Using Local and Indigenous Ecological Knowledge to Examine Local-scale Perceptions, Effects of, and Resilience and Adaptation to, Climate Change on Human/Landscape Interactions on the Pacific Coast of North America

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Abstract

The aims of this research were to investigate the perceptions and impacts of climate change on the ecological and cultural aspects of landscape through understanding local and Indigenous knowledge. Key cultural and ecological species were chosen for study by bridging Traditional Ecological Knowledge (TEK) and western scientific knowledge in a constructive, equitable, and practical way. These Cultural Keystone Indicator Species (CKIS) provide a novel and cross-culturally meaningful analytical framework for investigating the socio-ecological effects of environmental change.

In 2013 and 2014 I interviewed 96 resource users in 11 Indigenous communities in Northern British Columbia and Southeast Alaska. TEK data was collected on weather and landscape changes, resilience and adaptation techniques, and changes in biodiversity. I also reviewed the scientific and ethnoecological literature, and meteorological data. Three CKIS groups were chosen for monitoring: five species of salmon, five species of berries, and Sitka black-tailed deer, all key species highly impacted by weather changes.

The findings from the research show that these communities are observing and adapting to significant environmental changes, including more rain, warmer temperatures, and less snow, which have been accelerating over the last 15–20 years. These weather changes are impacting the terrain (e.g. isostatic rebound, erosion), the distribution and availability of marine and terrestrial resources, and people's confidence and ease in moving about their territory and ability to harvest and preserve resources. This research suggests that delineating CKIS is an efficient way of understanding the impacts of climate change, envisioning potential adaptation opportunities, and creating resilient social-ecological ecosystems.

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I hereby state that this entire thesis is my own work, apart from a map which has been used to show the region of Cascadia and is one of the officially produced maps of the region, and the map of my study area, which was produced specifically for me and my research by a friend with expertise in GIS, both of which have been credited.

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Chapter 1 Introduction and Literature Review

1.1 Introduction overview

For time immemorial, Indigenous Peoples of the northern Pacific Northwest (PNW) Coast region have adapted to changes in the environment they inhabit through their close ties of reciprocity to, and cultivation of, resources. They have recorded a multitude of environmental and biodiversity changes and can correlate these along both long term and more immediate timescales, as well as having dealt with the struggles and exigencies of the impacts of change (Comberti *et al*. 2015; Deur and Turner 2005; Thornton 2015; Thornton *et al*. 2015; Turner 2014; Wyllie de Echeverria and Thornton 2019). These records, maintained through oral histories and generational transmission of knowledge, detail intimate observations of different plants and animals to identify correct harvesting times, movement, and how species interrelate. The results presented in this thesis represent observations made by the vast majority of the research participants according to phenomena they encounter year to year in situ and in vivo according to the places they inhabit and the resource gathering activities they habitually (and historically) engage in, and show a broad overview of the weather, landscape, and biodiversity changes noticed in the region.

It has been established that there are correlational links between biological and cultural diversity (Loh and Harmon 2005), and higher rates of cultural diversity occur in regions of high biological diversity (particularly floral diversity), however little research has been done on how these diversities co-evolve and co-adapt in relation to the environmental changes seen in the current century. As recent shifts in climate further modify the coastal environment, the ability of Indigenous Peoples to effectively maintain customary uses of these coastal areas is being challenged, as are their previous adaptation strategies and reciprocal relationships with the ecosystem. However, in many instances we have yet to uncover the nature and magnitude of these changes from the point of view of the Indigenous Peoples that live in these coastal areas.

My conceptual framework (further elaborated in the methodology chapter) involved looking at the effects of climate change in this area by examining the relationships between Traditional Ecological Knowledge (TEK), biocultural knowledge, Cultural Ecosystem Services (CES), western science, and co-varying social-ecological diversity values, and focusing particularly on important cultural and ecological keystone indicator species and impacts of climate change on Indigenous Peoples dwelling in this sensitive area. In this thesis, I address how local and traditional ecological knowledge of ecosystem change, adaptation, and resilience can be linked to climate data to improve communication, understanding, and future adaptation strategies between local communities and governmental agencies. Using a multidisciplinary approach (such as that laid out in this project) is still gaining popularity, but it is becoming more common to include knowledge from Indigenous (and other local) Peoples into scientific enquiries and policy management (Fatoric and Morén-Alegret 2013; Gomez-Baggethun *et al*. 2012; Holmes and Jampijinpa, 2013; Hunn *et al*. 2003; The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services 2021).

One of the main purposes of this study is not only to explore appropriate ways to bridge Indigenous Knowledge with western scientific knowledge, but also to productively combine TEK with climate science, an integration which is not as widespread but also becoming more popular (Cochran *et al*. 2013; Garay-Barayazarra and Puri 2011; Gearhead *et al*. 2010; Green and Raygorodetsky 2010; Murray *et al*. 2011; Pinkerton *et al*. 2014; Raymond-Yakoubian *et al*. 2017). This is important because as climate models and predictions are evaluated under various scenarios, examining the ways that Indigenous Peoples have responded to their environment over millennia can inform development of appropriate adaptations to future climate scenarios. Additionally, while climate models are suitable on regional and global scales, TEK is more intimate, forged on a place-based scale, and provides a fine-grained view of local variation and adaptation possibilities. Thus, it is both practical, and just, to take into account the needs of Indigenous resource users and other local harvesters and the resources themselves (e.g. flora and fauna). The Indigenous Peoples in the Pacific Northwest and elsewhere on the North Pacific ring of fire have lived and adapted to a particularly dynamic environment over millennia. Their local, long-term, place-based knowledge should contribute substantively to the development of climate policy alongside western science (Herman-Mercer *et al*. 2011; Murray *et al*. 2011; Raymond-Yakoubian *et al*. 2017; Thornton 2001; Thornton and Manasfi 2010).

This chapter serves to review the literature of the region on the topics of climate change research and Indigenous knowledge, including the linking of these two knowledge systems, and the literature on focal species and ecosystem conservation. This sets the structure to delineate the theoretical framework in this thesis and for its application to case studies of key species identified in interviews as being impacted by climate change. The drastic changes in weather have greatly affected the mosaic of ecosystems of the Pacific Northwest coast, and the premise of this research is that local people will be more likely to monitor ecologically and culturally important species, and have noticed changes and fluctuations in populations, migration, and phenology, and thus it is these species that should be focused on for conservation efforts in response to climate change impacts. Therefore, the main proposition behind this research project is that if people are paying more attention to the quality and quantity of species linked to climate indicators, in turn these species can be used to monitor by proxy, and thus appropriately respond to climate change in the region. The significance to both the ethnoecological and climate disciplines is that these proxy species can be a way to tie scientific knowledge in with local and traditional ecological knowledge in a practical way that will contextualise both Indigenous knowledge within climate trends and climate data within a regional focus. The overarching ethnographic findings from this research show that Indigenous residents of these communities are aware of significant environmental changes over their lifetimes, and an acceleration in changes over the last 15–20 years, not only in weather patterns, but also in the behaviour, distributions, and availability of important plants and animals. These observations also correlate with findings in the scientific and ethnographic literature.

1.2 Aims and Objectives of Research

The overarching aim of this research is to investigate the effects of climate change on landscapes and biodiversity through understanding local and Indigenous knowledge of culturally and ecologically important species. While the Indigenous knowledge that is held by the Peoples living in the PNW is highly documented in various forms, only a small body of research in the PNW examining TEK, oral history, and landscape perceptions, has touched on environmental change issues to a significant degree (Cruikshank 2005; Dauenhauer and Dauenhauer 1987; Fedje and Mathewes 2005; Thornton 2008; Turner 2014). This research aims to contribute to filling this gap, and to building upon the literature specifically on how to integrate human perceptions of, and responses to, environmental change on ecosystems, and apply these knowledges in addressing contemporary and future climate change responses and adaptations (Howard and Pecl 2019; Turner and Spalding 2013).

In order to meet this aim, three major objectives were developed:

The first objective was to elucidate the climate changes that have been observed by the local and Indigenous peoples by recording their observations of weather changes and its effect on the landscape and biodiversity in general. The PNW is not as well studied as Small Island States with regards to rising sea levels and the increasing frequency and intensity of storms, but increasingly unpredictable weather is already being cited as contributing to unsafe travel conditions on the ocean and nearshore in the PNW by my participants, observations that have also been reported in the literature by Artic peoples (Cochran *et al*. 2013; Krupnik and Jolly 2002), but not yet in literature from the PNW. Going by 'old rules' to structure harvesting procedures and travel plans may not only be unsafe due to this unpredictable weather, but also unproductive, as these weather conditions may also adversely affect what resources people are able to harvest and when. For example, shellfish are a key winter and famine food, but Indigenous Peoples have long recognised the effects of paralytic shellfish poisoning/harmful algal blooms on shellfish (Deur et al. 2015; Moss and Wellman 2017; Newton and Moss 2009) and planned their harvesting accordingly. However, higher incidences of warmer water temperatures causing harmful algal blooms (leading to shellfish toxicity) have now been reported to create unsafe harvesting conditions for key shellfish foods (McKibben *et al*. 2015; Moore *et al*. 2011; Ryan *et al*. 2017; Shimada *et al*. 2016), leading to the need to change harvesting times and amounts. Given the impacts of weather conditions that appear to be worsening due to climatic change (Turner and Clifton 2009), this highly dynamic area is extremely important to conduct more research in, due to a long-lived Indigenous population who have adapted to a continuously changing environment for generations (Herman-Mercer *et al*. 2011; Murray *et al*. 2011; Thornton 2001; Thornton and Manasfi 2010).

The second objective was to explore how culturally and ecologically important species can be used as indicators of climate change. Indigenous people have practised landscape and resource management and cultivation for centuries. Their deep knowledge of biodiversity, landscapes, and weather patterns allows them to notice changes in species and their environments (Deur and Turner 2005; Turner 2014; Thornton *et al*. 2015), providing a valuable resource in collaborations between scientists, policy makers, resource managers, and resource users. The conservation and restoration discourse for decades has used both single species and whole ecosystem management frameworks for a variety of purposes, in particular as a focus species or ecosystem to conserve, or as indicators of environmental conditions, although use of indicators in a climate change context is rarer (Siddig *et al*. 2016). Despite these conservation frameworks being widespread in western science conservation, it is more recent to include people as an aspect of conservation – both people existing as a component in the landscape, and the knowledge Indigenous Peoples contribute to conservation. Identifying species that local and Indigenous Peoples pay attention to because they are not only culturally important, but also ecologically important, leads to recognition of shifts in their distribution, behaviour, quality and quantity, and provides better knowledge for the conservation frameworks for these species. This research will thus contribute to the smaller bodies of literature around incorporating local and Indigenous knowledge into conservation frameworks and situating indicator species into a climate change setting.

The third objective was to understand how people have been resilient and adaptive in response to how changing weather patterns have affected how they harvest, preserve, and manage resources, and interact with the landscape. The Indigenous Peoples in this region, as in many other areas, have had to adapt to changing environmental conditions for centuries. For example, there are many stories in oral histories regarding floods, glacial advancement and retreat, and sea level rise, etc. (Barbeau 1950, Boas *et al*. 2006, Clark 2003, Fedje and Mathewes 2005, Richard 2017), events also found in an examination of the geological history, which illustrate how people have adapted to past changes (Frazer 1930, 2013; Harris 1997; Hunt *et al*. 2016, Hutchinson and McMillan 1997; Moodie *et al*. 1992). In addition to environmental changes, Indigenous Peoples have also adapted to changes in their technology and lifestyles, such as now using freezing, canning, and modified drying and other preservation techniques, learning to read rapidly changing weather patterns, and the push and pull of a modern lifestyle that includes juggling working and holiday time and incorporating high gas prices into harvesting costs. This flexibility will be useful in the application of adaptation strategies into the future to meet the current ecological and climatic instability, and this research aims to bridge this TEK and perceptions of climate change and climate trends in the western scientific literature.

1.3 Location of Research

Within the Pacific Northwest, this study is focused specifically in the region of Southeast Alaska and Northern British Columbia. This location is an ideal place to apply the aims and objectives of this research because it is a very dynamic region, with strong history of environmental change and long-dwelling Indigenous Peoples with a track record of resilience and transformative adaptations. This refugia area is connected by similarities between geographical features (coastal, with mountains to the east) and the local Indigenous Peoples. However, it is also geologically, geographically, ecologically, and culturally diverse as to how people adapted and responded to ecological and geographical change, particularly in the ways that they engage with their resources (Brandt *et al*. 2014; Clague and Mathewes 1996; Dixon 2001; Fedje and Mathewes 2005; Langdon 1979; Moss 2008b; O'Neel *et al*. 2015). The geography of the region, as well as detailed descriptions of the study communities, is presented in Chapter 2, Methods.

1.3.1 Environmental characteristics of the Pacific Northwest Coast (PNW)

1.3.1.1 Coastal environments

Coastal environments are known to be particularly sensitive to and influenced by climatic change, as these ecosystems exist in delicate balance at the land-sea interface and have complex interactions between biological and geophysical changes (Fatoric and Chelleri 2012; Glick *et al*. 2010; Harley *et al.* 2006; Moss 2008a; Nicholls *et al*. 2007; Turner 2007). Throughout these regions, changes often consist of rising sea levels (which both erode and build beaches and coasts), changing abundance and distribution of species, and unpredictable weather (Abeysirigunawardena and Walker 2008; BC Ministry of the Environment 2013; Harley *et al.* 2006; IPCC 2007a; Moss 2008a; Nicholls 2003). However, despite being vulnerable and rapidly changing, these coastal ecosystems are comparatively understudied (Liquete *et al.* 2013; Savo *et al*. 2017). Little research has been carried out on climate change in the PNW Coast that specifically examines human perceptions of and responses to ecological change (Howard and Pecl 2019; Turner and Spalding 2013). As well as being greatly influenced by climate change, coastal environments are also considered to be some of the most ecologically diverse and productive ecosystems in the world (O'Neel *et al.* 2015; Suttles 1990). As these ecological systems shift in response to climate change, the relationships between the people that live there and how they use the environment, flora, and fauna will change, and it is this change which is explored throughout this thesis.

1.3.1.2 Edges and edge effects

The 'edge effect' concept (Turner *et al*. 2003 from Odum 1971) posits that edges between ecological zones are quite diverse and often productive (Thornton 2017), as they not only have species from the adjoining ecosystems, but often have distinct species of their own. The Northwest coast of North America is a region of land dominated by landscape and land-sea 'ecological edges' (Turner 2007) due to a complex coastline broken by a plethora of rivers, inlets, and fjords, with a sharp and steep gradient to high coastal mountains (Biogeoclimatic Zones of British Columbia 2013). This diversity in landscapes, combined with the high productivity of North Pacific coastal waters (Fitzhugh and Crowell 1988), and exchanges across these keystone (particularly estuarine) environments (Thornton 2017) correlates with high biological and cultural diversity in the study area (Berkes and Davidson-Hunt 2006; Brandt *et al*. 2014; Loh and Harmon 2005; Thornton 2017; Turner 2007; Turner *et al*. 2003).

1.3.2 Cultural characteristics of the PNW Coast

This region has had a long history of study by anthropologists, ethnoecologists, and archaeologists, and a brief outline of this background is presented below.

