ensuring that cultural, social and political resources are strong will also help in addressing the other socio-economic impacts of climate change. These issues are known and the cultural, social and political resources of the communities are fairly strong and yet these issues have not been planned for in any detail as yet. Until they are planned for, the social, cultural and political resources in the Clayoquot First Nation communities will be moderately vulnerable.

References

Intergovernmental Panel on Climate Change. Climate Change 2007. Synthesis Report. http://www.ipcc.ch/pdf/assessment-report/ar4/syr/ar4_syr.pdf

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Appendix 1

Individual Community Vulnerability Assessments

Ahousaht Vulnerability Assessment

Table 7: Key Socio-Economic Vulnerabilities for Ahousaht

Health and Safety		
• Somewhat remote and modest resources on-reserve but emergency preparedness volunteers well trained and organized		
Livelihood/Economy		
• Relatively vulnerable to disruptions in fishingand fish farming economy, • Capacity building in sawmilling and construction a good long-term investment • Although some progress recently, further efforts to diversify the economy very important.		
Cultural/Social/Political		
• Fairly strong cultural, social and political resources • Cemetery vulnerable to erosion from storm surges		
Housing & Infrastructure	**Timeline***	**Likelihood****
Housing and Public Buildings		
• Houses in low-lying areas vulnerable to inundation and erosion from storm surge and rain-induce flooding • Roofs and siding vulnerable to damage from wind force in unsheltered areas • Old houses vulnerable to increased mould/mildew from driven rain • New houses must be designed with the best technology for ventilation to reduce mould/mildew	Short-term	Likely

Table continued on next page

Table 7: Key Socio-Economic Vulnerabilities for Ahousaht

Water		
• Pump house vulnerable to inundation from storm surge • Pipe support from reservoir intake vulnerable to erosion or under water breakage • Increased vulnerability to siltation, water turbidity and boil alerts • Vulnerable to water shortages in late summer	Short-term	More Likely than Not Likely Very Likely Very Likely
Sewer		
• Outfall vulnerable to obstruction with sand • Sewer vulnerable to exceeding capacity resulting in back-up and overflow • Sewer near gym vulnerable to damage from surge inundation/ erosion	Short-term	More Likely than Not Likely Likely
Stormwater Drainage		
• Flows from heavy rains or surge inundation could exceed drainage capacity in low-lying areas (below 5m) causing flooding and erosion	Short-term	Likely
Breakwaters		
• Existing rocks near cemetery and beach vulnerable to settling or movement	Short-term	Likely
Roads		
• Roads vulnerable to flooding and erosion in low-lying areas (below 5m) (due to ↑ rain intensity and risk of exceeding culvert capacity	Short-term	Likely
Wharves/ Docks		
• Government and Hydro docks vulnerable to damage from storm surges.	Short-term	Likely

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Table 7: Key Socio-Economic Vulnerabilities for Ahousaht

Energy/Hydro		
• Hydro power vulnerable to interruptions due to windthrow, esp. on Kakawis • Power poles near shore vulnerable to storm surge erosion	Short-term	Likely
Solid Waste		
• Dump site vulnerable to slumping and leaching near shore (due to storm surges and increased rain)	Short-term	Likely
Telecommunications		
• Towers vulnerable to windthrow and lightning strikes	Short-term	Likely

* Time Scale = Short-term (0-10 years), Medium-term (11-30 years), Long-term (31+ years)
** Likelihood Scale = Very Likely, Likely, More Likely Than Not, Unlikely, Very Unlikely
Source: Discussions with community leaders and Don MacKinnon.

Tla-o-qui-aht Vulnerability Assessment

Table 8: Key Soci-economic Vulnerabilities for Tla-o-qui-aht

Health and Safety		
Moderately vulnerable to natural disasters/ emergencies (Opitsat) • Population does not appear very aware of emergency procedures • Evacuation facility on hill (Opitsat) not well outfitted. • Access to Tofino and Ucluelet resources requires boat		
Livelihood/Economy		
• Local economy relatively vulnerable to disruptions in the tourism economy. • Shortage of jobs tends to lead to out-migration of skilled members. • Capacity building in construction a good long-term investment.		
Cultural/Social/Political		
• Cemetery vulnerable to erosion from storm surges (Opitsat)		
Shelter & Infrastructure	**Timeline***	**Likelihood****
Housing and Public Buildings		
• Houses in lower Esowista and Opitsat vulnerable inundation from storm surge	Short-term	More Likely than Not
• House foundations in Opitsat vulnerable to rain induced flooding and erosion		Likely
• High vulnerability to roof damage from wind force in Lower Esowista and Opitsat		Likely
• Old houses vulnerable to increased mold/mildew from driven rain and condensation		Likely
• New houses must be designed with the best technology for ventilation to reduce mould/mildew		Likely

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Table 8: Key Soci-economic Vulnerabilities for Tla-o-qui-aht

Sewer		
Opitsat • Outfall vulnerable to obstruction with sand • Septic tank vulnerable to infill / overflow • Sewer capacity vulnerable to back-up and overflow • Sewer pipes near cemetery and Band office vulnerable to damage from surge inundation/erosion Ty'histanis-Esowista • Regional Sewage Collection(Tofino) vulnerable to obstruction with sand • Lift station vulnerable to damage/ overflow and sewer backup from flooding/inundation in Lower Esowista • Sewer collection/forcemain piping near on-site streams vulnerable to damage from erosion	Short-term	More Likely than Not Likely Likely More Likely than Not More Likely than Not Likely More Likely than Not
Stormwater Drainage		
Opitsat		
• Base of slope by existing 12-lot subdivision vulnerable to flooding	Short-term	More Likely than Not
• Culvert under water treatment plant access road vulnerable to flooding	Short-term	More Likely than Not
Ty'histanis-Esowista		
• Stormwater collection systems and inlets/ outlets to sediment ponds near south tributary of Esowista vulnerable to erosion	Short-term	More Likely than Not
• Bridge foundations and culverts at Esowista Creek vulnerable to erosion	Short-term	More Likely than Not

Table continued on next page

Table 8: Key Soci-economic Vulnerabilities for Tla-o-qui-aht

Roads		
Opitsat • Roads vulnerable to flooding and erosion in low- lying areas (below 5m) • Vulnerability to erosion or slumping along steep slopes from Kakawis to Opitsat (limited culverts) *Ty'histanis-Esowista* • Roads vulnerable to flooding and erosion in low- lying areas (below 5m) • Vulnerability to erosion or slumping along steep slopes and along on-site stream channels/ sidewalls	Short-term	Likely More Likely than Not Likely More Likely than Not
Wharves/ Docks		
Opitst • Government dock vulnerable to damage from storm surges • Approach ramp vulnerable to wave erosion	Short-term	Likely Likely
Breakwaters		
Opitsat • Existing timber breakwater and access pathway near cemetery and Band Office vulnerable to erosion. Every year losing more sand/dirt from shore. *Ty'histanis-Esowista* • Lower Esowista vulnerable to erosion potentially damaging residences, Day-Care and road/water/sewer infrastructure (storm-surge)	Short-term	Likely Likely

Table continued on next page

Table 8: Key Soci-economic Vulnerabilities for Tla-o-qui-aht

Solid Waste		
Opitst • Capped landfill vulnerable to slumping and leaching from shore erosion below and rain-induced erosion above.	Short-term	More Likely than Not
Telecommunications & Hydro		
Opitsat • Risk to telephone communications from extreme weather (lightening)	Short-term	Likely
Ty'histanis-Esowista • Power poles vulnerable to windthrow	Short-term	Very Likely

* Time Scale = Short-term (0-10 years), Medium-term (11-30 years), Long-term (31+ years)
** Likelihood Scale = Very Likely, Likely, More Likely Than Not, Unlikely, Very Unlikely
Source: Discussions with community leaders and Don MacKinnon.