1.3.2.1 Anthropological background

Western academics first became fascinated in studying the PNW region between the 1880s to the 1940s, and many of these early anthropologists such as Barbeau, Boas, Forest, Garfield, Sproat, and Swanton (Fedje and Mathewes 2005; Harris 1997; Hutchinson and McMillan 1997; Kew 1993) travelled to collect oral histories, along with the cultural and physical features, of many different groups throughout this region. In addition to anthropologists, missionaries greatly impacted Indigenous cultures because as they travelled to different villages trying to convert Indigenous Peoples to Christianity, they also collaborated with anthropologists to collect knowledge from the people they visited (Tomalin 2009).

The Pacific Northwest Indigenous Peoples, like those in many other regions, have been majorly impacted by colonisation, through the introduction of human diseases, the fur trade, residential schools, and other issues, all leading to a loss of knowledge (Cruikshank 2005). Colonisation has affected nearly all aspects of Indigenous culture, including livelihoods, language, community memory, and TEK of the environment. In addition, as access to information has increased, such as radio and news reports, this has changed how people have reported their own histories, as I discuss further down. However, because ethnology in the PNW was amongst the earliest to engage professional anthropologists with respect for local languages, worldviews, socio-political organisation, and ethnoecology, their recordings of knowledge and representations of people captured an element of Northwest culture before it had been influenced overly much by outside sources, like it has been in more recent times (Baehre 2008; Lewis 2001). This literature has been valued as a source of climatic, environmental, and bioecological historical change which has been uninfluenced by scientific viewpoints (further discussed regarding how myths and legends of large events such as floods predate scientific research, and thus show connections between people and landscapes). This early research has further been expanded in modern day anthropological analysis to recognise Indigenous sovereignty over the land, management of resources, and co-production of knowledge, which will be vital to understand as this region pursues climate change resiliency (Central Council of the Tlingit and Haida Indian Tribes of Alaska 2019, Dowie 2017). Some limitations of this data are that this knowledge exchange was usually one sided (anthropologists learned more in the exchange), and there are issues with the mindsets, ethical outlooks, data collection methods, and interpretation of Indigenous knowledge by many of these early anthropologists (Pöhl 2008). However, from this early anthropological work, researchers have realized just how rich and complex this region is, and this has led to decades of substantive ethnoecological and anthropological research in this region.

1.3.2.2 Ethnoecological background

Multiple ethnoecological studies of every NWC group have been conducted in the region, as well as species and ecosystem level TEK studies, and thus the richness of the region has been widely studied and recorded in terms of Indigenous Knowledge regarding plants, animals, insects, linguistics, taxonomy, toponomy, etc. with a plethora of research

(See Cruikshank 2005; Emmons and de Laguna 1991; Dauenhauer and Dauenhauer 1987; de Laguna 1960, 1972; Deur and Turner 2005; Fedje and Mathewes 2005; Newton and Moss 2009; Thornton 1999, 2001, 2008, 2010, 2012, 2015, 2017; Thornton *et al*., 2015; Turner 2014). In addition to recording people's stories, ethnoecological knowledge, and heritage for their future use before it gets lost with the passing of elders, there has also been much work revitalising language, working in culture camps, and creating partnerships between communities and national governments. This ensures that their knowledge is not simply recorded in a library, removed from the geographical context (i.e. at a university), but they are able to assert ownership over their knowledge and keep it within their own communities and archives, as well as use it for co-management between other organisations to increase resiliency in future conditions.

1.3.2.3 Archaeological background

The longevity of occupation (15,000+ years, Peros *et al*. 2010) on the Northwest Coast can be seen through examination of the archaeological record (Moss 2008b, 2011). Throughout the region, archaeology has not only been done on above ground sites, but also in marine wet sites that used to be above the tide line and are now under water, showing how much the coastline has moved over the time of human occupation in the region. These sites, particularly those currently underwater, not only show where people used to live, but also resource use and distribution. It has been shown that the coastline, particularly on Haida Gwaii (Figure 2.2), is very dynamic, and many environmental changes have been experienced by people over time including vegetation changes, sea levels rising and falling, floods, and ice movement (Fedje and Mathewes 2005; Richard 2017; Walker *et al*. 2007). Sea level change was particularly noted in the archaeological record when the sea level fell by about 100m around 11,000 BP, before rising again to the current level (James *et al*. 2005).

This is one of the reasons which has led to numerous sites being underwater now, such as the site studied by Cohen (2014), which investigated archaeobotanical remains in the Haida Gwaii area. Not only have archaeological sites been uncovered in the specific study region of this research, but also further along the coast, where plant and animal remains have been tied to sites to show resource trends, such as for the Makah People in Washington State (Welchel 2005). Using the archaeological record, it has been shown that throughout prehistory (Archaic (>10,500 to 4,400 BCE), Early Pacific (4,400 to 1800 BCE), Middle Pacific (1800 BCE to 200-500 CE), and Late Pacific (200-500 to 1775 CE) Periods) resource use and intensification, harvesting and storage techniques, and sedentism have fluctuated (Ames 2003; Moss 2008b, 2011; Suttles 1990). It was interesting that deer were specifically noted by Ames (2003) to be the primary terrestrial resource harvested in the Early Pacific Period, and was not pin pointed in the other periods, perhaps due to changing technology allowing varying harvest or preference of other resources, and Moss and Cannon (2011) illustrate the widespread usage of fish throughout the archaeological record.

1.4 Cultural-Geographical characteristics of the PNW

Indigenous Peoples recognise and mark the above-mentioned diversity through both landscape terminology and place names. Northwest Coast Peoples have a rich geographic nomenclature and dense toponomy, which embody nuanced perceptions of the coastal and upland environments, including thousands of features on the landscape (Anderson 2014; Cruikshank 2001; Johnson 2010; Johnson and Hunn 2010; Thornton 1999, 2008, 2012). This knowledge of landscape history and features resulting from a long-term connection to the land is expressed in Indigenous languages. For example, English Settler terms for places in North America tended to be one dimensional, perhaps naming a location after a famous person with no link to the area named, or simply referring to a single feature in a landscape

(Thornton 2008). However, in contrast, by the virtue of the complexity of Indigenous languages and Peoples interactions with the land, Indigenous place names can convey not just a word which labels a place, but also contains the geomorphological, cultural, and resource use history through time as related to a location (Thornton 2008). For example, in Glacier Bay, Alaska, the English name simply names a bay with a glacier ('Glacier Bay'), while the Tlingit name of Sít' Eeti Geeyi, meaning "bay taking the place of the glacier", is signifying the process of how the bay formed as a glacier receded, and thus describes a geomorphological event (Thornton 2008).

1.5 Indigenous Peoples and climate change worldwide

While the effects of climatic change are being felt by all people around the world (Fatoric and Chelleri 2012), Indigenous Peoples are often found to be living on the forefront of changes and are disproportionately impacted (Salick and Byg 2007; Turner and Clifton 2009). Yet they are continually at the margins of the worldwide discussion of climate adaptation (Comberti *et al*. 2019; Shawoo and Thornton 2018). Although a number of studies incorporating Indigenous knowledge of climate change have been conducted among especially vulnerable groups, the majority of this research is centred in the Arctic (e.g., Berkes 2012; Crate and Nuttall 2009; Ford *et al*. 2006; Ford *et al*. 2010; Krupnik and Jolly 2002; Nakashima *et al.* 2013; UNESCO 2009), or Small Island States (Barnett and Campbell 2010; Lazrus 2012; Rudiak-Gould 2013), and the knowledge of climate change by local people is not as well known in the literature from the PNW. While the PNW is not as highly impacted by the effects of polar amplification and albedo as the Arctic, its habitats are still on the edges of these impacts and being influenced by the reverberations of these impacts through the environmental system.

1.5.1 Oral history of climate change in the PNW Coast

Even though Indigenous People may not have used the language of climate change to describe certain phenomena, there is evidence that they recognised drastic environmental changes that had happened in the past and included them in their oral history. Some examples of these environmental changes rooted in oral histories include the flood myths from the Pacific Coast, the story of “Tow Hill walking”, and various examples of landslides, rising sea level (seen in the story of Raven being said to have “pushed [the] islands apart [from the mainland] with his feet”, Fedje and Mathewes 2005, pg. 129), volcanic eruptions, and earthquakes (Barbeau 1950, Boas *et al*. 2006, Clark 2003, Fedje and Mathewes 2005, Richard 2017). These types of observations of long-ago landscape change, including sea level change, recorded in myths have also been seen in Australian Aboriginal stories (Nunn and Reid 2016; Reid *et al*. 2014). Some of these stories and myths were collected by the early anthropologists mentioned above (1880s to 1950s) largely before the interaction of climate change and the environment was a well-established concept in western science. Documentation of these types of events have been seen around the world and likely represent an oral history that has been passed down through generations and have their roots in an environmental episode that actually occurred (Frazer 1930, 2013; Hunt *et al*. 2016). In fact, there are several studies to date that have linked Indigenous stories with environmental and archaeological evidence to show that the events described in oral histories are reflected in the recorded history of the landscape itself, such as erupted volcanos and earthquakes/tsunamis (Harris 1997; Hutchinson and McMillan 1997; Moodie *et al*. 1992), and that these oral histories of survival can be linked to the capacity for resilience and adaptation by Indigenous People (Hunt *et al*. 2016).

1.6 Theoretical background of suggested concept

One of the largest issues to face the management, conservation, and preservation of ecosystems is how to quantify all of the links between biotic and abiotic factors, and it is impractical to do this without using some proxy measures. To date, ecologists and conservationists use several concepts to classify species and illustrate their importance to people, their role in an ecological context, and to show links for measuring biodiversity. The purpose of creating these terms is to provide a structure to conservation measures by focusing on one or more species which will then allow broader ecosystems and additional species to be protected. Ethnoecology is interdisciplinary by nature, and extremely useful for studying complex interactions between humans and their environments. Nevertheless, investigating one species and its' connections to the surrounding ecosystem can be useful in focusing this broad discipline (Garibaldi 2009).

1.5.2 Adaptation and Resilience Theory Background

The ability for organisms and ecosystems to adapt to change has become yet more paramount in recent times, as we move into an even more quickly changing world. The Intergovernmental Panel on Climate Change (IPCC) was founded in 1988 to collate the current knowledge on climate change and assess the impacts and future risks globally from a scientific perspective, as well as exploring adaptation and mitigation possibilities (IPCC 2020). In previous editions of the IPCC reports, the focus has been more at framing adaptation through a lens of biophysical vulnerability and how well people and environments can respond to that, as well as a focus on adapting through engineering and technological fixes (IPCC 2014a; Noble *et al*. 2014). More recently however, it has changed to looking more at how people are able to respond to different drivers, and how 'ecosystem-based, institutional and social measures' can add value to adapting to climate change into the future

(Noble *et al*. 2014). In this discussion, it is important to differentiate between adaptation and resilience, two words in the climate conversation which are frequently used but have slightly differing meanings and implications. Adaptation, as defined by the IPCC (Allwood *et al*. 2014), is "the process of adjustment to actual or expected climate and its effects. In human systems, adaptation seeks to moderate or avoid harm or exploit beneficial opportunities. In some natural systems, human intervention may facilitate adjustment to expected climate and its effects". It was specifically noted that this definition had changed from the previous IPCC report to acknowledge advances in scientific thinking (Allwood *et al*. 2014)[1]. Another major component in responding to climate change considered by the IPCC reports is mitigation, which is defined as "A human intervention to reduce the sources or enhance the sinks of greenhouse gases (GHGs)" (Allwood *et al*. 2014), although it does also refer to other types of human intervention to reduce impacts and has again been highly modified and honed from the 2007 definition[2], which refers more to technological change.

While it is important to have some practical mitigation and adaptation actions, such as building structures on shorelines to protect against sea level rise (not always feasible in rural areas, Thornton and Manasfi 2010; Wong *et al*. 2014), or management, such as inputting nutrients into the ocean in oceanic enrichment programs (Pörtner *et al*. 2014), overall, there needs to be greater emphasis on the role ecosystems and nature-based solutions play in creating a resilient system. For example, adaptation on its own has been considered to be "blind" by some of the resilience and adaptation literature (Thornton and Manasfi 2010), since it is more focused on 'preserving existing resources' (Wong-Parodi *et al*. 2015).

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[1] Previous definition was: "Initiatives and measures to reduce the vulnerability of natural and human systems against actual or expected climate change effects. Various types of adaptation exist, e.g. anticipatory and reactive, private and public, and autonomous and planned. Examples are raising river or coastal dikes, the substitution of more temperature-shock resistant plants for sensitive ones, etc." (IPCC 2007b).

[2] "Technological change and substitution that reduce resource inputs and emissions per unit of output. Although several social, economic and technological policies would produce an emission reduction, with respect to climate change, mitigation means implementing policies to reduce GHG emissions and enhance sinks" (IPCC 2007b)

Theoretically, both adaptation and mitigation are considered more static (and potentially more brittle), in the sense that they halt movement (such as reducing GHG or coastal erosion), but don't always build capacity to prepare for an event (COP23 2017; Wong-Parodi *et al*. 2015), even though in practice, many projects considered to be simply 'adaptation' also build resilience (Adaptation Fund 2019). In some instances, under adaptation processes, ecosystems would only be restored to their pre-climate conditions, or people or ecosystems will respond to their environmental conditions and might 'adapt', but they don't integrate knowledge for future responses or develop novel systems. Consequently, as tension builds in the system from adapting to multiple stressors, we see expressed the concept of 'panarchy', where cycles of destruction and reorganisation break up a system that has become too rigid and generates variability within the system, which can then be incorporated into the next iteration of organisation (Folke *et al*. 2002).

As seen above, adaptation and mitigation are actions taken with regards to responding to changes within systems. What is often presented as an alternative dialogue to adaptation, and yet also contains a form of adaptation within it, is resilience, defined as: "the capacity of a social-ecological system to absorb or withstand perturbations and other stressors such that the system remains within the same regime, essentially maintaining its structure and functions. It describes the degree to which the system is capable of self-organisation, learning and adaptation" (Resilience Alliance 2019). Another key concept within resilience is 'adaptive capacity'. When a system has high adaptive capacity, they are "more able to re-configure without significant changes in crucial functions or declines in ecosystem services" (Resilience Alliance 2019), and this is a vital trait for the ecosystem to buffer itself from changes.

While resilience is a part of IPCC conversation, the focus in this literature (IPCC 2014a) is more on adapting to the current and future conditions and mitigating them, rather being resilient to changes and being able to bounce back, and surprisingly the word only appeared twice in the entire report and was not defined in the glossary at all (IPCC 2007b). Even though it has been an established concept in the literature for at least the last 40 years (Brown 2016), it has become more prevalent in the last 10 (Biggs *et al*. 2015; Brown 2016), growing even more because of research done in a large part by research consortiums such as the Resilience Alliance and the Stockholm Resilience Centre (Resilience Alliance 2019; Stockholm Resilience Centre 2019). A group of researchers based at the Stockholm Research Centre developed seven principles of resilience synthesizing the main components of the actions of applying and increasing resilience (Biggs *et al*. 2015; GRAID 2020), and examples of these seven principles can be seen illustrated throughout my research, examples of which are elucidated in each point. A unique feature of these principles is that they are not just social or ecological principles, but rather the connectivity and feedback from each one affects and is dependent on the others. The seven principles are:

1) **maintain diversity and redundancy**: redundancy provides a form of 'insurance' against some resources being lost, so for example if people harvest a wide variety of resources, they can adjust if one of their resources is less common in one year (i.e., harvesting more moose that have now moved onto islands, instead of travelling further to find deer). Additionally, if the resources react differently to changes (such as weather changes), or different users utilise different fishing methods, this is considered to be 'response diversity' and lends further redundancy to the system, thus maintaining diversity.

2) **manage connectivity**: habitats or areas that are connected can be both positive and negative, either increasing recovery time after a disturbance (flow back into affected system) or allowing the disturbance to spread faster. For example, when deer cluster together at feeding stations, disease spreads faster, and they can then be spread throughout the habitat by deer dispersing away from the feeding station. However, on the positive side, the connectivity of old growth forests allow deer to escape snow, and have larger ranges, and the connectivity of streams to estuaries (and not blocked by debris) allow salmon to access their spawning sites. Additionally, when community and human networks (local governments, trade of resources and knowledge) increases their shared information, there is better management.

3) **manage slow variables and feedbacks**: feedbacks connect variables and can be either positive or negative. Respect and ceremonies can demonstrate examples of

this: if a resource was taken care of, it would return the next year to be harvested, but if it was treated badly or not appropriately managed (berries, salmon and deer), the resource wouldn't provide for people. Additionally, 'governance structures' can be established that can respond to information from TEK and scientific knowledge to adjust resource use, such as harvesting limits and opening times. This could be a key use for CKIS, as they will be noticed and monitored by people, and can inform management choices.

4) **foster complex adaptive systems thinking**: the 'complex interactions and dynamics' between people and ecosystems must be understood in order recognise the range of ecosystem services that are available, and the connections between species. For example, salmon affect and are affected by oceanic systems, freshwater systems and terrestrial systems, and this is recognised both by ecological studies and by Indigenous kinship worldviews.

5) **encourage learning**: participating in both learning about and experimenting with 'adaptive and collaborative management' is key for building resilience, and knowledge needs to be shared between both TEK and scientific knowledge holders, at all levels. For example, culture camps will allow cultural knowledge and traditions to be passed down to younger generations, and co-collaborating on research and management projects will allow TEK and scientific knowledge holders to learn from each other to reach a common understanding co-management ground.

6) **broaden participation**: having lots of participation of TEK knowledge holders and scientific knowledge in research projects can both build trust between groups and also greatly expand the depth of knowledge that is available to make co-management decisions. Again, as an example, it is key to involve TEK holders in scientific research, as they hold a type of knowledge from generations of observations that is unlikely to be uncovered by scientific research methods.

7) **promote polycentric governance systems**: This principle can again be linked with knowledge sharing, but in particular making sure that different governance structures are well connected to each other to appropriately co-manage resources. There may be issues here with power imbalances, and there may also be differences around what priorities should be followed for management, but communication between each stakeholder and each level or circle of the governance system is vital to creating working co-management systems.

While adaptation, mitigation, and resilience are not mutually exclusive, throughout this thesis I demonstrate how cultural and ecological key species are roadmaps to understandings of, and responses to, environmental change, including vulnerability, resilience, and adaptation. Although resilience is only one property of a complex system, the importance of collaborative dialogue amongst all levels of knowledge systems and with ecosystem management with increased resilience and adaptive capacity has become a more widespread discussion in the most recent IPCC reports (IPCC 2014a; IPCC 2014b; Pörtner *et al*. 2014; Romero-Lankao *et al*. 2014; Settele *et al*. 2014; Wong *et al*. 2014).

1.6.1 Single species conservation

There are many examples around the world of a single species being the focus for conservation efforts. These categories are listed below, along with a discussion of their main principles in order to compare them to justify the selection of the concept I am using in this thesis.

1.6.1.1 Keystone species

The earliest of these concepts was that of Ecological Keystone Species (EKS), coined by Paine (1969), who developed this concept by studying how the presence of sea stars preserved ecosystem balance and increased biodiversity in the nearshore environment. Keystone species are those which are considered to have an impact which is excessively larger than their abundance (Power *et al*. 1996), and therefore the interactions and population fluctuations of other species are likely to be moderated by 'keystone' species in different communities. Similar to the keystone stones being used at the top in doorway arches to hold the framework of stones in place, keystone species structure their environment. An important example of a keystone species in the PNW is the sea otter, *Enhydra lutris* (Estes and Palmisano 1974; Mills *et al*. 1993), which balances sea urchin and kelp abundance. If the sea otters do not consume enough urchins, the urchins will eat all the kelp, creating an underwater desert. The idea of a keystone species has since been expanded to include 'cultural' keystone species (CKS), developed by Garibaldi and Turner (2004) and further explained below.

Looking at both an ecological and cultural context, there are keystone species that are important for monitoring the health of an ecosystem, and the interactions between biotic and abiotic constituents in the social-ecological system. Additionally, some species that are culturally (and ecologically) keystones are also disproportionately affected by climatic impacts and can be used as climate indicators by recognising shifts in their biological reactions as a result of their sensitivity to climate change. These species are particularly worthy of focus in studying environmental change impacts on long-dwelling Indigenous Peoples in particular regions, and their recognition of, and responses to, these changes.

1.6.1.2 Umbrella species

A second concept, umbrella species, was developed by Wilcox (1984), who suggested that a 'target species' should be chosen for conservation whose 'minimum area requirements' were of a similar size as the community which the species lived in, which would then in turn provide a 'protective umbrella' for the rest of the species included in that community. In order for this target species to be chosen and warrant protection, it would often have the characteristics of a 'large body size…high trophic level…high metabolic requirements…patchy distributions…and species dependent on successional, rare or unpredictable habitats and resources' (Wilcox 1984). Thus, by focusing on the protection of this one target species which has many ecological interactions and whose home range is large, the surrounding species would be protected. Some examples in the PNW include northern spotted owl (*Strix occidentalis caurina*) and coho salmon (*Oncorhynchus kisutch*) (Branton and Richardson 2014; Simberloff 1998).

1.6.1.3 Flagship species

A third concept, flagship species, are defined as 'popular charismatic species that serve as symbols and rallying points to stimulate conservation awareness and action' (Heywood 1995). The species that are included in this category are often icons for conservation campaigns such as those spearheaded by the Worldwide Fund for Nature. They are picked because people will be able to identify with them as they are iconic in indexing relations to nature by being well known, local, cute, majestic and/or fierce. The hope is to protect whole ecosystems which are being threatened by issues such as deforestation, pollution and climate change, by tying them to the fate of these flagship species which people identify with strongly due to their iconic characteristics. While many common flagship species are tropical, one well known example in the Arctic region is the polar bear (*Ursus maritimus*) (Peacock *et al*. 2011).

1.6.1.4 Indicator species

The fourth and final single species classification concept I discuss is that of an indicator species. While the concept of an 'indicator species' has been discussed in the literature for many years (Landres *et al*. 1988), Siddig *et al*. (2016) provides a succinct definition: "Indicator species (IS) are used to monitor environmental changes, assess the efficacy of management and provide warning signals for impending ecological shifts". Chosen species have been used to 'indicate' within a wide range of contexts, including: implying levels of pollutants and toxins in a system (Hilty and Merenlender 2000; Parmer *et al*. 2016), categorising the local environmental conditions and ecosystem assemblages/biodiversity (Hilty and Merenlender 2000; Klinka *et al*. 1989), observing abundance and fluctuations of resources/taxa/endemic species (Hilty and Merenlender 2000), and monitoring ecosystem health and environmental/ecological stressors and changes, such as changes influenced by climate change (Hilty and Merenlender 2000; Siddig *et al.* 2016). Indicator species that specifically indicate environmental hazards are often referred to as 'sentinel species', an example of which is the well-known canary in the coal mine (Reif 2011) which provided an early warning system of hazardous gases.

One confusing aspect of the term 'indicators' is that it can also be used to refer to abiotic features, or community assemblages, for example: air and water quality, rainfall amounts, temperature, and shellfish beaches (Wong and Rylko 2014), and the habitat needs of one indicator species may be incompatible with another species, leading to conflict in management (Landres *et al*. 1988). Other issues of applying this term are similar to issues with the other three concepts I discussed above (keystone, umbrella and flagship), for example: having little consensus as to what these species actually indicate, uncertainty surrounding selection criteria, unsuitable taxa selected, unclear definitions, and varied methodologies (Hilty and Merenlender 2000; Kremen 1992; Siddig *et al*. 2016; Simberloff 1998). Hilty and Merenlender (2000) also feel that the criteria for selecting indicator species are often too 'conceptual', making it hard for managers to appropriately apply these concepts. However, the United States Department of Agriculture (USDA) Forest Service, as a major land manager and the predominant land holder in the Tongass National Forest in Southeast Alaska, endorses the concept through its programme of Management Indicator Species (MIS), defined as "vertebrate or invertebrate species whose response to land management activities can be used to predict the likely response of other species with similar habitat requirements" (USDA Forest Service 1997, Forest Plan, Chapter 3, pg. 3-351). This plan monitors a set of faunal species of interest in different protected regions of the United States to see how management affects them and the complexes of communities and habitats they live in. They have identified a total of 17[3] Management Indicator Species (MIS) in their 1997 Tongass National Forest plan for special management, six[4] of which also have 'special management concern' (Everest *et al*. 1997; USDA Forest Service 1997). Additionally, similar to the MIS identified above, the Council for the Haida Nation (CHN) have delineated 'Traditional Forest Features', which have a similar type of standing in denoting areas of high cultural significance, and to guide where to build roads and carry out logging (Council of the Haida Nation 2013). They have identified five 'Class 1' features[5], 10 'Class 2' features[6], and 31 'Class 3' features[7]. Three of the MIS species and two of the Traditional Forest Features species are focal species in this research (bolded in footnote below).

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[3] 13 terrestrial MIS in the Tongass National Forest includes: red squirrel (*Tamiasciurus hudsonicus*), black bear (*Ursus americanus*), brown bear (*Ursus arctos*), marten (*Martes americana*), river otter (*Lontra canadensis*), **Sitka black-tailed deer (*Odocoileus hermionus sitkensis)***, mountain goat (*Oreamnos americanus*), grey (Alexander Archipelago) wolf (*Canis lupus ligoni*), Vancouver Canada goose (*Branta canadensis*), bald eagle (*Haliaeetus leucocephalus*), red-breasted sapsucker (*Sphyrapicus ruber*), hairy woodpecker *Leuconotopicus villosus*), brown creeper (*Certhia Americana*); 4 aquatic MIS: **pink salmon (*Oncorhynchus gorbuscha*), coho salmon (*Oncorhynchus kisutch*),** cutthroat trout (*Oncorhynchus clarki*), Dolly Varden char (*Salvelinus malma*)
[4] Brown bear (*Ursus arctos*), marten (*Martes americana)*, **Sitka black-tailed deer (*Odocoileus hermionus sitkensis)***, grey wolf (*Canis lupus ligoni*), northern goshawks *Accipiter gentilis*) and marbled murrelet *Brachyramphus marmoratus*) (key species from this research are bolded).
[5] "extremely important to the Haida and particularly rare, because they are threatened by logging and/or introduced species" - Fairy-slipper (*Calypso bulbosa*), Black hawthorn (*Crataegus douglasii*), Northern riceroot (*Fritillaria camschatcensis*), Devil's club (*Oplopanax horridus*), Highbush-cranberry (*Viburnum edule*)
[6] "identified as being of importance to the Haida, but may be either less rare or less threatened by logging and/or introduced species" - Common Harebell (*Campanula rotundifolia*), Common Juniper (*Juniperus communis*), Pacific crabapple (*Malus fusca*), Yellow pond lily (*Nuphar lutea*), Stink Currant (*Ribes bracteosum*), Black swamp gooseberry (*Ribes lacustre*), Trailing currant (*Ribes laxiflorum*), Cloudberry (*Rubus chamaemorus*), Stinging nettle (*Urtica dioica*), Indian hellebore (*Veratrum viride*)
[7] Northern maiden-hair (*Adiantum aleuticum*), Old man's beard (*Alectoria sarmentosa*), Narcissus anemone (*Anemone narcissiflora*), Sitka columbine (*Aquilegia formosa*), Kinnikinnick (*Arctostaphylos uva-ursi*), Alpine bitter-cress (*Cardamine bellidifolia*) Snake liverwort (*Conocephalum conicum*), Round-leaved sundew (*Drosera rotundifolia*), Licorice fern (*Polypodium glycyrrhiza*), Sword fern (*Polystichum munitum*), Black cottonwood (*Populus balsamifera*), Common silverweed (*Potentilla anserine*), Bracken fern (*Pteridium aquilinum*), Labrador tea (*Rhododendron groenlandicum*), Thimbleberry (*Rubus parviflorus*), American glasswort (*Sarcocornia pacifica*), Spiny wood fern (*Dryopteris expansa*), Oregon beaked-moss (*Eurhynchium oreganum*), Large-leaved avens (*Geum macrophyllum*), Beach pea (*Lathyrus japonicas*), Running club-moss (*Lycopodium clavatum*), Single delight (*Moneses uniflora*), One-sided wintergreen (*Orthilia secunda*), Cloud lichen (*Platismatia glauca*), Hooker's willow (*Salix hookeriana*), Scouler's willow (*Salix scouleriana*), Sitka willow (*Salix sitchensis*), **Bog blueberry (*Vaccinium uliginosum*)**, Lingonberry (*Vaccinium vitis-idaea*), **Oval-leaved blueberry (*Vaccinium ovalifolium*)**, Giant vetch (*Vicia nigricans*).

1.6.1.5 Advantages and disadvantages of single species conservation concepts

There are advantages and disadvantages to each of the above conservation concepts with their use of a 'single species' focus to concentrate conservation research and biodiversity measurements. One advantage is that regardless of which category a species is classed in, it is likely that the protection of this one species will lead to the preservation of other species in their environments, which is the main aim of these concepts (Simberloff 1998). The largest advantage for all three is that by providing this focus on a species which appeals to scientists, local people and/or an international community, it allows conservation to be manageably understood. However, despite these advantages, Simberloff (1998) reports that there have been conflicts identified during the application of these concepts and the various species chosen for conservation, particularly with regards to umbrella and flagship species. These conflicts include:

1) contradictions in management needs between species
2) too expensive to reasonably protect
3) management and protection of the chosen species may not confer protection to other species in the ecosystem
4) confusion on which concept a species should be classed under

Finally, there are issues as to what happens when a focus species becomes extinct, or if an ecosystem doesn't have any key endangered species to fill the role of a focus species (Simberloff 1998).

While Hilty and Merenlender (2000) acknowledge that it's unlikely that a selected taxa or species would fit all criteria, they suggest that a group of species or a taxon should be grouped together to display a comprehensive picture, which would then fulfil several criteria. The information they delineated for criteria about species/taxa to make them viable indicators are as follows:

1) Known baseline information (such as 'biology, taxonomy and tolerance') and how humans change their characteristics
2) Limited biogeographical ranges, but occurring in many places (this will increase the number of studies, and also cut out anomalies from migration patterns)

3) Specific niche requirements and life history features, as well as low variability in their genetics and ecology, so that changes in the species/taxa more accurately provide early warnings – indicators – of ecological changes, rather than the species changing in response to a smaller ecological change.

Hilty and Merenlender (2000) also urge researchers to take into account how easy it is to measure and identify species/taxa and ecological changes, and the cost of the research. They suggest the selected species/taxa should be picked that respond to ecological changes easily and early, while resisting erratic variability; be more niche specific, so they can't alter their resources easily to limit the impacts of changes and thus accurately represent changes in resource abundance; and selecting species that are endangered or represent more than one political or social agenda.