Hesquiaht Vulnerability Assessment

Table 9: Key Soci-economic Vulnerabilities for Hesquiaht

Health and Safety
Quite vulnerable to natural disasters/emergencies • Isolated (1.5 hr by boat) • Few emergency resources on reserves (1st Responder, no Fire department) • Telephone system undependable for alerting members
Livelihood/Economy
• Very modest and undiversified economy, vulnerable to further out-migration
Cultural/Social/Political Resources
• Fairly modest cultural, social and political resources because of the small size of the community and because much of Council lives off reserve

Shelter & Infrastructure	**Timeline***	**Likelihood****
Housing and Public Buildings		
• Houses in low-lying areas vulnerable to inundation and erosion from storm surge and rain-induce flooding • Roofs and siding vulnerable to damage from wind force in unsheltered areas • Old houses vulnerable to increased mold/mildew from driven rain and condensation.	Short-term	More Likely than Not Likely Likely
Water		
• Water intake and sediment tanks at Refuge Creek vulnerable to landslide debris and stream sediment transport changes affecting (also affects water quality) • Pipe support from intake to tank vulnerable to erosion (↑rainfall intensity) or windthrow • Well (s) in Hesquiaht Harbour vulnerable to run dry	Short-term	Very Likely More Likely than Not Likely

Table continued on next page

Table 9: Key Soci-economic Vulnerabilities for Hesquiaht

Sewer		
• Sewer outfall lift station in Refuge Cove vulnerable to damage from storm surge • Septic field/tanks in Hesquiat Harbour vulnerable to damage from storm surge	Short-term	More Likely than Not Likely
Wharves/ Docks		
• Government dock(s) and wharves vulnerable to storm surges (Hesquiaht Harbour and Refuge Cove)	Short-term	Likely
Roads		
• Road vulnerable to flooding and erosion in low-lying areas (below 5m) (↑ rain intensity and risk of exceeding culvert capacity)	Short-term	Likely
Stormwater Drainage		
• ↑ risk of flooding/erosion in low-lying areas (below 5m) from heavy rainfall or storm surge in Hesquiat Harbour • ↑risk of exceeding capacity of stormwater detention pond or new storm drain system at Refuge Cove	Short-term	Likely More Likely than Not
Breakwaters		
• Existing rocks/logs breakwater Hesquiaht Harbour practically submerged, very vulnerable to storm surges.	Short-term	Very Likely
Telecommunications & Hydro		
• Risk to telephone communications from extreme weather (lightening) Refuge Cove • Off-grid power systems already breaks down regularly and so does the back-up system. The system is very vulnerable to extreme weather (wind)	Short-term	Very Likely

* Time Scale = Short-term (0-10 years), Medium-term (11-30 years), Long-term (31+ years)
** Likelihood Scale = Very Likely, Likely, More Likely Than Not, Unlikely, Very Unlikely
Source: Discussions with community leaders and Don MacKinnon.

Chapter 6

Community-based Climate Adaptation Strategies for Clayoquot Sound

contents

Adaptation Drivers

Although the Clayoquot communities know that they will have adapt to whatever comes their way, the motivation to take seriously a planning process for adaptation to climate change is generated by a number of drivers.

Changing weather and ecological conditions

As indicated in Section 3, the communities are aware that their climate is changing and that their natural environment is changing. They are increasingly concerned about coastal erosion, stronger storms, warmer winters and waters, and dwindling fish stocks and how this may affect their way of life and their children's way of life in the future.

Media Reports

Increasingly the communities are learning from the media of more dramatic climate changes and impacts in the interior of BC (wild fires) , in the polar regions (ice melting) and other parts of in Africa and Asia (storms and droughts). International climate meetings and new research, which warn of dire consequences, are also being reported. This is raising awareness and anxiety levels about the risks of climate change and what might happen locally.

Funds for Adaptation

The availability of INAC funding for research and planning to prepare a climate adaptation plan has allowed the communities to take a closer look at the local risks and possible adaptation options for dealing with climate change.

Community Leadership

The Band Councils and Hereditary Chief s in the communities consider climate change a real risk and wish to explore practical options for adaptation.

Consequences of Inaction

The communities are coming to realize that sitting back and waiting for climate change impacts to occur will increase the risk and magnitude of negative consequences on the communities.

Benefits of Action

Preparing for the likely impacts of climate change with appropriate investments can reduce the risks and magnitude of the negative impacts but it can also allow communities to capitalize on the opportunities associated with climate change. Increasing community adaptive capacity and resilience to climate change is consistent with the communities' vision for sustainable development and will bring a better quality of life regardless of whether climate impacts are significant or not.

Adaptation Resources

The Clayoquot communities have a number of resources available to them to support climate adaptation efforts including:

Cultural, Social & Political

- Existing adaptation culture (a long history of adaptation to significant climate, ecological and socio-economic challenges)
- Relatively strong local institutions (Band Council, Hereditary Chief system, Emergency Preparedness, Holistic Ctr., School, Elders meetings)
- Strong family support systems
- Some existing and ongoing planning relevant to climate change (emergency, fisheries, forestry, solid waste, energy)
- Youth are increasingly knowledgeable of traditional culture and modern technology
- Strong sense of community (sports, family, food collection, gatherings)
- Growing authority and management capacity over local resources (fish, forestry)
- Growing sense of self-reliance and confidence in self-government
- Relatively strong learning institutions (elementary or high school, ABE classes)

Infrastructure & Housing

- Improving infrastructure & housing (water, drainage, housing)
- Some infrastructure maintenance and operations capacity
- INAC block and project funding
- NTC advisory support

Health & Safety

- Relatively high emergency preparedness capacity and support
- Basic primary care services
- Support from FNESS, the Coast Guard, the RCMP and the Provincial Emergency Program

Livelihood

- Variety of natural resource management, trades, management, instructional, boating, hospitality and health skills
- A holistic view of development
- Relatively abundant natural resources (marine, forests, minerals, wildlife & viewscapes)
- Young workforce with growing skill base
- Access to credit and insurance (though not all covered)
- Access to employment insurance and social assistance available to buffer unemployment
- Partnerships for economic development (aquaculture, forestry, mining)

Food Supply

- Availability of fish, shellfish and game and wild plants and skills to harvest
- Canning, smoking and drying skills
- Food Fish License and program (Band supported)
- 6-7 commercial fish licenses
- Emerging gardening program (includes greenhouse)
- New community kitchen (in Ahousaht)
- Local catering (Ahousaht and Tla-o-qui-aht)

Resource Management

- Westcoast Aquatic Integrated Planning
- NTC Fisheries
- Iisaak Forest Resources
- Fisheries monitoring

Adaptation Constraints

The Clayoquot communities also face a number of constraints to climate adaptation efforts, including:

Cultural, Social & Political

- Lack of technical expertise for some adaptation options
- Competing issues, timelines and funding demands
- Need for external resources (funds, expertise, education)
- The large number of adaptation issues
- Lack of federal and provincial policy and program support
- Very limited public funds for adaptation investment
- Some resistance to change due to the vast amount change forced on community in the past by non-FN culture

Livelihood/Economic

- Very limited personal and Band funds for adaptation investments
- High unemployment and very limited livelihood development capacity
- Relatively fragile local economies, highly reliant on government transfers
- High dependency on social assistance and unemployment insurance has dampened innovation

Food Supply

- High dependence on wild seafood for food security
- Very little cultivation
- Most dry, fresh and frozen goods sourced from external providers

Health & Safety

- Awareness about climate risks is low to moderate
- Significant health challenges already. Increased climate issues may stress health further.
- Health and emergency services are very basic
- Emergency relief funding is bureaucratic

Infrastructure & Housing

- The cost of adaptation measures could be high
- Very limited personal and public funds for repair and replacement
- Emergency relief funding is bureaucratic
- Limited staff availability to monitor and undertake adaptation measures

- Vulnerable infrastructure and housing in low lying areas expensive to replace
- Lack of proper fire protection facilities restricts access to home insurance

Resource Management

- Parts of marine ecosystem degraded due to past over-exploitation and continued pollution and habitat destruction
- Some unstable riparian areas due to past forestry practices
- Real estate development impacting riparian and fore-shore habitat
- Increasing tourism pressures in the area

Adaptation Vision, Goals and Objectives

Although the Heshquiaht, Ahousaht and Tla-o-qui-aht are very different communities facing different challenges and at are various stages of planning and development, they all share many of the same values and visions for sustainable development and climate adaptation (Appendix 1). In general, all three communities believe it is better to respond proactively to climate change than react to it if and when it becomes apparent. Their general guiding principle is to live in balance and harmony with nature – to take what is needed but never more than what Mother Nature can sustainably provide. In so doing, it is believed that not only will the communities become more resilient to climate change but more resilient and sustainable in general.

Below are the vision, goals and objectives for the Clayoquot communities' climate adaptation strategy. These statements are based on their current sustainable development visions and goals and on discussions with the community regarding their climate adaptation interests.

Vision for Climate Adaptation

Become more adaptive to the changing climate, while at the same time sustainably developing our Ha-houlthee "...managing the Ha'wiih's Ha-houlthee (the Home) in a manner, which is consistent with Nuu-chah-nulth knowledge and values, ensuring that the land and the ocean provide for sustenance, ceremonial and societal needs, and helps to provide an economic base for healthy communities."(See Appendix 1).

Adaptation Goals

The general adaptation goals of the Clayoquot communities are as follows:

- Slow the negative impacts of climate change on the land and the ocean by reducing unsustainable human use and by restoring natural habitats where possible. Slowing the negative ecological effects of climate change will allow the Clayoquot communities time to adapt socio-economically.

- Build individual and community capacity to adapt to eventual climate and ecological changes by strengthening key community assets, including health and safety resources, local economies, food supply systems, housing and infrastructure and cultural, social and political resources.

Adaptation Objectives

The climate adaptation objectives of the Clayoquot communities to achieve these goals include:

- Maintain the ecological health of the Clayoquot Sound
- Improve health and safety resources of each community
- Diversify the food supply of each community
- Diversify the livelihoods/economies of each community
- Strengthen the shelter and Infrastructure of each community
- Strengthen the cultural, social & political resources of each community

Community Adaptation Strategies

The recommendations below include a list of measures that the communities may adopt to strengthen their climate resilience. These recommendations are structured around the adaptation objectives listed above and are largely restricted to adaptation measures held in common by all three communities. Where there are differences in adaptation measures, such as in infrastructure, these are noted in Appendix 2.

There are a large number of recommendations listed below, which may seem overwhelming at first glance; however, many of these recommendation are consistent with other objectives that the communities have (e.g. employment development, health improvement, and self-reliance) and therefore do not necessarily compete for resources and time with other community objectives. Moreover, because many of recommendations are shared in common across the Clayoquot communities and indeed across the entire region, there is a significant opportunity for collaboration, which could reduce costs per community and increase the scope and effectiveness of investments.

However, to be clear,all of the adaptation recommendations below require time, funds and/or expertise to move them along in a timely fashion. And because the Clayoquot communities have very limited resources, the federal and provincial government will need to partner with the communities on a long-term basis to support their adaptation initiatives.

Maintain Ecological Health

As was discussed in Chapter 4 the ecology of the Clayoquot Sound is changing and will likely continue to be unstable due to climate change for many decades to come. This creates a difficulty for the Clayoquot communities and regulatory agencies because an unstable natural environment is more difficult to manage "sustainably". It is difficult, for example, to manage a stock of Sockeye salmon in the Clayoquot Sound if, due to changing climatic and oceanic conditions, the species will move out of the area anyways.

And yet, what might be seen as a conundrum might also be regarded as an opportunity to rethink how the natural environment of the Clayoquot Sound or the Ha'wiih's Ha-houlthee is managed. The principle of balance or harmony that the Clayoquot communities espouse calls on us to be gentle with the ecosystems of the Clayoquot Sound – take what is needed but never more than what Mother Nature can sustainably provide. This wisdom directs us to take a more precautionary approach to using the natural resources of the Clayoquot Sound and to ensure the ecological health of the Clayoquot Sound is sustained. The benefit of this approach, as resilience theory suggests, is that the healthier and more diverse the ecosystem of Clayoquot Sound is, the more resilient it will be to pressures of climate change. And the more resilient an ecosystem is, the more options or choices the Clayoquot communities (and all of the communities of the area) will have to adapt to climate change.

Hence, a key strategy for adapting to climate changes in the Clayoquot Sound is to maintain or, in some cases, reduce additional stresses and restore the habitat of the area. This, objective is of course very large in scope and very challenging but some resilience principles that might guide future strategies include:

- Focus on components of the ecosystem that fundamentally affect its function (e.g. riparian forest protection or estuary eelgrass beds
- Focus on supporting foundation species (e.g. the species that define ecosystems such as cedar or salmon)
- Monitor changes in foundation species that have threshold consequences for the ecosystem (e.g. declines in plankton or forage fish species)
- Be aware of cascading impacts, where one change creates another change, snowballing into very different result (e.g. where decreased acidity reduces survival at the bottom of the food chain which cascades up the chain)
- Focus on species that provide a direct value or service to human communities (e.g. subsistence food supplies; culturally important species)
- Focus on preventing hazards that directly affect human communities and their values (e.g. increased flooding or landslides).

These principles as well as the First Nation principle of balance will guide recommendations below. Moreover, because the marine ecosystem is very important to the Clayoquot communities and perhaps the most at risk from climate change, many of the recommendations below will focus on maintaining this particular ecosystem, including changing management regimes, shifting catches and protecting and restoring marine habitat (Table 1).

Table 1: Recommendations to Maintain Ecological Health in the Clayoquot Sound

Marine Ecosystem
Reform Planning • Integrate an ecosystem-based management approach into fisheries management • Integrate climate projections and adaptive management principles into fisheries management planning *Shift Fishery Catch* • Monitor marine species and Introduce catch reductions/closures on vulnerable species (Sockeye, Chinook, Rockfish, Manila Clams, Pacific Oysters) • Shift fishing to pest species and species more tolerant to lower oxygen levels and higher temperature and acidity levels *Protect and Restore Marine Habitat* • Increase salmon enhancement measures • Enforce existing habitat protection for forage species • Restrict shoreline development and bulk heading • Reduce, divert and treat sewage and storm water in sensitive habitats • Preserve marine and riparian wetlands and re-vegetate beaches and rivers near development • Levy an ecosystem fee (levied on sports fishers) to pay for ecosystem management • Improve handling of toxic substances near water (e.g. diesel, gas, oil) • Clean up toxic sites on reserves *Improved Coordination* • Coordinate efforts between communities • Partner with national and regional advocacy groups to strengthen efforts *Other* • Explore a limited sea otter cull

Table 1 continued on next page

Terrestrial Ecosystem
• Maintain an ecosystem-based management approach to forest management • Adjust silviculture prescriptions to support western red cedar growth at higher elevations • Ensure that adequate old growth representation is maintained in forest management • Collaborate with Iisaak Forest Resources and the Ministry of Forests in long term planning • Clean-up toxic sites
Freshwater Aquatic Ecosystem
• Reassess terrain stability hazard ratings and stream buffer requirements in light of new precipitation projections. • Carry out stream stabilization or restoration where necessary • Partner with national and regional advocacy groups to strengthen efforts

Source: Katie Beach, Martin Carver, Neil Hughes, Tom Okey and Rachel Holt and discussions with Clayoquot community leaders.

Improve Health and Safety Resources

• Health

As mentioned in Chapter 5, all three of the Clayoquot communities face health challenges and although these challenges will not be remedied through an adaptation process, the adaptation capacity of the communities will be strengthened through improving the health of the communities. All of the communities are addressing their health challenges to some degree. They are working on improving their diets, exploring the production of their own fresh fruits and vegetables, continuing to eat fresh and preserved fish and game, and offering traditional and allopathic healing services. These measures will improve the health of the communities but more can be done to support these measures, including:

- Further diversifying their food supply systems and diet (see Food Supply)
- Retrofitting older homes and building new homes to cope with projected rain and wind conditions (see Shelter and Infrastructure)
- Diversifying local livelihoods/economies to provide employment (see Livelihood/Economies)

In addition, due to the likely rise of new pests and diseases in the Clayoquot communities with a warming climate, it is advised that the communities begin to:

- Partner with Community Health Resources to monitor for the emergence of new pests and diseases in the area and keep the community health authorities appraised of any anomalies.

- **Safety**

Similarly, although the Clayoquot communities appear relatively prepared for natural disasters, some of the communities (particularly Hesquiaht and Tla-o-qui-aht) could still strengthen their emergency planning for more severe storms and floods by undertaking the following activities:

- Review emergency preparedness planning and training with FNESS in light of climate projections and determine if existing planning is sufficient
- Coordinate storm surge early warning with MOE and the Coast Guard
- Locate and construct new buildings in areas 5m or higher above sea level (see Shelter & Infrastructure)
- Ensure back-up energy and water systems are in place (see Infrastructure)

Diversify Food Supply

Climate change is likely to cause gaps in traditional seafood supplies and create overall food supply uncertainty among the Clayoquot First Nations. To strengthen the communities' resilience in this area, it is recommended that they continue to diversify the food supply systems (Table 2). Some of the options for doing so include: shifting consumption into less vulnerable seafood species; exploring closed containment farming systems for salmon or other types of seafood for the community food fish program; continuing and perhaps even expanding the hunting of wild game and the collection of wild plants; teaching the youth the value of eating fresh and/or wild foods; expanding community and household gardening as well as food preservation training and food storage options; and continuing to develop inter-Band trading of food stuffs. Lastly, although it has been tried in the past, it may also be beneficial to explore the possibility of expanding the sale of frozen or dry goods on-reserve. Not only will this provide an added avenue of food supply, it could reduce income leakage out of the communities.