1.6.2 Ecosystem Conservation

While there is evidence from the above four terms that there are advantages to a single species conservation concept, it is also helpful to expand our view to the entire ecosystem, and it has been suggested that groups of organisms should be used instead of single species, as noted in the preceding paragraph (Hilty and Merenlender 2000; Kremen 1992). Thus, another way to look at species conservation (also known as habitat conservation) is to look at the ecosystem as a whole, with a comprehensive view to preserving biodiversity in its entirety. This has been thought to be beneficial to all processes and species (Daily *et al*. 1997; Ingram *et al*. 2012; Simberloff 1998) and might be better than a 'single species' focus (Simberloff 1998). However, some weaknesses of the 'ecosystem management' concept are:

1) the boundaries of an ecosystem are ill defined
2) 'ecosystem healthiness' is a fluctuating concept
3) reconciling how an ecosystem's processes and functions can be preserved regardless of species present, and thus have no need for a focus on protecting individual 'umbrella' and 'flagship' species.

An issue with ecosystem conservation is that sometimes the relationship and interconnections between humans and ecosystems are ignored when discussing the protection of biodiversity

(Simberloff 1998); this omission is addressed in the next section on incorporating people into conservation.

1.6.3 Incorporating people into conservation

The inclusion of humans as an aspect of conservation challenges the original tenets of the American conservation movement, which focused on the preservation of the environment by excluding people to protect a supposedly "untouched" wilderness (Library of Congress, 2002). Traditionally, conservationists and preservationists saw that the role of humans in the ecosystem was to be completely removed from the system to protect it, and that systems should be preserved solely for biodiversity and not for human resource needs. Partially this was due to early conservationists and preservationists not realising the impact Indigenous and local people have had on landscape and biodiversity composition over centuries. As ideas and research have progressed further, people have realised that there are no such things as untouched wilderness and that people need to be considered in environmental management (Balée 1998; Cronon 1996; Thornton 2010).

Ecosystems around the world are experiencing change, and as these changes occur, the dynamics between people and their landscape are changing as well. For the last several decades, economists and ecologists have collaborated in an attempt to place value on aspects of the environment that were not easily assignable, referred to as 'Ecosystem Services' (ES) (Costanza *et al*. 1997; Daily 1997; MEA 2005; Patterson 2011). From this initial assessment, four main themes of services from ecosystems to people have been identified: supporting, provisioning, regulating, and cultural. In this research I will be focusing on cultural ecosystem services and examining not only how ecosystems service people in a cultural aspect, but also looking at how people service the ecosystem and strengthen the resiliency of ES (Biggs *et al*. 2012; Burger *et al*. 2008; Comberti *et al*. 2015; Holmes and Jampijinpa

2013). These discussions tie in quite well with the worldview that many Indigenous Peoples hold, where they are connected to the rest of the world, both human and animal, by ties of kinship (Salmón 2000), injunctions of reciprocity, and respecting and managing a landscape, so that the landscape, animals, and plants, will continue to care and provide for you into the future (Deur and Turner 2005; Thornton *et al*. 2015; Turner 2014).

Taking Cultural Ecosystem Services (CES) one step further, and bringing in Indigenous kincentric worldview concepts, there has lately more literature focusing on how humans should be integrally incorporated into concepts of 'the environment' – both in the literature around ecosystem management, and ES mentioned above. But these discussions have gone beyond monetising the environment for humans needs and quantifying what people can obtain and use from the environment and are now moving into what (some) humans 'give back' to their environments by ways of "services to ecosystems" and the reciprocal relationships inherent in Cultural Ecosystem Services (Comberti *et al*. 2015). Indigenous Peoples have complex techniques to unobtrusively manipulate, cultivate and manage key resource species and ecosystems and build reciprocal relationships. For example, people interacted with the cultural keystone species I examined in this thesis in a variety of ways, including, but not exclusively restricted to, controlled burns to encourage berry growth, also leading to increased deer accessibility to this habitat, clearing streams for salmon access, transplanting salmon eggs, and pruning berry bushes (Comberti *et al*. 2015).

1.6.4 Keystone Indicator Species

I have chosen the concepts of both indicator and keystone species as the most appropriate ones to apply to my framework of culturally important species, i.e., ones that can detect changes in climate and the environment that affect harvesting frequency and the durability of the resource and the cultural process into the future. Combining these two concepts with a whole ecosystem view guided by Indigenous worldviews provides a good balance between the identification of whole ecosystem climate change issues and those affecting culturally salient single species at the local social-ecological system level.

Using cultural and ecological indicator and keystone concepts focuses attention on single species for management, but also situates the chosen species to illustrate the interconnections within both natural and human ecosystems, because they are influenced by environmental and ecological changes, and human adaptation. This allows us to have a dual view of a single species focus within a broader social-ecological ecosystem context. While indicator species haven't frequently been used in a climate change context (Siddig *et al*. 2016), the concept provides a means of monitoring the effects of a changing climate on the ecosystem into the future and monitoring the species that respond to this climate change as an indicator.

Following on from my intended use of the indicator and keystone concepts in an ecological and environmental context, I refer to Cultural Ecological Species, a concept developed to apply these ecological terms in the arena of TEK, which was coined in two unique environments. Cristancho and Vining (2004) developed the term 'Culturally Defined Keystone Species' from their research in the Amazon, and con-currently Garibaldi and Turner (2004) developed the term 'Cultural Keystone Species' from work in Canada. In addition to this concept development, Garibaldi and Turner (2004) also discussed how to incorporate CKS into conservation and restoration. They define CKS as "culturally salient species that shape[s] in a major way the cultural identity of a people, as reflected in the fundamental roles these species have in diet, materials, medicine, and/or spiritual practices" (Garibaldi and Turner 2004, pg. 4).

From the above frameworks, I use these theoretical concepts of 'Indicator' and 'Keystone' within a 'Cultural' setting, and in their overlapping regions I place my concept of a Cultural Keystone Indicator Species (CKIS) (Wyllie de Echeverria and Thornton 2019), defined in the next section (Figure 1.1).

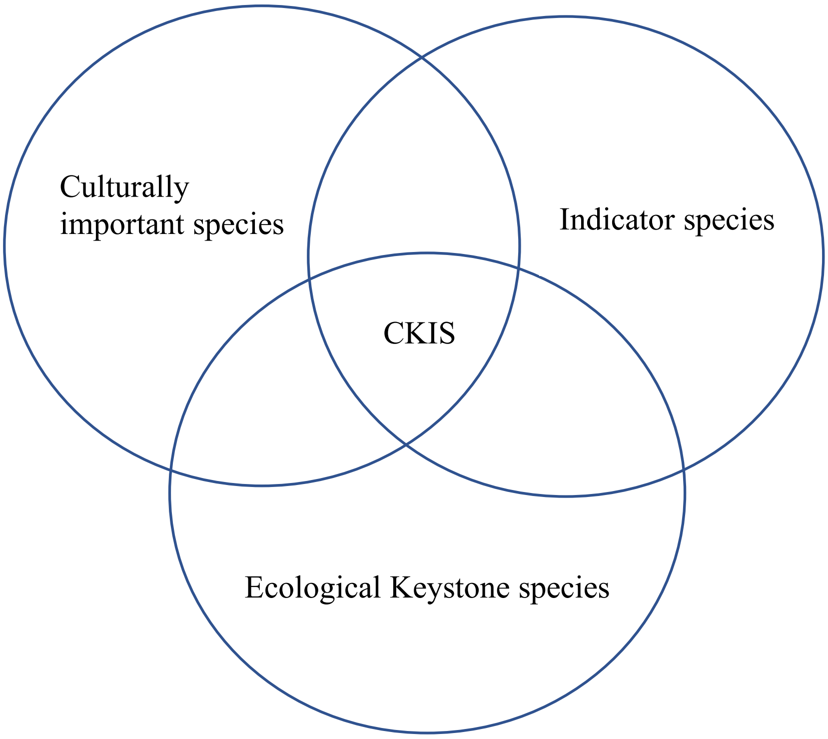

Figure 1.1. Venn Diagram showing how my three main theoretical concepts overlap to delineate the Cultural Keystone Indicator Species Concept that I present.

1.7 Definition: Cultural Keystone Indicator Species (CKIS)

Formed from the analysis of interview data and conceptual background data, I propose the concept of 'Cultural Keystone Indicator Species' (CKIS), which I define as a '*critical species of both cultural importance and perceptual salience in relation to environmental change*'.

I documented TEK on the topics of ecosystem and landscape change in the PNW and identified culturally important keystone indicator species. These were species that were important contributors to the functioning of the ecosystem (ecological keystone species), indicated changes in weather variables (such as air and ocean temperatures and amounts of sun, snow and rain; indicator species) and were highly used by Indigenous People in the interviews (and mentioned in literature; culturally important species). Using these three concepts will identify species that are culturally important, so local people pay attention to their population fluctuations, and meet the criteria to be both indicator and ecological keystone species in their ecosystems. Overall, 11 species emerged as the best examples to illustrate my suggested Cultural Keystone Indicator Species (CKIS) concept from the ethnographic data collected in this study (although other species in this region may be candidates for my concept) and my final choices were supported using past ethnoecological studies and ecological data, showing their importance as cultural keystone species (CKS), ecological keystone species (EKS) and indicator species (IS):

1) Sitka black-tailed deer (*Odocoileus hermionus sitkensis*)*[8]
2) Salmon (*Onchorynchus spp*.)
    a. Chinook/king/spring (*O. tshawytscha*)
    b. Chum/dog (*O. keta*)
    c. Coho/silver (*O. kisutch*)*
    d. Pink/humpy (*O. gorbuscha*)*
    e. Sockeye/red (*O. nerka*)
3) Berries
    a. Blueberries (*Vaccinium spp.*)
        i. Alaskan blueberry (*V. alaskaense*)
        ii. Ovalleaf blueberry (*V. ovalifolium*)*
        iii. Dwarf bilberry (*V. caespitosum*)
        iv. Bog blueberry (*V. uliginosum*)*
    b. Salmonberry (*Rubus spectabilis*)

To investigate how CKIS can reflect climatic influences in an ecosystem, these 11 species were broken into the three case studies numbered above (Sitka black-tailed deer, Salmon, Berries), as it was sometimes more practical to use a wider classification of species,

[8] * on some of the species denotes starred CKIS were mentioned as being indicator species to monitor in the MIS and Forest Features concepts above (section 1.5.1.4, Council of the Haida Nation 2013; USDA Forest Service 1997).

a 'functional group', for a CKIS rather than a single species because there may be several related species possessing very similar cultural and ecological roles. For example, all five major species of Pacific salmon are treated as a 'functional group' in the salmon CKIS case study as they have similar ecological requirements and cultural uses, despite having differing life cycles and uses. Similarly, the four species of blueberries that grow in the study region and salmonberry are aggregated into one functional group of 'berries' for the purposes of this analysis, as interview data show that these species hold similar ecological and cultural roles in the region and are being impacted by climate change in similar ways despite variation in patterns of harvest, use, and ecological needs.

1.8 Research Questions

As stated in section 1.2 above, the aim of this research was to investigate how climate changes affect the landscape and biodiversity, and the specific objectives delineated to meet this aim were to record the local and traditional knowledge of: observed changes in weather, landscape, and biodiversity; how important species are watched and monitored to indicate climate changes; and the implementation of resilient and adaptative responses to these changes. In order to address the aim and objectives, I have framed the impacts of climate change on culturally important plants, animals, and the coastal landscape through the concepts of cultural and ecological keystone species, indicator species, conservation, TEK, and scientific knowledge explored above, culminating in my Cultural Keystone Indicator Species concept. This led me to develop the following overarching research question:

1) To what extent can species which hold critical relevance in people's lives due to their cultural and ecological significance be used as proxy measures to understand and monitor the impact of climate change on a regional landscape scale, and serve as an

indicator of the impacts on the landscape and socio-ecological systems in the face of climatic changes?

In order to support and understand this main research question, I developed several sub questions based on the objectives I identified above which allowed me to draw connections between the diverse groups in this region, examine how the ecosystem alters due to changes in weather patterns (whether climate induced or not), and how this will affect the landscape, (including the plants, animals, and people that depend on this landscape), and see the similarities and differences in human responses to climate change and engagement with the biodiversity of their ecological systems not only with the CKIS examples, but biodiversity as a whole. These sub-questions were framed to gather a wide dataset of observations surrounding landscape and biodiversity knowledge and climate science, and are as follows:

1) Are Indigenous Peoples noticing changes in the weather and if so, what weather patterns (as indicative of climate changes) are happening?
2) Are observed weather changes affecting how people access, harvest, and prepare resources in their territory?
3) Which species (culturally and ecologically important and otherwise) were observed by people throughout this region to be experiencing change?
4) How do observed changes indicate broader shifts in biodiversity?
5) How can Traditional Ecological Knowledge and climate data be used in conjunction to present a comprehensive picture of local climate change effects and inform adaptive responses, including knowledge transmission between generations, and capability for resilience into the future?

To answer these questions, I documented ethnographic knowledge from interview participants and examined both ethnographic and scientific literature to elucidate what services people perceive themselves as gaining from, and giving to, the ecosystem, and how changes to the local environment, plant, and animal distributions, and ability to harvest food, affects peoples' engagement with ecosystems, and changes the ecosystem services that are offered to both parties (people, and ecosystems). By gathering a wide data set, this also allowed for further fine-grained analysis, presented in the later chapters of this thesis and this synthesized knowledge can hopefully be utilised by local communities to assist in their future adaptation practices and collaborations.

1.9 Organisation of Thesis

This thesis is broken down into eight chapters. The general structure of the thesis is that the first two chapters, Introduction and Methodology, cover the theoretical background and justification of methods, and the purpose of these chapters is to situate the study both in the literature and geographically. The next four chapters discusses the regional changes and three CKIS case studies from the research data, and the purpose of these chapters are to present the TEK gathered through interviews and contextualise it through both climate knowledge and previous literature. The last two chapters investigate how people are adapting to climate change practically and speculatively into the future, how the different threads of policy and TEK knowledge interact, and also concludes the thesis. The aims and objectives of each chapter is explained below in depth.

In Chapter 1, the introductory chapter, the aim is to provide an overview of the entire research study by summarising background literature and delineate research aims, objectives and questions. The objectives of this chapter are to review the background literature covering the cultural, ecological, environmental and geographical characteristics and history of the study region, and relevant theoretical concepts of single species and ecosystem conservation, and examine the nuances between adaptation and resilience. I also outline the aims and objectives of the entire study and research questions, and then bring these threads of ecological and culturally important species and climate change adaptation and resilience together to develop my theoretical framework around the Cultural Keystone Indicator Species (CKIS) concept presented in this thesis.

The aim of Chapter 2, Methodology, is to present a synopsis of the study area and the methods used in this study. The objectives are to present a justification of the research methods, describe ethical approval and community access, and delineate both how the ethnographical research was designed, gathered and analysed, and how the climate and harvest data were analysed. This chapter also contains information about the study region, including profiles of each community, and a reflection on limitations of this type of research.

Chapter 3 aims to provide an important regional overview of the study area by establishing the continuity and discontinuity of TEK observations on general weather patterns, landscape changes, and biodiversity gathered in research interviews in the whole region. It covers two main objectives. Firstly, it examines observations of weather (Section 3.2 and 3.3) and landscape changes (Section 3.4) for this study region as an entire bioregion and situates this TEK into the climate and geographical literature. Secondly, it describes TEK regarding biodiversity changes (Section 3.6), including species interactions, connections, and responses to the perceived weather changes broadly throughout the region, including the impact of these shifts on harvesting patterns and traditional livelihoods.