Table 2: Food Diversification Recommendations for the Clayoquot Communities

General	**Retail/Bartered Foods**
• Continue to explore a food barter opportunities within and between other FN communities • Continue to educate youth about the importance of wild and fresh food diets	• Explore the feasibility of retailing frozen or dry goods in the community • Continue to develop an inter-Band food bartering system
Seafood	**Cultivated Foods**

• Shift seafood harvesting to less vulnerable species of finfish
    ◦ Monitor Sockeye, Chinook, Rockfish, clams & oysters stocks and reduce harvesting as stocks weaken
    ◦ Shift salmon fishing to species more likely to cope with climate change (Chum, Pink, Coho)
    ◦ Consume bivalves more likely to cope with climate change (geoduck)
    ◦ Focus on unexploited marine species and on new in-migrating species (e.g. sardines, squid, mackerel, others?)
    ◦ Ensure community access to less vulnerable species in future fishery or treaty negotiations
• Explore closed containment systems for farming salmon or other seafood to stock the community food fish program
• Foster more bivalve growth in buffered areas for community food fish program
	Gardening
	• Continue expansion of household and community gardening
	    ◦ Continue to educate the community on appropriate gardening techniques and technologies
	    ◦ Tailor fruit and vegetable varieties to community tastes and local climate
	    ◦ Continue to educate the community about how to cook with fresh fruits and vegetables
	    ◦ Explore a long-term funding mechanisms for continued program support
	
	Beef/Poultry
	• Explore community interest in raising laying hens or beef cattle for subsistence purposes

Wild Meats and Plants	**Food Preservation and Storage**
• Continue and even expand hunting for wild meats and gathering of wild plant (berries, roots & medicines) • Continue to educate youth about hunting and gathering	• Continue to educate the community about how to preserve and store fish, meat, fruits and vegetables • Explore community cold storage options that are black-out proof and animal proof

Source: Discussions with Clayoquot community leaders and Stephanie Hughes

Diversify Livelihoods/ Economies

Although climate change is likely to have a relatively neutral effect on the forest sector, it is likely to create uncertainty in the fishery and shell-fishery sectors and perhaps even the tourism sector. To strengthen the communities' resilience to this uncertainty, it is recommended that they continue to diversify their local economies as much as possible. This might include exploring and, if feasible, investing in opportunities in the fishery/shellfishery, forestry, tourism, agriculture, energy and mining and service sectors (Table 3). Also important, is an effort to reduce risk to existing livelihoods and to improve education and skill levels. Improving education and skill levels is particularly important since new skilled workers and entrepreneurs will be needed to fill jobs in a more diversified economy but they will also become a catalyst to increasing community innovation and resilience in general.

Table 3: Livelihood/Economic Diversification Recommendations for the Clayoquot Communities

Fishery/Shellfishery	Forestry
• Explore expanding closed pen aquaculture development • Explore Geoduck farming in select sheltered areas • Explore seaweed farming and/or integrated multitrophic aquaculture • Shift commercial fishery to salmon species more likely to cope with climate change (Chum, Pink, Coho) • Shift commercial catch to under-exploited species (sardines) or new species (squid, mackerel, etc.) • Enhance business development support for First Nation commercial and sport fishing and seafood processing • Explore licensing arrangements that allow participation in multiple fisheries	• Review Clayoquot Value-Added Strategy and determine what opportunities might be feasible at this time. • Continue to explore revenue opportunities from maintaining ecosystem services (carbon, clean water and clean air from forest conservation) • Review cedar/hemlock annual allowable cut in light of climate projections (long-term)

Table 3 continued on next page

Tourism	Agriculture
• Develop tourism businesses built around aboriginal culture, eco-tourism……and storms! • Develop First Nation sports fishing businesses built around climate tolerant fish species	• Explore cultivation and processing of fruits and vegetable for local market and tourist market • Collect and process NTFPs for tourist market or for export where culturally and ecologically sustainable
Energy	**Mining**
• Continue to explore the viability of community geothermal, wind, wave, solar and mini-hydro developments	• Examine Catface mine and other mining opportunities in the area light of climate change impacts and maintaining ecosystem health.
Retail/Services	**General**
• Explore the feasibility of expanding or offering new services and retail businesses (formal or informal) in the communities	• Explore mechanisms for facilitating enterprise development in the communities (e.g. shared economic development professional, community development corps, etc.)

Source: Katie Beach, Neil Hughes, Stephanie Hughes, Tom Okey and discussions with Clayoquot community leaders.

- **Risk Reduction**
  - Take safety precautions to protect commercial properties (wharfs, aquaculture pens, boats, and buildings near shorelines)
  - Ensure businesses are aware of business, property and loan insurance options
  - Ensure businesses are aware of financing programs and options (line of credit, bridging loans) in the event of business disruption or the need to grow and diversify

- **Skill Development**
  - Broaden education and skills training based on livelihood diversification goals
  - Provide cross training in a variety of skills to cope with seasonal employment fluctuations
  - Enhance entrepreneurial instruction and incubation services in the communities

Strengthen Infrastructure and Shelter

The Clayoquot communities face a wide range of infrastructure and housing vulnerabilities to climate change, particularly due to increased storm and wave activity. Below are some recommendations for strengthening shelter and infrastructure in the Clayoquot communities (Table 4). Most of the recommendations are associated with water management; either defending structures from flooding or erosion from high intensity rains or storm surges or ensuring back-up water systems in the event of drought, contamination or power outage. More specific recommendations for each community can be found in Appendix 2.

Table 4: Shelter and Infrastructure Strengthening Recommendations for the Clayoquot Communities

General	Solid Waste
• Insure shelter and infrastructure where sensible • Familiarize Council and staff with disaster relief coverage for shelter and infrastructure • Explore opportunities for collaboration over infrastructure investments and expertise	• Monitor performance of new landfill capping materials to identify/correct areas subject to erosion • Develop a maintenance program for barge ramp and container transfer area
Housing and Public Buildings	**Sewer**
• Rain-screen & upgrade ventilation in all existing buildings to the best possible standard • Improve drainage capacity in low lying occupied areas • Locate new buildings above possible inundation levels (5m elevation might be reasonable) and orient buildings to be more wind proof • Design & build new buildings for high winds and driving rain	• Complete annual inspection of outfall and verify viable maintenance if outfall diffuser ports become blocked with sand • Regularly clean/flush sewers, particularly old AC sewers in low-lying areas of village. • Repair breaks or openings in pipes and manholes • Consider options to protect lift stations from storm surges • Improve shoreline erosion protection adjacent to sewer collection pipe

Table continued on next page

Table 4: Shelter and Infrastructure Strengthening Recommendations for the Clayoquot Communities

Water Supply	Roads
• Undertake a risk assessment of key water sources, addressing supply and demand profiles • Flood-proof existing water pumphouse • Erosion-proof pipes and tanks • Install diesel generator or back-up diesel pump at water pumphouse • Develop emergency water supply options	• Implement a road inspection routine to seasonally upgrade culverts, bridges, clean ditches before stormy season • Develop overland stormwater flow paths within potential inundation areas.
Energy/Hydro	**Wharves/ Docks***
• Regularly inspect condition of individual power systems • Regularly inspect condition of Hydro poles in low-lying areas or weak soils	• Reinforce existing wharves, check/repair interconnections of floating dock slabs at regular frequency • Protect approach ramp from wave erosion in conjunction with barge ramp improvements
Telecommunications*	**Stormwater Drainage**
• Regularly inspect condition of microwave towers	• Complete drainage improvements to increase capacity in low -lying areas (< 5m)
Breakwaters*	
• Develop monitoring/maintenance activities and contingencies • Understand coastal sediment transport mechanisms • Improve shoreline erosion protection for cemetery and beach	

Source: Discussions with community leaders and Don MacKinnon.
* Excluding Ty'histanis-Esowista

Strengthen Political, Social and Cultural Resources

Climate change and the physical and economic impacts they will impose will likely stress the cultural, social and political resources of the Clayoquot communities significantly. To strengthen these resources, it is recommended that the community leaders familiarize themselves and their community members with the Adaptation Plan information and make efforts to their implement adaptation priorities. A particularly important component for community leaders to explore is how best to encourage a culture of openness to change and continuous learning via the political, social and cultural institutions of the community.

Table 5: Recommendations to Strengthen Political, Social and Cultural Resources for the Clayoquot Communities

Political	• Review the Adaptation Plan with Band Council and Hereditary Chiefs and staff to integrate into planning • Increase awareness in the community of the possible impacts of climate change and community decisions regarding adaptation priorities • Hire an adaptation coordinator to facilitate adaptation implementation and/or identify institutions and champions in the community to implement adaption priorities • Council and Hereditary Chiefs take a leadership role in promoting self-reliance, adaptation and continuous learning
Social	• Establish a conflict management process for FN and non-FN fishery disputes • Use traditional stories in schools and social services to reinforce the reality of continuous change and that adaptation and resilience are positive
Cultural	• Take defensive measures against storm surges on cultural sites near shoreline (e.g. graveyard) • Use traditional stories and ceremonies to reinforce the reality of continuous change; that change is natural and that adaptation and resilience are a way of being in harmony with nature

Source: Discussions with Clayoquot community leaders.

References

Arbour, D. Kuecks, B & Edwards, D. Nuu-Chah-Nulth Central Region First Nations Governance Structures 2007/08, EcoTrust Canada

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Appendix 1

Regional and Community Visions for Sustainable Development

Clayoquot Nations Vision[106]

The term **Hishukish tsa'walk** is central to the Nuu-chah-nulth vision of the life. The term means that everything is interconnected, that everything is one. In following with this vision is a vision for development that entails managing the Ha'wiih's Ha-houlthee (the Home) in a sustainable manner, which is consistent with Nuu-chah-nulth knowledge and values, ensuring that the land and the ocean provide for sustenance, ceremonial and societal needs, and help to provide an economic base for healthy communities.

Goals for sustainable development pursuant to this vision include:

1. Protect, rehabilitate, and maintain clean water, air, soil, and sunlight.

2. Build a strong Nuu-chah-nulth culture, including a clear understanding of and respect for spirituality, values, principles, language, teachings, traditions, and roles and responsibilities.

3. Ensure secure access to healthy resources within Ha-houlthee for sustenance, cultural, and economic purposes now and in the future.

4. Build individual and community capacity to take experiences and information and turn them into sources of growth and fulfillment.

5. Build mutually beneficial relationships based on a clear sense of roles and responsibilities with others who can affect the achievement of these goals.

[106] Adapted from Uu-a-thluk vision and goals: http://uuathluk.ca/about.htm

Ahousaht Vision[107]

In addition to the general vision outlined above, the Ahousaht envision community development that:

- Involves hands on learning and skills development
- Encourages local ownership
- Allows for use of resources in the Clayoquot Sound
- Entails long term benefits and economic independence
- Allows people to work and live at Home
- Provides employment
- Is self-sustaining
- Fosters self esteem and inner strength
- Encourages creativity and less consumerism
- Catalyzes new opportunities and wealth creation and
- Encourage social unity
- Respects and integrates our culture

Tla-o-qui-aht Vision[108]

The Tla-o-qui-aht express a vision for oneness similar to the general vision:

> *We are all Quu-us (human beings). As Quu-us we are a link between our ancestors and future generations. Our inheritance includes our bodies and our teachings and all of the medicines used to sustain them, including water, air, salmon, cedar, and all of the abundance in biodiversity from healthy old-growth forests, rivers, streams, lakes, and adjacent ocean ecosystems.*

The Tla-o-qui-aht envision community development that re-establishes a healthy integration of economy and environment in which there is a balance of creation and consumption and a continual investment in biological and economic diversify. To this end, the community is guided by four main goals:

- A Sustainable Future for the Region
- A Healthy, Abundant Watershed Ecosystems
- Working with Traditional Teachings
- Economic Independence through Sustainable Resource Management

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[107] Adapted from The Report on Ahousaht Community Dialogue and Working Session, May 2008.

[108] Adapted from Ha'uukmin. Tla-o-qui-aht Tribal Park Land Use Plan.

Heshquiaht Vision[109]

The Hesquiaht people view the forest and its resources as gifts of the Creator, to be used with respect and to be maintained by careful stewardship through the legislative power of tribal government found within "hahuolthi."

The Heshquiaht have identified seven common areas we wish to evolve including:

- Assertion governance over our territory, including controlling access to the area and collecting of fees for any usage of the territory by parks, government or industry
- Improvement of the health and social wellbeing of our people
- Development of sustainable enterprise
- Development of affordable and sustainable transportation systems,
- Development of community infrastructure
- Development of sustainable energy production
- Re-attracting members back to the community

[109] Adapted from Heshquiaht Statement of Intent, April 22 2009

Appendix 2

Individual Community Adaptation Strategies

Below are strategies recommendations for the individual Clayoquot communities. These recommendations are supplemental to those above due to particular community needs or priorities.

Ahousaht Adaptation Strategy (Supplementary Community Actions)

Table 6. Shelter and Infrastructure Strengthening Recommendations for Ahousaht

Diversify Livelihoods/ Economies	**Water Supply**
Continue to develop MOUs with companies interested in sustainably investing in the Ahousaht traditional territory	Restore support beneath water pipe along/across Anderson Creek (possibly re-locate portions under future access road)
Ensure meaningful management control and input into our traditional territory	Investigate options to control algae blooms in Anderson Creek Reservoir. Continue to clean and maintain water system
Solid Waste	**Stormwater Drainage**
Review lower levels of existing landfill to identify over-steepened fill slopes that could be subjected to surge inundation and support with rock to protect from potential erosion	Complete drainage improvements suggested by Associated Engineering
	Hydro
	Support regular maintenance by BC Hydro, particularly at Kakawis, for clearing danger trees near existing overhead lines

Source: Discussions with Clayoquot community leaders and Don MacKinnon.

Tla-o-qui-aht Adaptation Strategy (Supplementary Community Actions)

Table 7: Shelter and Infrastructure Strengthening Recommendations for Tla-o-qui-aht

Diversify Food Supply	**Sewer (Ty'histanis-Esowista)**
Restore chum to Meares Island	Improve shoreline erosion protection adjacent to sewer collection piping (roads and water mains) parallel to the beach at Lower Esowista
Raise cattle on Meares Island	Consider options to protect lift station from damage (storm surge) in Lower Esowista
Water Supply (Opitsat)	**Stormwater Drainage(Opitsat)**
Repair/buttress unstable slopes supporting water pipe from Kakawis to Opitsat and maintain access trail	Complete drainage improvements along base of slope by existing 12-lot subdivision and consider new culvert under water treatment plant access road
Investigate options to convert Brother Creek intake into infiltration gallery	
Water Supply (Ty'histanis-Esowista)	**Stormwater Drainage(Ty'histanis-Esowista)**
Inspect water pipeline burial/support on airport property at stream gullies and report issues/blocked culverts to ACRD	Monitor new stormwater collection systems and inlets/ outlets to sediment ponds near south tributary of Esowista Creek and repair as needed
Consider water meter installation and dual-flush / low-flow toilets for new housing and existing housing toilet replacements	Monitor bridge foundations and culverts at Esowista Creek
Breakwaters (Opitsat)	**Energy/Hydro (Opitsat)**
Consider relocation of most vulnerable grave sites.	Support regular maintenance by BC Hydro, particularly at Kakawis, for clearing danger trees near existing overhead lines

Source: Discussions with Clayoquot community leaders and Don MacKinnon.

Hesquiaht Adaptation Strategy (Supplementary Community Actions)

Table 8. Shelter and Infrastructure Strengthening Recommendations for Hesquiaht

Diversify Livelihoods/ Economy	**Telecommunications**
Explore opportunities related to the hot spring (accommodation, tours, food services etc.)	Regularly inspect condition of microwave towers
	Explore alternate means of telecommunications that are more reliable
Improve Health and Safety Resources	**Stormwater Drainage**
Upgrade to improve access to medivac landing site in HSC	Complete drainage improvements to increase capacity in lower reaches, retaining and storing water for irrigation
Improve efficiency of medivac system for Hesquiaht Harbour. Medivac is out of Hot Spring Cove	**Solid Waste**
	Review functionality of existing barge ramps for loading out garbage
Obtain new siren for emergencies	**Sewer**
Rebuild volunteer fire department	Complete annual inspection of outfall lift station and improve resistance to damage from surge/flooding at Refuge Cove
Water Supply	Regularly inspect anchors on sewer outfall pipe under Refuge Cove
Verify/test flood-resistance of existing water pumphouse at Refuge Cove	
Evaluate sediment volume and transport upstream of Refuge Creek Intake and develop strategies to retain/divert sediment and restore channel stability where possible	Evaluate alternates to septic tanks and septic fields if necessary at low-lying areas of Hesquiat Harbour
Improve erosion protection for Refuge Creek sediment tanks at water intake and review infiltration gallery protection from burial by additional sediment	**Wharves/ Docks**

Establish alternate water supplies for fire protection (Refuge Cove) and drinking water (Hesquiat Harbour)	Reinforce existing wharves, check/repair interconnections of floating dock slabs at regular frequency (Refuge Cove)
Energy/Hydro	**Breakwaters**
Conduct regular maintenance of Refuge Cove power plant, check existing grounding and/or need for lightening arrestors	Replace log breakwater (Refuge Cove)
	Consider relocation of most vulnerable grave sites (Hesquiaht Harbor).