The next 3 chapters all apply my CKIS concept to specific species or functional groups as examples, using TEK and literature sources. In them, I first talk about broader scale changes in population fluctuation, spatial distribution, behaviour change, flowering and fruiting patterns, and then move into quality of habitat, size, harvesting issues, and timing of harvest, before mentioning any climate related diseases and pests. I then go through non-climatic effects on the species, and wrap up with TEK about adaptations, management, respect, regulations, and processing issues.

Chapter 4 aims to apply the CKIS concept to an example species, that of the Sitka black-tailed deer (*Odocoileus hemionus sitkensis*). The objectives in this chapter are to situate deer in the ecological and cultural literature and analyse the TEK data gathered from interviews from this study for knowledge of the influence of climate and weather changes on population fluctuations, spatial distribution and behavioural changes, harvesting patterns, meat quality, and disease. Additionally, I briefly investigate non-climatic factors on deer, and using TEK and literature sources, examine human adaptations to resource changes and management decisions, and justify why this species is a good example of a CKIS.

Chapter 5 aims to apply the CKIS concept to an example of a suite of closely related species that can function as group, that of the five Pacific salmon species (*Onchorynchus* spp.). The objectives of this chapter are to situate all five species of salmon in the ecological and cultural literature, along with delineating similarities and differences between each species, and justifying why they are grouped into one functional group for this study. As well, the TEK data gathered from interviews from this study was analysed for knowledge of the influence of climate and weather changes on population fluctuations, spatial distribution and behaviour changes, habitat quality, size, and harvesting patterns. Additionally, I briefly investigate non-climatic factors on salmon, and using TEK and literature sources, examine human adaptations to resource changes, and management and regulation decisions, and justify why this functional group is a good example of a CKIS.

Chapter 6 aims to apply the CKIS concept to an example of a suite of species that are not all related closely taxonomically but share very similar ecological and cultural roles, four species of blueberry (*Vaccinium* spp.) and salmonberry (*Rubus spectabilis*). The objectives of this chapter are to situate all five species of berries in the ecological and cultural literature, along with delineating similarities and differences between each species, and justifying why they are grouped into one functional group for this study. As well, the TEK data gathered from interviews from this study was analysed for knowledge of the influence of climate and weather changes on population fluctuations, flowering and fruiting patterns, fruiting capacity, fruit quality, and harvest patterns. Additionally, I briefly investigate non-climatic factors affecting berries, and using TEK and literature sources, examine human adaptations to resource changes, and management and regulation decisions, the commercialisation of this resource by local people, and justify why this functional group is a good example of a CKIS.

Chapter 7 aims to compare observations from participants and scientific literature regarding adaptation and resilience, human impact on ecosystems, how co-management schemes are being implemented between governmental and tribal entities, how knowledge is transmitted through generations, and capability for resilience into the future.

The last chapter is Chapter 8, which concludes the thesis with a summary of the main results, including how each research question is answered by the results and a summary of limitations. This chapter then concludes with implications of this research and the CKIS concept, and future research possibilities.

1.10 Summary - Importance of connecting TEK and climate science

I believe that this CKIS concept, when applied in ethnographic research, fills a major gap in the effort to bridge between Indigenous Knowledge and climate and ecological knowledge to integrate both knowledge sources. It does so in a compatible (if not unified) framework by emphasizing climate sensitive species that are important to people and ecosystems (Herman-Mercer *et al*. 2011). This will lead to a better understanding of the functioning and interactions of the ecosystems, and how best to adjust climate and management policies to reflect the needs of the people that are using the system, as well as the needs of the plants and animals themselves – in short resilience to a changing world (Biggs *et al*. 2015). Using CKIS that are monitored as markers of changes in the environment and climate, we can examine these causal changes and changing relationships between climate, culture, and ecosystems in coordinated detail in a way not done before in the North Pacific. New ethnographic data in conjunction with ethnographic sources, or re-analysed past ethnographic sources in this context, can document and evaluate how climatic change impacts are "cascading" (Turner and Clifton, 2009) through social-ecological systems, and how local communities are responding to these changes. Overall, this thesis demonstrates how TEK of ecosystem change, adaptation, and resilience can be linked to climate and ecological data, with the hope that this integration can improve communication, understanding, and future adaptation strategies between local communities and governmental agencies, using CKIS to guide collaborations.

Chapter 2 Methodology

2.1 Methodology overview

This study employs a mixed methodology combining detailed ethnoecological case studies at the community level, based on interviews and participant observation, with comparative reviews and interrogations of the ethnographic literature and scientific literature on climate and other social-ecological changes in the region. The research for this project was carried out on the Pacific Coast of North America, specifically in Northern British Columbia and the panhandle of Southeast Alaska, in the Cascadia bioregion (Cascadia Institute 2010), as previous research indicates these areas are experiencing large impacts from climate change, but these impacts have not been studied in depth. While this area is geographically united in being a coastal ecosystem, and has similarities between the local Indigenous groups, this refugia area is ultimately spatially diverse geologically, geographically, and ecologically (Brandt *et al*. 2014; Clague and Mathewes 1996; Dixon 2001; O'Neel *et al.* 2015), as well as culturally and geopolitically, from the ways that people engaged with their resources all the way through to how they adapted and responded to ecological and geographical change (Fedje and Mathewes 2005; Langdon 1979; Moss 2008b). Thus, this research provides an overarching framework for the region, while still acknowledging details that are unique to each community's response to ecological and climate change.

2.1.1 Justification of research methods

When engaging with both scientific and community-based Indigenous Knowledge systems, diverse methods from both social sciences and natural sciences are needed. Bernard and Gravlee (2015), among others, provided justification for the key social science methods deployed in this research. They suggest a two-stage data collection for interviews: firstly, have a 'pilot stage' to explore in depth the topic of interest as related to your region of interest, and secondly to use a 'structured or systematic interviewing' technique to investigate the topic more deeply and gather comparative and quantitative data. Additionally, they discussed the most appropriate way to sub-sample a population. Because I had limited time during the data collection period, most of the preliminary research was done by analysing the past literature about the region and drawing upon the guidance and knowledge of my supervisor who has worked in the region for many years, along with my more limited personal knowledge of the region because of my own previous research. In the second stage of data collection, I primarily used semi-structured interviews. I felt this was the best interviewing method to use because I was able to have structure to the interview that would allow some comparison between participants, and guide the interview, but also allowed the participant to freely discuss topics that were of particular importance to them and have some free-flowing dialogue which would allow me to access information I hadn't originally anticipated as being of relevance.

I sampled my population using non-probability sampling, using firstly judgement sampling (based on my supervisor's previous research), and then snowball, or chain referral, based on participants recommending other participants for me to talk to. While Bernard and Gravlee (2015) report that there is no accepted minimum subsample size in the literature, but "that sample sizes in qualitative research should be determined inductively and continue until 'theoretical saturation' is reached" (the point where no new data is being gathered), it is suggested by several of the authors they reviewed that an ethnographic study should have about 30 - 60 participants (Bernard 2000; Morse 1994). Working in a total of 11 communities with a total of 96 participants, allowed me to meet this suggested sample size using a regional lens, and by having 8-10 participants from each community, I was also able to employ a "community case study" approach, and apply a sub-regional and microclimatic lens to the data. In addition to semi-structured interviews, when the opportunity arose, I used participant observation research, particularly joining berry picking trips, lunches of Indigenous foods at elder centres, and visiting notable sites to gain a deeper understanding of the connections between people and their landscape. While extensive participant observation was not conducted, and it was not a major method of this study, partially due to the limited time in each community, participant observation is an important technique because it allows the researcher to capture 'day to day' events in a more natural setting than that of an interview (Bernard and Gravlee 2015).

For the natural science methods, I chose to examine governmental climate data at regional and sub-regional scales to compare to the weather observations made by participants. This regional and sub-regional data also provided important context for interpreting responses to environmental change, including shifting patterns in Alaska Department of Fish and Game (ADFG) harvest data. This can help us to understand how people's hunting and management protocols may be changing in response to keystone species' distributions and gives us insights into how quantitative harvest data can be used in conjunction with people's observations of resource fluctuations.

2.2 Ethical approval

Ethics approval was obtained for this research as a whole from the University of Oxford's Central University Research Ethics Committee (CUREC 2019). See Appendix 1 for the completed ethics approval. I developed a letter introducing the collaborator, the project, and an ethics consent form for people to sign, which can be found in Appendix 2a, b, and c, following ethnoecological guidelines, and local and University regulations. When each participant was approached for their interview, they were guided through the information letter and consent form to make sure they understood it, and the consent form was signed. In addition to this free and prior informed consent, as part of the consent form participants were able to determine their level of anonymity, attribution, and how their interview was both recorded and shared. Since people were asked about changes to the landscape, and availability and locations of valued plant and animal resources and harvesting locations can be highly guarded secrets, they could answer generally if they wished to suppress public knowledge of key harvesting spots or ask to have it withheld.

2.3 Ethnographic Methods

The ethnographic data used in this study was carried out in the study area delineated above.

2.3.1 Interview recruitment

Once the communities to be visited were selected (described in section 2.6.1), the first step in the research process included contacting the relevant Tribal and First Nations governing bodies in each community to establish connections and protocols for initiating research. Upon entering communities, I met with established contacts and typically was advised to visit the senior or elders centre to introduce the project and recruit knowledgeable consultants. Through this process and referrals from interviewees, officials, and previous researchers, I developed a targeted sample of local knowledge experts through snowball sampling methods.

The research participants were classed into two age groups. This was to provide a range of experiences in landscape and resources. One group consisted of interviewees between 60-90 (no interviewee was older than this), who are considered Elders in the community. This group was primarily chosen for their knowledge about long-term perspectives on climate and resource shifts, which can attempt provide a temporal context to the recorded knowledge. The second group consisted of interviewees between 25-59, (adults which are not Elders). This group was chosen because they are still active harvesters and spend time on the landscape monitoring various changes in local species' health, abundance, distribution, and responses to climate change. Their knowledge is critical for understanding how changing weather patterns are impacting current harvesting and preserving techniques and any adaptations to environmental change they are engaged in. The age division of the two groups was based on what people customarily consider to be an 'Elder' in these communities, which is broadly thought of as someone over the age of 60. However, some of the younger and more fit Elders consulted in this study are also active harvesters, and people on the upper limit of the second, younger group may also have a long-term perspective, so there is inevitable blurring of this arbitrary age boundary from a resource use perspective. By interviewing people in both categories, this allowed me to access significant historical and contemporary climatic and ecological information.

2.3.2 Interview process

Interviews in communities were conducted between August and October 2014 except in Old Massett, BC, which was visited in February 2015. Interviews were conducted in English, but numerous interviewees also shared relevant terminology and concepts in their Indigenous languages, particularly ethno-geographic, ecological, and biological terms, and terms or phrases relating to clan, crest, and moiety connections to territory and historical (environmental change) events. Interviews ranged between 20 minutes and 2 hours and took place almost exclusively in the person's home, or another community space such as the elder centre in the community or a coffee shop. Where possible, interviews were supplemented with participant observation experiences such as walks, drives, and berry collecting expeditions for experiential learning, mostly to look at areas where landscape change had occurred or to investigate resource availability (primarily berries).

The majority of the data was collected via conducting semi-structured interviews, the guiding questions for which can be found in Appendix 3. This format was picked because it gave basic topical structure to the interview process, while still allowing the interview conversation to flow naturally, perhaps connecting themes that the researcher had not anticipated, or mentioning additional topics beyond the original interview questions. The full interview was formatted around 16 multi-part questions, covering knowledge on topics such as: weather changes; landscape changes; ecosystem services and interactions; resource use; species biometric patterns; historical adaptation techniques; interactions with governmental bodies; stories of change and adaptation events from ancestors and more recently; and planning and adapting for the future. However, depending on the participants expertise and age, sometimes only some questions were covered in depth, and others were not discussed at all.

2.3.3 Interview Analysis

When permission was given, interviews were recorded with a Zoom H1 recorder and saved as .MP3 files. If permission was not given, hand-written notes were taken during the interview that noted down the observations, answers, and comments of the interviewees. Recorded interviews were transcribed by listening to .MP3 files through ExpressScribe© and typing them into a Microsoft © Word document with the assistance of hotkeys. ExpressScribe© is a software that allows you to slow down, rewind, pause, etc., the recording using hot keys that are active when you are typing into a word processor, speeding up the time between listening to a segment and transcribing it. Completed transcriptions were then copied into Scrivner©, a management system for organising writing with a stacked index on the side that allows multiple documents to be clicked open in nested folders. This was useful as a key word could be searched in all interviews simultaneously; each interview the key word appeared in could be searched through to find the context it appeared in, and then the interviews could be coded. Coding was done by hand by searching for instances of key words which allowed me to code for themes and organise participant's statements by observation type, with additional geographical ordering.

These transcribed semi-structured interviews were analysed using a manual thematic qualitative analysis, primarily by using the search function in Scriver that allowed me to search all interviews for key words and reoccurring and overlapping themes, and then collating the observations. I chose to use Scrivner as an organising and search tool as I found NVIVO and other structured analysis software programs were more geared to structured interviews and didn't allow for the scope of digressions and tangents that existed in my data. People often discussed their observations in a round-about manner, and I wasn't able to simply search for the question to find how they answered each interview question. By using manual thematic analysing, I was able to provide additional context to the perceptions and lived realities expressed.

2.3.4 Dissemination of results

In addition to this thesis, this research will also be disseminated in the form of community profiles for each community I worked in, which will include the results of the research from each location expressed in easily understood terminology and with illustrations. Each community profile will include a summary of the ethnoecological data that was collected from the entire region, along with more detail about community specific data, references to how it fits into the broader regional research perspective, and a plan of action developed from the results of this project which can be used by local and community land managers to assist them in implementing adaptations to future environmental conditions, so as to retain optimal cultural and biological diversity and conservation of keystone species. Additionally, all interview recordings, transcripts, maps, and other relevant materials will be provided to each community via local governmental representatives to keep in their archives (following each participant's preferences as stated in the consent forms), and they will also be given a full copy of the thesis and subsequent articles that come out of this research.

2.3.5 Participant response

In this study, a total of 93 local community members and three governmental personnel were interviewed. Of the 93 community members, all but five were Indigenous (but the five non-Indigenous participants had lived in the communities for a long time), 40 were men, and 53 were women (see table 2.1). Full names (where consent to identify was indicated), community, age (if given) and pseudonym/code for use in this research has been identified in Appendix 4.

Table 2.1. Demographics of participants divided by gender and community.

Sub Region	Community	Women	Men	Total
Northern Southeast (NSE)	Juneau, AK	6	5	11
	Hoonah, AK	8	7	15
	Kake, AK	3	6	9
Southern Southeast (SSE)	Klawock, AK	5	1	6
	Craig, AK	1	1	2
	Hydaburg, AK	3	4	7
	Ketchikan, AK	2	1	3
Mainland BC (MBC)	Metlakatla, BC	3	2	5
	Hartley Bay, BC	1	0	1
Haida Gwaii (HG)	Skidegate, BC	8	3	11
	Old Massett, BC	13	10	23
	Governmental Employees	3	0	3
	Total	56	40	96

2.4 Climate Data Analysis

Weather data in the region was examined using primarily the GCHN database, provided by the Climate Explorer website (KNMI Climate Explorer 2019), but also with some comparisons to Berkeley Earth (Berkeley Earth 2019), and global and regional scientific literature. Some weather information was gathered from the grey literature provided by the Alaska Department of Fish and Game website.

2.5 Analysis of Harvest Data

To place specific harvesting perceptions, knowledge of amounts of resources harvested, and thus the fluctuations year to year, into a quantitative data framework, government websites and grey literature were investigated for harvest records. These records were examined for specific species, and information about the ecological and cultural importance of the CKIS used in this research. The two federal governments involved in this research area, The United States of America and Canada, in addition to the two state/provincial governments of Alaska and British Columbia, have different regulations. In Alaska, the Community Subsistence Information System (CSIS) website provided by the Alaska Department for Fish and Game Division of Subsistence (Alaska Dept of Fish and Game Division of Subsistence 2019), was accessed for all Alaskan study area communities which had recorded data, and the years that data had been gathered were compared. These communities included Craig, Hoonah, Hydaburg, Kake, and Klawock. Ketchikan only had resource records for deer in one year, and Juneau and did not have harvesting data, because they are in a 'nonsubsistence area', where you can hunt for personal use but not subsistence due to their dense (urban) population (Alaska Dept of Fish and Game Fishing Matrix 2020). Resource data was examined for deer, salmon and berries (sometimes berry harvesting records were differentiated into blueberries and salmonberries, and sometimes just the generic category of 'berries' was used).

In British Columbia there is a completely different system for measuring community harvests. Because First Nations are not required to have permits to hunt or fish, most of them do not report their harvest, so there is no government record of harvest data by First Nations (BC Ministry of Forests Lands and Natural Resource Operations 2007; Kuzyk 2016). This can be an issue for resource management decision-making by the government, so there is discussion of a 'New Relationship with First Nations and Aboriginal Peoples' (BC Ministry of Forests Lands and Natural Resource Operations 2007) to help coordinate the best way to co-manage resources for everyone's use in an ecologically sustainable way. Thus, harvest data was not examined for British Columbian communities in this study and cannot be used to compare harvesting between years and communities.

2.6 Cascadia Bioregion

The Cascadia Bioregion (Figure 2.1), a concept coined in 1970 by David McCloskey, describes the idea of the PNW being a unique biogeographical region (Cascadia Institute 2010; McCloskey 1988). While the concept of the Cascadia Bioregion movement as a whole also has elements of secession and independence geopolitically, with its own flag and political identity, it is used here to describe the unique geographical, ecological, and biological traits of this region. It is geographically defined as "the watersheds of the rivers that flow into the Pacific Ocean through North America's temperate rainforest zone. Cascadia, or the PNW, extends from Northern California to Southern Alaska – along a coastline once cloaked in nearly continuous rainforest – and inland as far as the Continental Divide" (The Decolonial Atlas 2014). While Cascadia has the political and biogeographical definitions discussed above, ultimately McCloskey felt that the overall concept of Cascadia ‘transcended’ the above definition and was “more a cultural [and] ideological identity” (The Decolonial Atlas 2014).

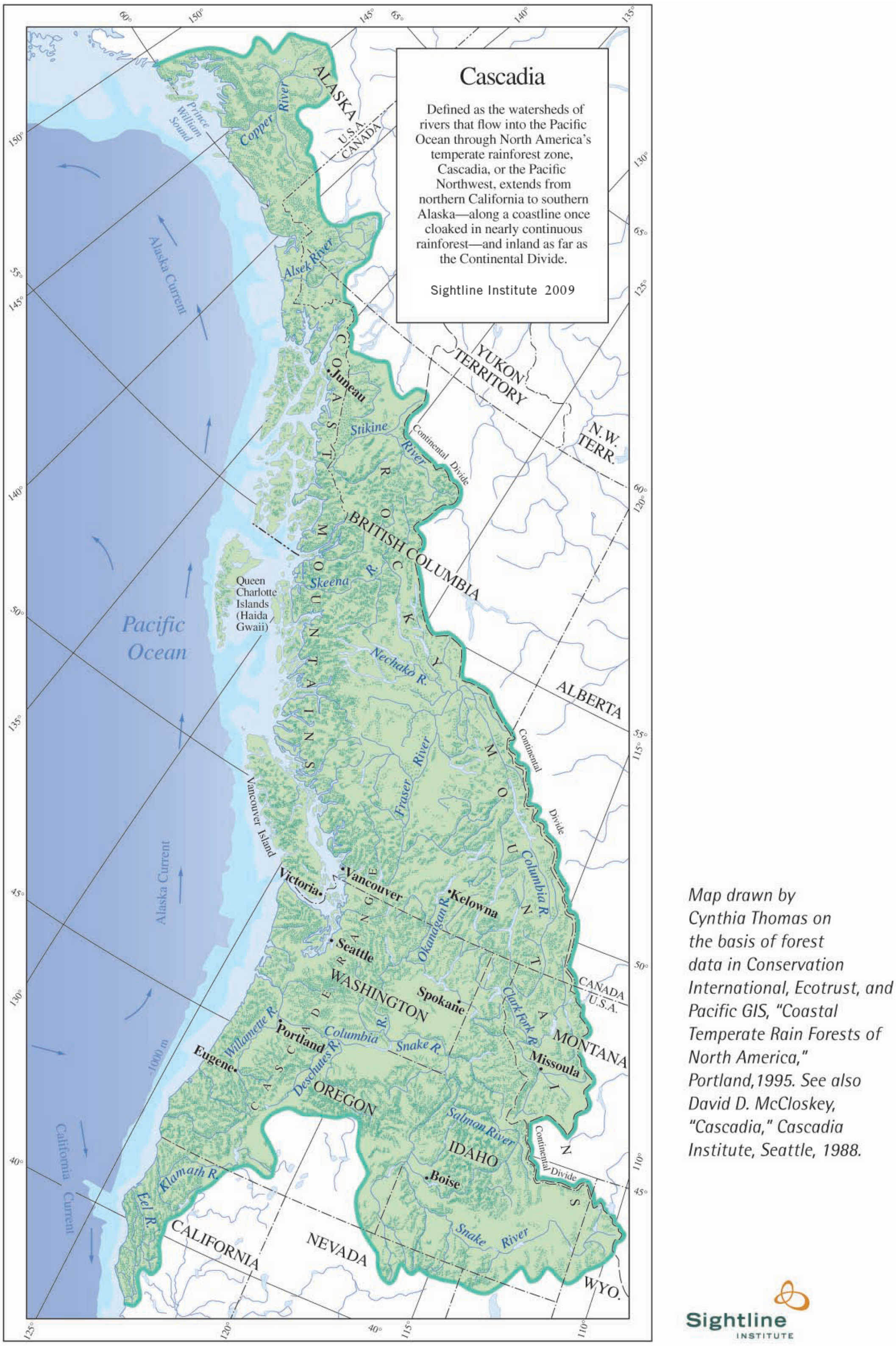

Figure 2.1. Map of the Cascadia Bioregion, from https://www.sightline.org/maps-and-graphics/cascadia_cs05m/.

2.6.1 Justification of research region and community selection

Like the bioregion itself, which illustrates the unitedness of a region independent of US-Canadian boundaries, and showing the interconnectedness of the mountains, rivers, land, and sea while still recognising the micro-climates that exist in this area, all three Indigenous groups participating in this study share basic characteristics, especially as 'salmon cultures'. They share some patterns of engagement with their local environments, including patterns of weather reckoning, resource harvest and use, and adaptations, which cut across current geopolitical borders. At the same time, however, the Haida, Tlingit, and Tsimshian represent distinct language groups with their own knowledge systems, social structures, and specific livelihood adaptations to the micro-climates in which they dwell (cf. Langdon 1979).

While each culture is uniquely distinct, particularly the Haida, their origin stories again show interconnectedness (Emmons and de Laguna 1991), which can also be seen in the histories of intermarriages and trading routes between these three groups. There are similarities in the species that people utilise across this Pacific Coastal region, which is important when identifying regional keystone indicators and observing how people respond to climatic and ecological change broadly. Thus, while recognising the distinctions between each of these cultures and communities, this research draws upon trends on multiple scales (individual, cultural, local, and regional) to connect adaptations and species use within the entire region, to chart how peoples' perceptions are coalescing on ecosystem change and responses through a centrally used keystone indicator species concept and by focusing on the perception and response of every community in-depth.

This region was selected because it is a region where long-dwelling Indigenous People still rely on local plants and animals, thus recognising key indicator species and their links to social-ecological change. Furthermore, it has been relatively understudied in terms of regional climate change, yet greatly impacted by environmental change. Additionally, both myself and my supervisor were familiar with this region, which helped in identification of key collaborators and coordination of the research plan.

2.6.2 Community profiles

A total of 11 communities were sampled (Craig, Juneau, Kake, Ketchikan, Klawock, Hartley Bay, Hoonah, Hydaburg, Metlakatla (BC), Old Massett and Skidegate; Figure 2.2). These communities consist of people of European descent and members of one (or sometimes more) of the three main Indigenous groups in the region, the Tlingit Nation, the Haida Nation, and the Tsimshian Nation. The profile of each community is presented below, illustrating their unique cultural, social, biogeographical, and climatic setting (Table 2.2). In the following thesis chapters, the interview data is presented biogeographically with communities grouped into four bioregions. The communities in Alaska have been divided into Northern Southeast (NSE – Juneau, Hoonah, Kake) and Southern Southeast (SSE – Craig, Klawock, Hydaburg, Ketchikan) for analysis. In addition to the geographical distance between Kake in the southern part of NSE and Klawock in the northern part of SSE, Elders from Kake and Hoonah are more likely to move to Juneau, whereas elders from Prince of Wales Island (POW) are more likely to move to Ketchikan (Elders which had moved from smaller communities to larger towns, which might have affected their observations[9] has been noted in the interview table, Appendix 4). British Columbia has been divided into Mainland British Columbia (MBC – Metlakatla, Hartley Bay) and Haida Gwaii (HG – Old Massett, Skidegate) (also in Figure 2.2). All participants have been noted by names/initials (or pseudonym if they didn't want to be identified) in the text. All Alaskan communities are considered to be in the maritime climate zone in general, located in Southeast, the South

[9] While it was not often specifically delineated, elders from different communities originally (Kake and Hoonah primarily) that now live in Juneau, may be observing and commenting upon resource trends in both Juneau and their home community.

Coast, and Southwestern Islands (Stewart *et al.* 2013; Western Regional Climate Centre 2019), however due to microclimates and geographical positioning, there are slight differences between each community, which are detailed below. In British Columbia, ecozones are described through a Biogeoclimatic Ecosystem Classification (BEC) into biogeoclimatic zones (BEC zones) and are named after the dominant species of vegetation. The researched communities in British Columbia were all in the Coastal Western Hemlock zone (CWH). This zone consists of low and middle elevation coastal forests, from about sea level to 900m in elevation, dominated by coastal Western hemlock (*Tsuga heterophylla*), and on the shoreline, spruce (*Picea sp.*). This zone is usually found west of the Cascade/Coast Mountains, unless it is in a river valley, and in addition to BC also occurs in Washington, Oregon and Alaska, and is considered to be the rainiest of the BEC zones. The climate is typified by winters that are mild and wet, and summers that are cool, with frequent dry and sunny days. The mean annual temperature is 8°C, and the mean annual precipitation is 222 cm. While only approximately 15% of this precipitation falls as snow in the southern part of the zone, closer to 40-50% of the precipitation is snow in the north (Pojar *et al.* 1991). The British Columbia communities did not have as much specific microclimate data associated with them as the Alaskan ones, so the general BEC climate classification has been extrapolated to cover these communities. Other community information, such as population, economies, geography and climate statistics were synthesized solely from DCRA (Division of Community and Regional Affairs) Information Portal (2019) for the Alaskan communities, whereas BC community profiles have been synthesized from several websites, which are listed in each of the four BC communities.

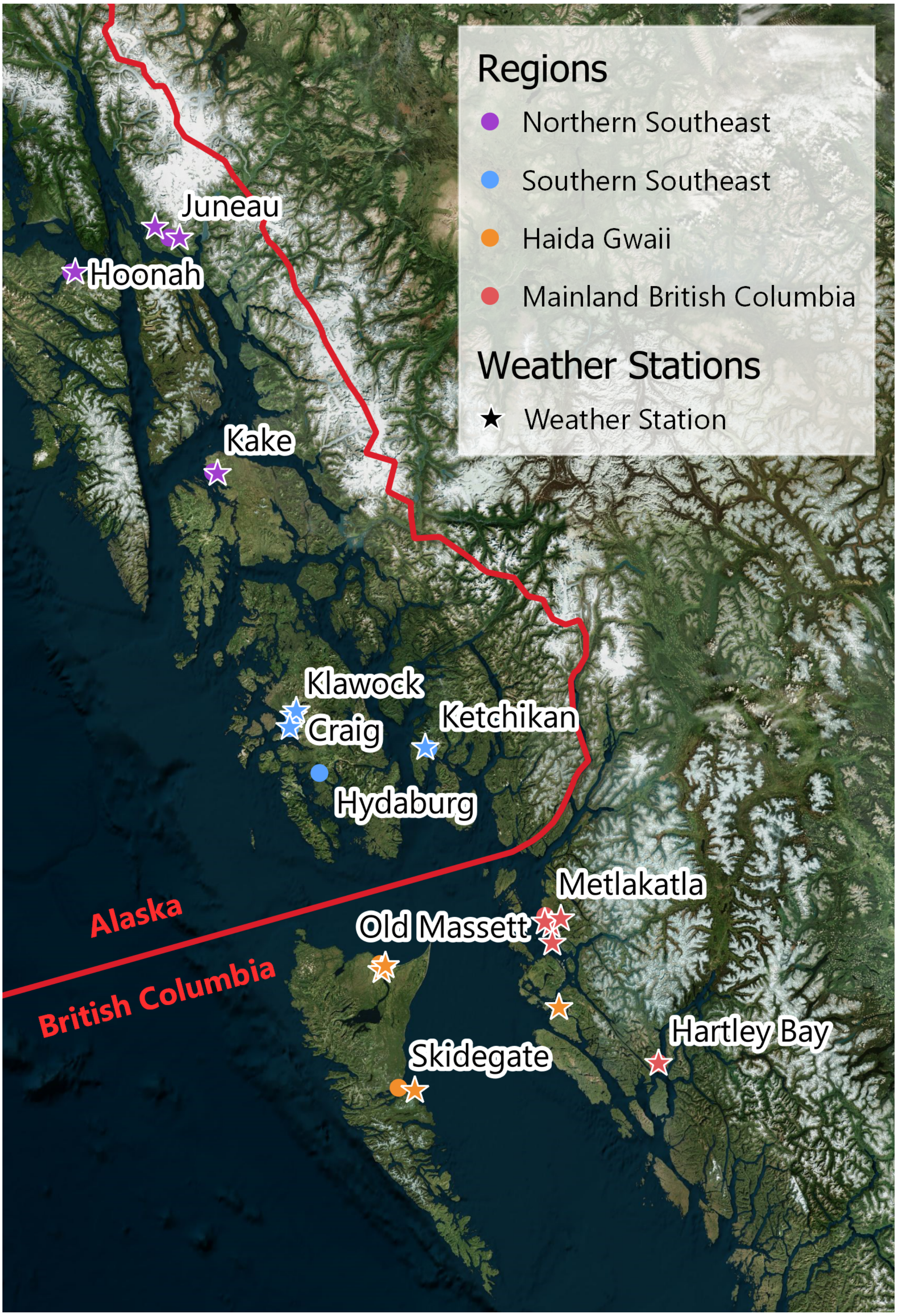

Figure 2.2. Map of communities visited during this fieldwork on the coast of British Columbia, Canada and Alaska, United States of America. Colour coding refers to which sub-region each community was in, and coloured stars represent weather stations. Map courtesy of Dr. Conrad Zorn, University of Oxford.