Source: Discussions with Clayoquot community leaders and Don MacKinnon.

Chapter 7

Clayoquot Community-based Climate Adaptation Action Plan

contents

The following tables comprise the Action Plan of the Clayoquot Community-based Adaptation Plan, which is divided into two sections, including regional and community sections. The regional section or the Clayoquot Regional Adaptation Action Plan consists of those activities which are best carried out in a broad regional fashion (e.g. maintaining ecological health) or which are carried out in the communities but are common to all of the communities (e.g. diversification of livelihoods or strengthen a particular type of infrastructure). The community section consists of activities which are particular to the Ahousaht, Tla-o-qui-aht and Hesquiaht communities.

The reader will note that each activity is evaluated in terms of priority (Low, Medium or High), timeline to begin (short-term – 1-10 yrs, medium-term – 11-30 yrs, long-term – 31+ years) and investment requirement in terms of time and funds (insignificant, some and significant). These measures are of course very subjective and also very preliminary but it is expected that the Clayoquot communities will fine tune these measures and their application over time as well as assign responsibilities for given tasks.

Clayoquot Regional Adaptation Action Plan

MAINTAIN ECOLOGICAL HEALTH	Priority	Timeline (to begin)	Investment	Responsibility
Marine Ecosystem				
Reform Planning				
Integrate an ecosystem-based management approach into fisheries management	High	Short-term	Some	
Integrate climate projections and adaptive management principles into fisheries management planning	High		Insignificant	
Shift Fishery Catch			Significant	
Monitor marine species and Introduce catch reductions/closures on vulnerable species (Sockeye, Chinook, Rockfish, Manila Clams, Pacific Oysters)	High		Some	
Shift fishing to pest species and species more tolerant to lower oxygen levels and higher temperature and acidity levels	High		Some	
Explore a limited sea otter cull	Medium		Insignificant	
Protect and Restore Marine Habitat				
Increase salmon enhancement measures	High		Significant	
Enforce existing habitat protection for forage species	High		Some	
Restrict shoreline development and bulk heading	High		Some	
Reduce, divert and treat sewage and storm water in sensitive habitats	High		Some to Significant	
Preserve marine and riparian wetlands and re-vegetate beaches and rivers near development	High		Some	
Improve handling of toxic substances near water (e.g. diesel, gas, oil)	High		Some	

Clean up toxic sites on reserves	High		Some to Significant	
Levy an ecosystem fee (levied on sports fishers) to pay for ecosystem management	High		Some	
Improve Coordination		Short-term		
Coordinate efforts between communities	High		Insignificant	
Partner with national and regional advocacy groups to strengthen efforts	High		Insignificant	
Explore a limited sea otter cull	Medium		Insignificant	
Terrestrial Ecosystem				
Maintain an ecosystem-based management approach to forest management	High	Ongoing	Insignificant	
Adjust silviculture prescriptions to support western red cedar growth at higher elevations	Medium	Medium-term	Insignificant	
Ensure adequate old growth representation is maintained in forest management	High	Medium-term	Some	
Clean-up toxic sites	High	Short-term	Some to Significant	
Collaborate with Iisaak Forest Resources and Ministry of Forests	Medium	Short-term	Insignificant	
Freshwater Aquatic Ecosystem				
Reassess terrain stability hazard ratings and stream buffer requirements in light of new precipitation projections.	Medium	Short-term	Some	
Stream stabilization or restoration where necessary	High	Short-term	Some to Significant	
Partner with national and regional advocacy groups to strengthen efforts	Medium	Medium-term	Insignificant	
STRENGTHEN HEALTH AND SAFETY				
Take safety precautions to protect commercial properties (wharfs, aquaculture pens, boats, and buildings	High	Short-term	Some to Significant	

near shorelines)				
Partner with Community Health Resources to monitor for the emergence of new pests and diseases in the area and keep the community health authorities appraised of any anomalies.	Medium	Medium-term	Insignificant	
Review emergency preparedness planning and training with FNESS in light of climate projections and determine if existing planning is sufficient	High	Short-term	Some	
Coordinate storm surge early warning with MOE and the Coast Guard	High	Short-term	Insignificant	
Locate and construct new buildings in areas above 5m above sea level (see Shelter & Infrastructure)	High	Short-term	Insignificant to Some	
Ensure back-up systems (energy & water) are in place (see Infrastructure)	High	Short-term	Some to Significant	
DIVERSIFY FOOD SUPPLY				
General				
Continue to explore a food barter opportunities within and between other FN communities (web-based)	Medium	Short-term	Some	
Continue to educate youth about the importance of wild and fresh food diets	High	Short-term	Some	
Seafood				
Shift Fishery Catch				
• Monitor Sockeye, Chinook, Rockfish, clams & oysters stocks and reduce harvesting as stocks weaken	High	Short-term	Some	
• Shift salmon fishing to species more likely to cope with climate change (Chum, Pink, Coho)	High	Short-term	Some	
• Focus on unexploited marine species and on new in-migrating species (e.g. sardines, squid, mackerel, others?)	High	Medium-term	Some	

• Ensure community access to less vulnerable species in future fishery or treaty negotiations	High	Short-term	Some	
Explore closed pen aquaculture options for farmed salmon or other seafood for community food fish program	Medium	Short-term	Some	
Foster bivalve growth in buffered areas for community food fish program	Medium	Short-term	Some	
Wild Meats and Plants				
Continue and even expand hunting for wild meats and gathering of wild plant (berries, roots & medicines)	High	Short-term	Insignificant	
Continue to educate youth about hunting and gathering	High	Short-term	Insignificant	
Cultivated Foods				
Gardening				
Continue expansion of household and community gardening				
• Continue to educate the community on appropriate gardening techniques and technologies	High	Short-term	Some	
• Tailor fruit and vegetable varieties to community tastes and local climate	High	Short-term	Insignificant	
• Continue to educate the community about how to cook with fresh fruits and vegetables	Medium	Short-term	Some	
• Explore a long-term funding mechanisms for continued program support	High	Short-term	Some	
Beef/Poultry				
Explore community interest in raising laying hens or beef cattle for subsistence purposes	Medium	Medium-term	Some	
Retail				
Explore the feasibility of retailing frozen or dry goods in the community	Medium	Medium-term	Some	

Food Preservation and Storage				
Continue to educate the community about how to preserve and store fish, meat, fruits and vegetables	High	Short-term	Some	
Explore community cold storage options that are black-out proof and animal proof	High	Short-term	Some	
DIVERSIFY LIVELIHOODS/LOCAL ECONOMIES				
General				
Explore mechanisms for facilitating enterprise development in the communities (e.g. shared economic development professional, community development corps, etc.)	High	Short-term	Some	
Ensure businesses are aware of business, property and loan insurance options	High	Short-term	Insignificant	
Ensure businesses are aware of financing programs and options (line of credit, bridging loans) in the event of business disruption or the need to grow and diversify	Medium	Short-term	Insignificant	
Enhance entrepreneurial instruction and incubation services in the communities	High	Short-term	Some	
Provide cross training in a variety of skills to cope with seasonal employment fluctuations	High	Short-term	Some	
Broaden education and skills training based on livelihood diversification goals	High	Short-term	Some	
Fishery/Shellfishery				
Explore closed pen aquaculture development	Medium	Short-term	Some	
Explore geoduck farming in select sheltered areas	Medium	Short-term	Some	
Explore seaweed farming and/or integrated multi-trophic aquaculture	High	Short-term	Some	

Shift commercial fishery to salmon species more likely to cope with climate change (Chum, Pink, Coho)	High	Short-term	Some	
Shift commercial catch to under-exploited species (sardines) or new species (squid, mackerel, etc.)	High	Medium-term	Some	
Enhance business development support for First Nation commercial and sport fishing and seafood processing	Medium	Short-term	Some	
Explore licensing arrangements that allow participation in multiple fisheries	High	Short-term	Some	
Tourism				
Develop tourism businesses built around aboriginal culture, eco-tourism……and storms!	High	Short-term	Significant	
Develop First Nation sports fishing businesses built around climate tolerant fish species	High	Short-term	Significant	
Energy				
Continue to explore the viability of community geothermal, wind, wave, solar and mini-hydro developments	High	Short-term	Significant	
Retail/Services				
Explore the feasibility of expanding or offering new services and retail businesses (formal or informal) in the communities	Medium	Medium-term	Some	
Forestry				
Review cedar/hemlock annual allowable cut in light of climate projections	High	Medium-term	Some	
Review Clayoquot Value-Added Strategy and determine what opportunities might be feasible at this time.	High	Short-term	Some	
Forest carbon credits for forest retention	High	Short-term	Some	
Continue to explore other revenue opportunities for ecosystem services (	High	Medium	Some	

clean water and clean air from forest conservation)				
Agriculture				
Explore cultivation and processing of fruits and vegetable for local market and tourist market	Medium	Medium-term	Some	
Collect and process NTFPs for tourist market or for export where culturally and ecologically sustainable	Medium	Short-term	Some	
Mining				
Examine Catface mine and other mining opportunities in the area light of climate change impacts	High	Short-term	Some	
POLITICAL, SOCIAL & CULTURAL RESOURCES				
Political				
Review the Adaptation Plan with Band Council and Hereditary Chiefs and staff to integrate into planning	High	Short-term	Insignificant	
Increase awareness in the community of the possible impacts of climate change and community decisions regarding adaptation priorities	High	Short-term	Insignificant	
Hire an adaptation coordinator to facilitate adaptation implementation and/or identify institutions and champions in the community to implement adaption priorities	High	Short-term	Some	
Council and Hereditary Chiefs take a leadership role in promoting self-reliance, adaptation and continuous learning	High	Short-term	Insignificant	
Social				
Establish a conflict management process for FN & non-FN fishery disputes	Medium	Short-term	Some	
Schools and social services use traditional	High	Short-term	Some	

stories to reinforce the reality of change and that adaptation and resilience are positive				
Cultural				
Take defensive measures against storm surges on cultural sites near shoreline (e.g. graveyard)	Medium	Short-term	Significant	
Use traditional stories and ceremonies to reinforce the reality of continuous change; that change is natural and that adaptation and resilience are a way of being in harmony with nature	High	Short-term	Insignificant	
STRENGTHEN SHELTER & INFRASTRUCTURE				
General				
Insure shelter and infrastructure where sensible	High	Short-term	Some to Significant	
Familiarize Council and staff with disaster relief coverage for shelter and infrastructure	High	Short-term	Insignificant	
Explore opportunities for collaboration over infrastructure investments and expertise	High	Short-term	Some	
Housing and Public Buildings				
Improve drainage capacity in low lying occupied areas	High	Short	Some	
Locate new buildings above possible inundation levels (5m elevation might be reasonable) and orient buildings to be more wind proof	Medium	Medium-term	Some	
Design & build new buildings for high winds and driving rain	High	Medium-term	Significant	
Rain-screen & upgrade ventilation in all existing buildings	High	Short-term	Some	
Water Supply				

Undertake a risk assessment of key water sources, addressing supply and demand profiles	High	Short-term	Insignificant	
Flood-proof existing water pumphouse (raise electrical works, consider perimeter sandbag dyke and sump pump system)	Medium	Short-term	Some	
Erosion-proof pipes and tanks	Medium	Short-term	Insignificant to Some	
Install diesel generator or back-up diesel pump at water pumphouse	High	Short-term	Some	
Develop emergency water supply options	Medium	Short-term	Insignificant	
Breakwaters				
Develop monitoring/maintenance activities and contingencies	Medium	Short-term	Insignificant	
Understand coastal sediment transport mechanisms	Medium	Short-term	Insignificant	
Improve shoreline erosion protection for cemetery and beach	Medium	Short-term	Some	
Consider relocation of most vulnerable grave sites.	Medium	Medium-term	Some	
Solid Waste*				
Monitor performance of new landfill capping materials to identify/correct areas subject to erosion	Medium	Short-term	Some	
Develop a maintenance program for barge ramp and container transfer area	Medium	Short-term	Insignificant	
Sewer				
Complete annual inspection of outfall and verify viable maintenance if outfall diffuser ports become blocked with sand	Medium	Short-term	Insignificant	
Regularly clean/flush sewers, particularly old AC sewers in low-lying areas of village. Repair breaks or openings in pipes and manholesflooding/inundation	High	Short-term	Some	
Consider options to protect lift stations	Medium	Short-term	Some	

from storm surges				
Improve shoreline erosion protection adjacent to inlet where sanitary collection piping (and water mains) parallel the shoreline	Medium	Short-term	Significant	
Stormwater Drainage				
Complete drainage improvements suggested by Associated Engineering	Medium	Short-term	Significant	
Wharves/ Docks*				
Reinforce existing wharves, check/repair interconnections of floating dock slabs at regular frequency	High	Short-term	Some to Significant	
Protect approach ramp from wave erosion in conjunction with barge ramp improvements	Medium	Short-term	Some	
Energy/Hydro				
Support regular maintenance by BC Hydro for clearing danger trees near existing overhead lines	High	Short-term	Insignificant	
Regularly inspect condition of Hydro poles in low-lying areas or weak soils	Low	Short-term	Insignificant	
Telecommunications*				
Regularly inspect condition of microwave towers	Medium	Medium-term	Insignificant	
Roads				
Implement a road inspection routine to seasonally upgrade culverts, bridges, clean ditches before stormy season (Oct to April)	Medium	Short-term	Some	
Develop overland stormwater flow paths within potential inundation areas.	High	Short-term	Some	

Ahousaht Adaptation Action Plan
(Supplementary Community Actions)

DIVERSIFY LIVELIHOODS/LOCAL ECONOMIES	Priority	Timeline (to begin)	Investment	Responsibility
Continue to develop MOUs with companies interested in sustainably investing in the Ahousaht traditional territory	High	Short-term	Some	
Ensure meaningful management control and input into our traditional territory	High	Short-term	Some	
STRENGTHEN SHELTER & INFRASTRUCTURE				
Water Supply				
Restore support beneath water pipe along/across Anderson Creek (possibly re-locate portions under future access road)	Medium	Short-term	Insignificant to Some	
Investigate options to control algae blooms in Anderson Creek Reservoir	Medium	Short-term	Insignificant	
Solid Waste				
Review lower levels of existing landfill to identify over-steepened fill slopes that could be subjected to surge inundation and support with rock to protect from potential erosion	Medium	Short-term	Some	
Stormwater Drainage				
Complete drainage improvements suggested by Associated Engineering	Medium	Short-term	Significant	
Energy/Hydro				
Support regular maintenance by BC Hydro, particularly at Kakawis, for clearing danger trees near existing overhead lines	High	Short-term	Insignificant	

Tla-oqui-aht Adaptation Action Plan (Supplementary Community Actions)

DIVERSIFY FOOD SUPPLY	Priority	Timeline (to begin)	Investment	Responsibility
Restore chum to Meares Island	High	Short-term	Some to Significant	
Raise cattle on Meares Island	High	Short-term	Insignificant	
STRENGTHEN SHELTER & INFRASTRUCTURE				
Water Supply (Opitsat)				
Repair/buttress unstable slopes supporting water pipe from Kakawis to Opitsat and maintain access trail	Medium	Short-term	Significant	
Investigate options to convert Brother Creek intake into infiltration gallery	Medium	Short-term	Some	
Water Supply (Ty'histanis-Esowista)				
Inspect water pipeline burial/support on airport property at stream gullies and report issues/blocked culverts to ACRD	Medium	Short-term	Some	
Consider water meter installation and dual-flush / low-flow toilets for new housing and existing housing toilet replacements	High	Short-term	Some	
Sewer (Ty'histanis-Esowista)				
Improve shoreline erosion protection adjacent to sewer collection piping (roads and water mains) parallel to the beach at Lower Esowista	High	Short-term	Significant	
Consider options to protect lift station from damage (storm surge) in Lower Esowista	High	Short-term	Some	
Stormwater Drainage (Opitsat)				

Complete drainage improvements along base of slope by existing 12-lot subdivision and consider new culvert under water treatment plant access road	High	Short-term	Some to Significant	
Stormwater Drainage(Ty'histanis-Esowista)				
Monitor new stormwater collection systems and inlets/ outlets to sediment ponds near south tributary of Esowista Creek and repair as needed	High	Short-term	Insignificant	
Monitor bridge foundations and culverts at Esowista Creek	High	**Short-term**	**Insignificant**	
Breakwaters (Opitsat)				
Consider relocation of most vulnerable grave sites	High	Short-term	Insignificant	
Energy/Hydro (Opitsat)				
Support regular maintenance by BC Hydro, particularly at Kakawis, for clearing danger trees near existing overhead lines	High	Short-term	Insignificant	