Table 2.2. Synthesized community information table.

Subregion	Community	Indigenous Group	Past economy	Current economy	Microclimate	Population
Northern Southeast	Juneau, AK	Auke Bay (Tlingit)	➢ gold mines ➢ fishing ➢ canneries ➢ sawmills ➢ transportation and trading services	➢ state and federal employees ➢ tourism	➢ cool summers ➢ mild winters ➢ heavy rain, fog and cloudiness ➢ many mountain glaciers ➢ heavy precipitation and low temps at high altitudes ➢ little freezing at low altitudes	12% Alaska native 69% European
	Hoonah, AK	Huna (Tlingit)	➢ fishing ➢ canneries ➢ logging	➢ fishing ➢ canneries ➢ logging ➢ 'subsistence' lifestyle	➢ cool summers ➢ mild winters ➢ heavy rain, fog and cloudiness ➢ many mountain glaciers ➢ heavy precipitation and low temps at high altitudes ➢ little freezing at low altitudes ➢ airport often closed 20-30 days a year (due to fog) ➢ temperatures between -32°C and 31°C recorded	43% Alaska native 33% European
	Kake, AK	Kake (Tlingit)	➢ fishing ➢ logging	➢ fishing ➢ logging ➢ 'subsistence' lifestyle	➢ cool summers ➢ mild winters ➢ 137 cm rain and 112 cm snow per year on average ➢ less precipitation than other communities in southeast	66% Alaska native 18% European
Southern Southeast	Klawock, AK	Klawock (Tlingit)	➢ fishing ➢ canneries ➢ salteries ➢ hatcheries	➢ fishing ➢ canneries ➢ salteries ➢ fish hatcheries	➢ cool summers ➢ mild winters ➢ heavy rain, fog and cloudiness ➢ many mountain glaciers	45% Alaska native 43% European

			➢ logging and timber	➢ logging and timber ➢ 'subsistence' lifestyle	➢ heavy precipitation and low temps at high altitudes ➢ little freezing at low altitudes ➢ temperatures between -43°C and 31°C recorded	
	Ketchikan, AK	Tlingit	➢ fishing ➢ canneries ➢ mining (gold and copper) ➢ logging	➢ fishing ➢ canneries ➢ mining (gold and copper) ➢ logging ➢ tourism ➢ "salmon capital of the world"	➢ cool summers ➢ mild winters ➢ heavy rain, fog and cloudiness ➢ many mountain glaciers ➢ heavy precipitation and low temps at high altitudes ➢ little freezing at low altitudes	14% Alaska native 60% European
	Craig, AK	Tlingit and Haida	➢ fishing ➢ logging	➢ sawmills ➢ salteries ➢ canneries ➢ high runs of pink salmon contributed to substantial growth ➢ 'subsistence' lifestyle	➢ cool summers ➢ mild winters ➢ heavy rain, fog and cloudiness ➢ many mountain glaciers ➢ heavy precipitation and low temps at high altitudes ➢ little freezing at low altitudes ➢ gale force winds common in autumn and winter	22% Alaska native 66% European
	Hydaburg, AK	Haida	➢ fishing ➢ canning ➢ logging	➢ fishing ➢ canning ➢ logging ➢ 'subsistence' lifestyle	➢ cool summers ➢ mild winters ➢ heavy rain throughout year	84% Alaska native 4% European
Mainland British Columbia	Metlakatla, BC	Metlakatla (Tsimshian)	➢ fishing ➢ logging	➢ transportation services ➢ petrol station ➢ shellfish hatchery	➢ mild and wet winters ➢ cool summers ➢ frequent day and sunny days ➢ mean annual temp 8°C	25% North American Aboriginal ethnic origin

				➢ heavy construction ➢ tourism ➢ training and educational advancement	➢ mean annual precipitation 223cm ➢ about 40-50% of precipitation is snow	100% Other North American or European origins
	Hartley Bay, BC	Gitga'at (Tsimshian)	➢ fishing ➢ logging	➢ salmon enhancement program ➢ forestry ➢ tourism ➢ village admin and public works ➢ housing, social and health services ➢ ecological research ➢ treaty negotiations ➢ hatchery ➢ petrol station ➢ marina ➢ transportation services	➢ cool summers ➢ mild winters ➢ average temps of 15.5°C in July and -2.2°C in January ➢ mean annual precipitation 223cm ➢ about 40-50% of precipitation is snow	75% North American Aboriginal ethnic origin 20% Other North American or European origins
Haida Gwaii	Old Massett, BC	Old Massett (Haida)	➢ fishing ➢ logging	➢ fishing ➢ forestry ➢ sustainable economies ➢ sawmill ➢ briquette plant ➢ biomass boilers	➢ mild and wet winters ➢ cool summers ➢ frequent day and sunny days ➢ mean annual temp 8°C ➢ mean annual precipitation 223cm	96% North American Aboriginal ethnic origin >1% Other North American or

					➢ about 40-50% of precipitation is snow	European origins
	Skidegate, BC	Skidegate (Haida)	➢ fishing ➢ logging	➢ commercial fishing ➢ tourism ➢ logging ➢ service industry ➢ government positions ➢ ecocultural tourism ➢ forestry ➢ aquaculture ➢ sustainable economies	➢ mild and wet winters ➢ cool summers ➢ frequent day and sunny days ➢ mean annual temp 8°C ➢ mean annual precipitation 223cm ➢ about 40-50% of precipitation is snow	85% North American Aboriginal ethnic origin 38% Other North American or European origins

Note: In the population data in this table, and in the proceeding community profiles, the percentages of ethnicity do not always add up to 100%. If it doesn't add up to 100%, then other nationalities/ethnicities might have been identified, and an overlap (more then 100%) occurs because in the census people were allowed to pick more than one choice, so some might have picked both Indigenous and European backgrounds.

2.6.2.1 Juneau, Alaska

While the city of Juneau wasn't officially incorporated until 1900, Auke Bay (in particular) and other areas around Juneau were thriving and vibrant centres for the local Indigenous Peoples long before this time. The main economies have consisted of three gold mines, fishing and canneries, sawmills, transportation, and trading services. More recently people are mainly employed by the state and federal government (due to Juneau being Alaska's state capital) and the tourism trade (cruise ships travelling the Inside Passage). Juneau is situated on the mainland of Alaska, and the borough as a whole includes the community on Douglas Island, which lies opposite, connected by a bridge. Its general "Southeast Maritime Climate Zone" is particularly characterised by cool summers and mild winters. There is often heavy rain throughout the year, as well as much fog and cloudiness, and there are many mountain glaciers. At high altitudes in the coastal mountains heavy precipitation and low temperatures are seen, but at low altitudes very few periods of freezing weather occur. Finally, in the latest census it was recorded that about 69% of the population was white, and 12% were Alaska Native.

2.6.2.2 Hoonah, Alaska

Hoonah is currently the main village for the Huna People, which have historically and prehistorically lived in the Glacier Bay/Icy Strait area, and the name translates as 'village in the cliff'. It is thought that this village became populated after an original home in Glacier Bay was covered by glacial advances, and it is recorded that in 1887 450-500 people were overwintering in Hoonah. The main economy consists of commercial fishing, canneries, and logging, with most inhabitants relying on a 'subsistence' lifestyle. Hoonah is situated on the northeast side of Chichagof

Island. Within the 'Southeast Maritime Climate Zone', Hoonah is also particularly characterised by cool summers and mild winters. There is often heavy rain throughout the year, as well as much fog and cloudiness, and there are many mountain glaciers. At high altitudes in the coastal mountains, heavy precipitation and low temperatures are seen, but at low altitudes very few periods of freezing weather occur. In addition, the airport can often be closed 20-30 days a year because of bad weather, such as foggy episodes in the spring and autumn, and temperatures of between -32°C and 31°C have been recorded. Finally, in the latest census it was recorded that about 33% of the population was white, and 43% Alaska Native.

2.6.2.3 Kake, Alaska

Historically, control of the trade routes around Kuiu and Kupreanof Islands have been under the Kake People, and they have lived throughout this region. However, they were scattered after conflicts with European traders and prospectors, and in 1889 re-formed a community at the current site of Kake. Main economies include fishing and logging, with most inhabitants also relying on a 'subsistence' lifestyle. Kake is situated on the northwest coast of Kupreanof Island, alongside the Keku Straits. Kake is considered in the 'Southeast Maritime Climate Zone' with cool summers and mild winters. While it is noted to still have heavy rain during the year, it was recorded as getting less precipitation than other studied communities in Southeast typically get, with about 137cm of rain and 112cm of snow a year. Finally, in the latest census it was recorded that 18% of the population is white, and 66% Alaska Native.

2.6.2.4 Klawock, Alaska

Klawock was originally a summer camp for the people from Tuxekan, an overwintering village to the north, and was known by several names including Klawerak, Tlevak, Clevak, and Klawak. In 1878, the first cannery in Alaska was based in Klawock, and the economy has consisted of fishing (including canneries, salteries and hatcheries) and logging and timber, and most inhabitants rely on a 'subsistence' lifestyle. Klawock is situated on the west coast of Prince of Wales Island (POW), along Klawock Inlet and opposite Klawock Island. In the 'Southeast Maritime Climate Zone' this area is particularly characterised by cool summers and mild winters. There is often heavy rain throughout the year, as well as much fog and cloudiness, and there are many mountain glaciers. At high altitudes in the coastal mountains heavy precipitation and low temperatures are seen, but at low altitudes very few periods of freezing weather occur. Temperatures have been recorded from -43°C and 31°C in King Salmon, and in the summertime fog in particular is extremely common. Finally, in the latest census it was recorded that 43% of the population is white, and 45% is Alaska Native.

2.6.2.5 Craig, Alaska

The area around Craig has been traditionally used by both the Tlingit and Haida Peoples due to its rich resources. Fishing and logging have both been major economies here, and through the modern history there have been sawmills, salteries, and canneries. Extraordinarily high runs of pink salmon in particular led to a boom in fishing in the 1930s, resulting in substantial development and growth. While fishing drastically reduced in the 1950s, people still fish today as a main economy and most inhabitants rely on a 'subsistence' lifestyle. Craig is situated on the west coast of

POW, on a small island which is connected by a causeway to the main POW island. In the 'Southeast Maritime Climate Zone', this area is particularly characterised by cool summers and mild winters. There is often heavy rain throughout the year, as well as much fog and cloudiness, and many mountain glaciers. At high altitudes in the coastal mountains heavy precipitation and low temperatures are seen, but at low altitudes very few periods of freezing weather occur. It has been noted that in the autumn and winter months gale force winds are very common. Finally, in the latest census it was recorded that 66% of the population is white, and 22% is Alaska Native.

2.6.2.6 Hydaburg, Alaska

Hydaburg was traditionally in the Tlingit territory, but it is thought that the Haida came in during the mid to late 1700s from Graham Island. The people currently in Hydaburg originally came from three villages in the surrounding area, Sukkwan, Howkan, and Klinkwan, which were condensed into the current village of Hydaburg for the children to go to school in 1911. It is the largest Haida village in Alaska, and the main economy is fishing and logging, with canneries located here, and most inhabitants relying on a 'subsistence' lifestyle. Hydaburg is situated on the southwest coast of POW. In the 'Southeast Maritime Climate Zone', this area is particularly characterised by cool summers and mild winters. There is often heavy rain throughout the year. Finally, in the latest census it was recorded that 4% of the population is white, and 84% is Alaska Native.

2.6.2.7 Ketchikan, Alaska

Ketchikan was originally Kichx̱áan and was used as a seasonal fish camp by the Tlingit from the Tongass and Fox Cape areas. In more recent times, due to this plethora of rich resources, many non-natives arrived in the area and in the recent past the main economies were fishing (along with canneries), mining (gold and copper) and logging (known particularly for its high supply of spruce), with tourism becoming very important in more recent years. It is also currently a thriving arts community, with what is considered to be the biggest collection of totem poles in the world and is known as 'the salmon capitol of the world'. It is situated on the southwest coast of Revillagigedo Island, with Gravina Island opposite, in the southern part of the Alaskan panhandle. It is in the general 'Southeast Maritime Climate Zone' particularly characterised by cool summers and mild winters. There is often heavy rain throughout the year, as well as much fog and cloudiness, and there are many mountain glaciers. At high altitudes in the coastal mountains heavy precipitation and low temperatures are seen, but at low altitudes very few periods of freezing weather occur. Finally, in the latest census it was recorded that 14% is Alaska Native and 60% of the population is white.

2.6.2.8 Metlakatla, British Columbia

The village of Metlakatla is located on one of the 10 reserves belonging to the Metlakatla People (BCAFN 2019; Metlakatla Land Use Plan 2018), and takes its name from the word 'Maxlaxaala' which means a 'salt water pass' (BCAFN 2019; Metlakatla Land Use Plan 2018). The other nine reserves have little habitation, but are variously used for harvesting camps, commercial activities, and some are undeveloped. While economies in the past have made use of the rich ocean and rainforest resources (BCAFN 2019), in the last 30 years the Metlakatla Development Corporation has been developed to take advantage of the many economic opportunities in the area. They have formed partnerships or co-own land and marine transportation services (including two ferry companies), a petrol station and a shellfish hatchery, amongst other economic activities (such as heavy construction and tourism), and also promote training and educational advancement within the Metlakatla community (Metlakatla First Nation 2016). In a recent report (Metlakatla Land Use Plan 2018) it was estimated that 62% of the population participate in harvesting activities, while 78% participate in processing or preparing activities. Salmon are the most commonly harvested resource, with 53% of the population harvesting this resource. Metlakatla is located about 5 kms northwest of Prince Rupert, along the Metlakatla Pass (2018 land use plan). Metlakatla is in the Coastal Western Hemlock BEC zone, and apart from the general characteristics from this ecozone, no further microclimate information was found. According to Statistics Canada (2017) approximately 25% of the population identifies with a North American Aboriginal ethnic origin, but all also identified as having some European heritage, as 100% of the population identified with having Other North American or European heritage.