Hesquiaht Adaptation Action Plan
(Supplementary Community Actions)

DIVERSIFY LIVELIHOODS/LOCAL ECONOMIES	Priority	Timeline (to begin)	Investment	Responsibility
Explore opportunities related to the hot spring (accommodation, tours, food services etc.)	High	Short-term		
STRENGTHEN HEALTH & SAFETY				
Upgrade to improve access to medivac landing site in HSC	High	Short-term	Some	
Improve efficiency of medivac system for Hesquiaht Harbour. Medivac is out of Hot Spring Cove	Medium	Medium-term	Some	
Obtain new siren for emergencies	High	Medium-term	Significant	
Rebuild volunteer fire department	High	Short-term	Some	
Water Supply				
Verify/test flood-resistance of existing water pumphouse at Refuge Cove	Medium	Short-term	In-significant	
Evaluate sediment volume and transport upstream of Refuge Creek Intake and develop strategies to retain/divert sediment and restore channel stability where possible	Medium	Short-term	Some to Significant	
Improve erosion protection for Refuge Creek sediment tanks at water intake and review infiltration gallery protection from burial by additional sediment	High	Short-term	Some to Significant	
Establish alternate water supplies for fire protection (Refuge Cove) and drinking water (Hesquiat Harbour)	Medium	Short-term	Some to Significant	
Breakwaters				
Replace log breakwater (Refuge Cove)	Medium	Short-term	In-significant	
Consider relocation of most vulnerable grave sites	Medium	Short-term	In-	

(Hesquiaht Harbor).			significant	
Consider relocation of most vulnerable grave sites (Hesquiaht Harbor).	Medium	Medium-term	Some	
Solid Waste				
Review functionality of existing barge ramps for loading out garbage	Medium	Short-term	Some	
Sewer				
Complete annual inspection of outfall lift station and improve resistance to damage from surge/flooding at Refuge Cove	Medium	Short-term	Some	
Regularly inspect anchors on sewer outfall pipe under Refuge Cove	Medium	Short-term	Some	
Evaluate alternates to septic tanks and septic fields if necessary at low-lying areas of Hesquiat Harbour	Medium	Short-term	Some to Significant	
Stormwater Drainage				
Complete drainage improvements to increase capacity in lower reaches, retaining and storing water for irrigation	Medium	Short-term	Significant	
Wharves/ Docks				
Reinforce existing wharves, check/repair interconnections of floating dock slabs at regular frequency (Refuge Cove)	Medium	Short-term	Some to Significant	
Energy/Hydro				
Conduct regular maintenance of Refuge Cove power plant, check existing grounding and/or need for lightening arrestors	High	Short-term	Some	
Regularly inspect condition of individual power systems at Hesquiat Harbour community	Low	Short-term	In-significant	
Telecommunications				
Regularly inspect condition of microwave towers	Medium	Medium-term	In-significant	
Explore alternate means of telecommunications that are more reliable	High	Short-term	Some	

Chapter 8

Climate Change in the Clayoquot Sound: Monitoring and Research Needs

contents

Initiating Monitoring and Research for Climate Change

With such a potentially overwhelming concept as climate change and the almost endless number of issues that need to be considered, there is a real challenge in knowing how to prioritize. Although much of the scientific research around climate change will be carried out by the major institutions and government departments, there is still lots that can be done locally to help understand what is going on and most importantly to get an idea of the rate at which some of the changes are occurring. The adaptation strategies and action plan detailed in the previous two sections are to be considered living documents and updated as time goes by based upon new findings and circumstances.

The following tables are a first attempt to identify areas and specific items for monitoring and researching that could be used to help the communities with the implementation of the adaptation strategies. This work does not all need to be done immediately, and much of it does not need to be carried out by the communities themselves. There are numerous research bodies such as Vancouver Island University, Simon Fraser or UBC that are always looking for projects, while local organizations such as the Clayoquot Biosphere Trust (CBT) are stepping up into taking on a role coordinating monitoring of ecosystem health in the region and climate change impacts would be a primary candidate. Most importantly for the marine work, West Coast Aquatic Tsawalk Partnership (WCA) have been working extensively on identifying monitoring needs and indicators for the region and much of this will be exactly what is needed to begin setting up baselines for long term ecosystem monitoring to detect climate change effects.

Monitoring Requirements for Climate Change

	Priority	Timeline (to begin)	Investment	Responsibility
Marine Monitoring				
Acidity, salinity, oxygen and temperature levels - Identify where this should occur and a schedule for carrying out	High	Short-term	Significant	Major commitment – partnerships with WCA, universities and CBT
Tides, storm winds and storm surges - Finalize identification of where this needs to be carried out	High	Short-term	Some	Local communities
Health of indicator species - as identified in Chapter 4 of this report and by WCA. An example is highlighted below.	Medium	Short to medium term	Significant	Major commitment – partnerships with WCA, universities and CBT
Compare euphausiids (krill) health with Barkley Sound – as identified in this report, this is a valuable indicator species at the bottom of the food chain that would provide very useful baseline information.	Medium	Short term	Significant	Major commitment – partnerships with WCA, universities and CBT
Forest Monitoring				
Impact of current harvesting practices on riparian areas and regeneration under new climate projections	Low	Medium term	Some	Major commitment – partnerships with Iisaak, CBT and Ministry of Forests
Freshwater Hydrology Monitoring				
Flows of key water sources and drainages – reinstate some of the now abandoned flow stations in the region	Medium	Short term	Significant for set up, some for running	Government Ministry or University group
Precipitation levels (including rainfall intensity levels) at various elevations within the study area	Médium	Short	Some	Government Ministry or University group

Community Infrastructure				
Erosion of shoreline and around infrastructure – to identify rates and frequency of events	High	Short term	Insignificant	Local community
Sewage outfall – to ascertain if it is or is becoming blocked by sand deposits	Medium	Short term	Insignificant	Local community with some assistance.
Storm water drainage – to ensure adequate as winter rains intensify	High	Medium term	Insignificant	Local community
Infrastructure disruptions due to climate events – regularity, type and extent for long term planning around maintenance and replacement.	Medium	Medium term	Insignificant	Local community
Health and Safety Monitoring				
Pests and disease – especially related to damp conditions.	Low	Long term	Some	Local Community and nursing.
Accuracy of storm alerts – rolls in with emergency preparedness.	Low	Medium term	Insignificant	Local community
Household mould & mildew	High	Short term	Significant	Combination of federal funding and local action
Household displacements due to climate events – rolls in with emergency preparedness	Medium	Short term	Significant	Combination of provincial funding and local action
Livelihoods				
Employment levels – especially in terms of diversification of activities for long term resilience	Low	Long term	Insignificant	Local action

Research Requirements for Climate Change

	Priority	Timeline (to begin)	Investment	Responsibility
Marine Research				
Investigate farming potential for giant kelp and sustainably harvest for commercial purposes. Investigate medicinal and commercial potential Pacific Rockweed Rockweed pilot plots to better understand changes	Medium	Mid term	significant	Major commitment – partnerships with WCA, universities
Plankton studies in Clayoquot similar to those in Barkley Sound	High	Short term	significant	Major commitment – partnerships with WCA, universities
Feeding habits of local grey whale & sea lions population	Medium	Medium term	significant	Major commitment – partnerships with WCA, universities
Climate effects on sea otter	Medium	Medium term	Some	Major commitment – partnerships with WCA, universities
Spawning success of salmon Climate change impacts on depths important to Rockfish	High	Short term	Significant	Major commitment – partnerships with WCA, universities
Analyze growth rate of pacific oysters Options for safely enhancing manila clam productivity Location of local geobeds and productivity	Medium	Medium	Significant	Major commitment – partnerships with WCA, universities
Inter-annual local eel grass growth rates Determine impact of climate change to existing kelp beds	medium	Medium term	Some	Major commitment – partnerships with WCA, universities

Impact of sea temperature on Cassin's Auklet Marbled murrelet breeding and survival rates	Low	Long term	Some	Scientific research by major university.
Forest Research				
Growth response of red cedar at high elevations to projected climate change	Medium	medium term	significant	Major commitment – partnerships with Iisaak, CBT and Ministry of Forests
Effects of new climate on coastal fog	Low	Long term	Some	Scientific research by major university.
Riparian function under new climate scenarios with current levels of forest protection – the importance is for maintaining salmon habitat	High	Short term	Significant	Scientific research by major university.
Community Infrastructure				
House designs to cope with increased moisture and warmth and at an affordable cost for implementation in all new houses.	High	Short term	Significant	Local community and federal funding