2.6.2.9 Hartley Bay, British Columbia

Hartley Bay is where the main village site of the Gitga'at First Nation is currently located, although they also utilise approximately 7500km^2 of the surrounding area which people still visit frequently as harvesting locations. They have visited these villages and campsites for millennia throughout the spring and summer seasons, however traditionally they would have overwintered at the current autumn harvesting site at Laxgal'tsap (Old Town), their ancestral home. First contact was made with European fur traders in the 1780s, and the Hudson Bay Company arrived soon after that in the 1830s, building forts near Prince Rupert and Bella Bella, and this led to a primarily economic relationship between the Gitga'at and Europeans. This relationship was altered slightly when the missionaries arrived, in particular William Duncan and Thomas Crosby, because while many Gitga'at still harvested seasonally throughout their traditional territory, they moved their base to Metlakatla (BC) to follow the missionaries and joined the Metlakatla Peoples already there. In the 1880s, there was a divide in Duncan's missionary community at Metlakatla (BC) and much of the community, including many Gitga'at People, relocated to Metlakatla (Alaska). However, at this time some Gitga'at People returned to their homeland and settled at one of their traditional camps, Txalgiu, for the practical reason of its proximity to the Inside Passage, which had recently been given a European name of 'Hartley Bay' by British surveyors. The name Gitga'at means 'people of the cane' ('canes' referring to poles used to navigate the shallow waters where the two rivers meet in Laxgal'tsap) and is in reference to sacred history regarding when the Gitga'at first settled in Laxgal'tsap, a spot where two rivers meet (Gitga'at Nation 2017). The Gitga'at not only used the rich resources from their lands in the past but continue to have a strong relationship with harvesting today. Historically their economy has been extremely reliant on commercial fishing, but in more recent times, while people still fish, their economies have broadened out to include a salmon enhancement programmes, forestry, tourism partnerships, jobs in village administration and public works, housing, social and health services, ecological research, and treaty negotiations. In addition, they have an Economic Development Department to maximise economic opportunities for residents, a hatchery (since 1979), a petrol station and marina located in the village, and they run a ferry transportation business jointly with Metlakatla and Kitkatla (Gitga'at Nation 2017). Hartley Bay is located about 145kms south of Prince Rupert, on the British Columbia mainland, at the junction of the

Douglas and Grenville Channels. Hartley Bay is in the Coastal Western Hemlock BEC zone, and in addition to the general characteristics from this zone, Hartley Bay is nestled between the shoreline and higher peaks to the back of the village. There is often a considerable volume of precipitation due to the temperature of the ocean and the prevailing westerly winds, as well as the regular occurrence of storms, predominately in the winter. The microclimate around Hartley Bay is characterised by mild winters and cool summers, with an average temperature of approximately 15.5°C in July and -2.2°C in January. According to Statistics Canada (2017) approximately 75% of the population identifies with a North American Aboriginal ethnic origin, and about 20% of the population identifies as having some European heritage.

2.6.2.10 Skidegate, British Columbia

Skidegate is currently the largest community on Haida Gwaii, and the name comes from sGiidagids, a word derived from sGiida, meaning chiton or red stone (BC Geographical Names, 2019a; DeVries 2014a). While the current location of the Skidegate Village has always had inhabitants, it grew in size after European contact in the 1800s because the high death rates from smallpox caused the surviving people from nearby villages to gather together. By 1893 the survivors from all the southern villages had congregated into Skidegate, and it became a 'main centre of Haida culture and life', along with Old Massett. The Skidegate Band has 11 reserves which it currently has access to, with the main population living at the Skidegate Village reserve, the largest reserve. Skidegate People have made use of the rich resources in this region and currently their main economies consist of commercial fishing (salmon, herring, halibut, black cod and crab), tourism, logging, the service industry, and positions in government (BCAFN 2019; Skidegate Comprehensive Community Plan 2017). In addition, they have two corporations to advance economic interests, and they are currently focusing specifically on ecocultural tourism, forestry, value added wood manufacturing, and aquaculture (BCAFN 2019; Skidegate Comprehensive Community Plan 2017), to develop sustainable economies on Haida Gwaii. Skidegate is located on the Southeast corner of Graham Island, a main island in the Haida Gwaii archipelago, on Skidegate Inlet. Skidegate is in the Coastal Western Hemlock BEC zone, and apart from the general characteristics from this ecozone, no further microclimate information was found. According to Statistic Canada (2017) approximately 85% of the population identifies with a North American Aboriginal ethnic origin, and 38% of the population identified with having European heritage.

2.6.2.11 Old Massett, British Columbia

Old Massett is currently the second largest community on Haida Gwaii, and is the home of the Old Massett Band, which historically consisted of four discrete villages (Old Massett Village Council 2019a). These four villages relocated to the current Old Massett village site in the late 1800s due to the drastic reduction in population after smallpox (Old Massett Village Council 2019a; Village of Masset 2013). Although not verified, it is believed that Old Massett is named after Maast Island, in Masset Sound, a distortion of the name of a European sailor buried on the island, and it is closely connected to the non-Indigenous village of Masset nearby (BC Geographical Names 2019b; Village of Masset 2013). The Old Massett People have always utilised the rich resources in this area, and currently they are included in one of the same corporations as Skidegate, HAICO, and are involved in the Haida Gwaii Forest Products venture, with the only sawmill and briquette plant on the island. In

Port Clements, the Old Massett Band also operate biomass boilers which heat all the buildings in the community. Old Massett is located along the North shore of Graham Island, on the east side of Masset Sound, 2 miles away from the non-Haida Village of Masset. Old Massett is in the Coastal Western Hemlock BEC zone, and apart from the general characteristics of this ecozone, no further microclimate information was found, except for in the neighbouring community of Masset. Due to an air current from Japan carrying warm air over the Pacific Ocean to this part of Haida Gwaii, the climate is mild with temperature only varying about 20°C throughout the year. Summer temperatures are typically between 15-20°C, and winter temperatures are typically 0-8°C. However, within a day, temperature may fluctuate drastically and can be unpredictable. Annual rainfall and snowfall were reported to be approximately 150cm and 28cm respectively, and rain can fall all year including the summer, although May and August are the sunniest months in general. In the winter, the primary form of precipitation is rain, but some snow also falls. It can get quite windy, with wind gusts of up to 160km/h (100 mph) recorded in nearby Masset (Village of Masset 2013). According to Statistics Canada (2017) approximately 96% of the population identifies with a North American Aboriginal ethnic origin, and less than 1% of the population identified with having European heritage.

2.7 Reflection on limitations and Decolonizing power

Throughout this research I paid strict attention to ethics and have been cognizant of collaborative protocol. Community members who participated were identified collaboratively from within the community, by the snowball method described in 2.3.1 above. The original data (along with resulting publications and reports) are being shared with the individual communities, who can then use them to support in whichever way they feel would be best, such as supporting evidence for resource co-management, input into governmental policy, or increasing adaptation to climate change. Two major limitations of this type of research, however, are that by its inherent nature doctoral research is an individualised process, and thus I conducted and analysed my interviews myself, and that I happen to be located at a university a long way from the PNW, which made connections to communities less regular, especially with elders who may have little internet connectivity.

Indigenous Peoples in this region, as in many other regions, and as is appropriate, are demanding more input into the way their knowledge is being used (Nadasdy 1999; Smith 2002), particularly as concerns its relation to western science. Instead of using western science as a lens to view TEK, by forcing it into a western science framework, Indigenous Peoples are rightly insisting that their knowledge of understanding and responding to environmental change be considered both independently and alongside western science (rather than merely through it), given equal weight in addressing conservation, policy, and climate change adaptation solutions, and considered full partners in research (Cuerrier *et al*. 2015b; Thornton and Scheer 2012). This approach has also been validated with the recent establishment of the United Nations 'Local Communities and Indigenous Peoples Platform', which has increased the inclusion of the tradition knowledge of Indigenous Peoples (IP) into the knowledge systems used in the UNFCCC process (UNFCCC 2017).

Chapter 3 Observations on general weather patterns, landscape changes and general species interactions

"we have to really start looking, if there is…kind of a normal spring where it gradually warms up and it's enough moisture, and there's enough moisture, and there's just enough sunlight, you'll get enough, but then it turns in the summer, turns to a drought" (Michael Jackson, Kake)

"there's changes, I know that in order for a blueberry to grow it needs all this information from even a tree, and the ground, and then it has to send out all these feelers and information before growth…that's just a blueberry bush… we're needing to recover this forest, and it's not going to happen in my lifetime, or my grandchildren's lifetime…so as it's healing itself, how are we going to let it heal if we continue to resource extract" (Ernestine Hanlon Abel, Hoonah)

3.1 Introduction

In this chapter, I outline Indigenous observations on general weather trends and patterns and landscape change in the study region, as described by my interviewees and localized regional scientific observations and data. I also examine general species interactions, as they are situated in an ecosystem view, and as they connect to associated abiotic and biotic factors of change. It is interesting to note that overall, most of the changes discussed below were seen relatively consistently throughout the whole study area. There was variation in intensity and some particular changes noted, but in many cases these observations were not clustered by community, but rather observed throughout the entire study area, or focused in either the northern or southern regions. The abiotic factors that had the biggest geographical north-south pattern in interviews were glacial retreat, isostatic rebound, and sea level rise, as seen in section 3.4, landscape changes.

3.2 General Weather Trends: Integrating Local Knowledge and Scientific Perspectives

Nearly all interviewees professed that general weather patterns have changed during the last 80 years, which was the amount of time encompassed in the collective memory during the lifetimes of the interviewees. Changes identified by respondents are synthesized in Table 3.5, and changes of type, frequency, intensity, and duration of weather patterns were considered by participants to be the most impactful on their lifestyles and resources.

The most common weather observation referred to the change from heavy snows and prolonged cold temperatures that used to occur every year, with observations that sometimes the snow used to accumulate up to the eves of houses, to current patterns where there is hardly any snow or frozen water all winter. These quotes, and the temporality of these observations, are expanded in section 3.2.1.

However, there were differing opinions of the intensity and duration of change, and of how much these changes affected distribution, harvesting, and processing of key resources. The range of variability expressed by interview participants is discussed below. One possible reason for the variation of responses has to do with the variety of regional micro-climates in this bioregion due to the diversity of ecosystem and geophysical characteristics (Biogeoclimatic Zones of British Columbia 2013; Turner *et al*. 2003). Beyond north-south temperature gradients, the topography and the orientation of the region's many islands can change wind angle, exposure to storms, and rain shadows in relation to landforms, thus diversifying weather patterns in different villages. As a consequence, residents observe different weather patterns, as seen, for example, in several people describing that Juneau was much rainier than their home communities of Hoonah (Marlene Johnson) and Kake

(A9, Harold Martin - also said about Angoon) which lie within a relatively close 20-50 mile radius.

Since it can be hard to measure TEK and local observations, it is useful to place a quantitative scale on them using comparable scientific data such as local weather station records and regional climate models. However, there are important details that may be missing or hard to decipher from the scientific data, and there are other drawbacks to relying exclusively on these data sets. For example, there are many areas in the northern British Columbia and Southeast Alaska region where weather stations are absent, for instance near Hydaburg, AK, or where stations only collected data from a limited span of years or have gaps or contradictions in their records.

Based on consultation with Dr. Karsten Hausten, a researcher in the Climate Systems and Policy research cluster at the School for Geography and the Environment, University of Oxford, past GCHN weather records from Climate Explorer (KNMI Climate Explorer 2019) were used for examining localized scientific weather observations. The total of 18 weather stations with 10 or more years of data records were found to be relevant for the 11 communities (Table 3.1, map of weather stations on Figure 2.2).

Table 3.1. Weather stations for each community.

Geographical region	Community	Weather station names	Dates of data collection
Northern Southeast	Juneau	Juneau international airport; Juneau downtown, two time periods	1936-2017; 1890-1965, 1965-2017
	Hoonah	Hoonah	1941-2017
	Kake	Kake, at two different time periods	1919-1992 (snow and precip), 1989-2017 (all)
Southern Southeast	Klawock	Klawock; Klawock airport	1980-1989; 1997-2017
	Craig	Craig	1936-2017

	Hydaburg	none	none
	Ketchikan	Ketchikan international airport	1910-2001 (snow) and 2017 (precip and temp)
Mainland British Columbia	Metlakatla	Prince Rupert; Prince Rupert A; Prince Rupert Mont Circ	1908-1962; 1962-2006; 1959-2017
	Hartley Bay	Hartley Bay; Holland Rock	1973-1998; 1991-2017
Haida Gwaii	Skidegate	Sandspit A	1945-2017
	Old Massett	Masset A; Masset Airport; Sewell Masset	1944-2016; 1897-2008;1974-2015

Spatial variability, particularly of snow measurements, have been known to vary widely in certain geographical contexts, such as mountains and/or land/water edges (Kunkel *et al*. 2016). Microclimatic differences and intra-temporal variabilities therefore may be missed or underrepresented in weather station data as compared to human observations and experiences. Climate models can be equally tricky to downscale, as they require: 1) long term trends of 'in situ records', which may not be available or consistent in key community locales, and 2) may be too regional in nature to apply broadly to overall trends, but also not fully capture the intricacies of regional weather dynamics (Cohen *et al*. 2012; Cohen *et al*. 2014; Kunkel *et al*. 2016).

While it is accepted that dramatic changes in weather and climate are occurring in the arctic, and that melting snow and glaciers are speeding up the warming process, especially through albedo effects and Arctic Amplification (Cohen *et al*. 2014), there is also uncertainty in identifying a clear regional trend for changes in rain, temperature, and snow in many cases (Cohen *et al*. 2012; Kunkel *et al*. 2016). The weather change that has the most significant trend in the scientific data is shallower spring and summer snowpack, which has decreased at an even more rapid rate then sea ice (Kunkel *et al*. 2016). June snow cover is being lost at approximately double the rate of sea ice in September (Cohen *et al*. 2014). Ironically, the melting snow in summer (June) has, in contrast, contributed to a deeper snowpack in the autumn

(Kunkel *et al*. 2016). This is due to an increase in precipitation from the summertime melt of snow and sea ice, further exacerbated by the albedo effect. All of this, in turn, increases moisture in the air, which then falls later in the year as snow due to temperatures being just cold enough to turn the precipitation to snow versus rain, and thus creating deeper autumnal snowpack (Cohen *et al*. 2012; Kunkel *et al*. 2016). In this way, an overall warming trend can actually yield snowier winters, with the large amounts of precipitation falling as snow creating the heavy snowfalls observed by participants from this research in some years.

I aim not only to describe the influences of abiotic and biotic factors on the biological diversity of culturally important species in general terms in this chapter for the coastal region as a whole, but also to delineate and place weather observations into a local geographical climatic context. In the following sections, I have grouped the observations of each 'abiotic' factor (such as rain, snow, temperature, etc.) and 'biotic' factors (new species, changes in size and distribution of harvested resources, etc.) to explore what is being observed with regards to different aspects of the weather and the landscape, and how these observations are connected and interlinked with geographical detail. I will further elucidate and detail the local and scientific observations of the ties between these factors and their influence on three case study species/functional groups in chapters 4-6, which have been chosen to illustrate the value of using my CKIS concept. In each of the weather changes in this section, I have first explored how the weather has been recorded by weather stations and governmental sources, and then I discuss how people have observed and experienced these changes in their daily lives, and how they recount the effects. In the last empirical chapter of this thesis, Chapter 7, I will go beyond weather observations to discuss the future resiliencies and adaptations discussed in interviews, and how this might help people create more resiliency into the future.

3.2.1 Temperature

Temperature ultimately determines whether rain or snow is the major form of precipitation in a landscape (Kunkel *et al*. 2016). Cohen *et al*. (2012) claims that the northern hemispheric air temperature trend is neutral, with some places experiencing the 'winter cooling' described above, with available moisture falling as snow. This variation in trends is evident in the climate data from various sources. Berkeley Earth (Berkeley Earth 2019) graphs of overall British Columbia and Alaska trends show recorded average temperatures in the region rose on average 1.65º in British Columbia between 1970 and 2002, and 1.9º in Alaska between 1970 and 2010. The graphs of the localized areas showed recorded average temperature rise of 1.45º in Prince Rupert between 1960 and 2000, and 1.5º in Juneau between 1970-2000. From the 2000/2002 ending dates of the warming trend until 2017, average temperatures decreased in British Columbia (-0.15º), Prince Rupert (-0.3º) and Juneau (-0.35º). While Juneau specifically decreased in average temperature, in Alaska as a whole, mean temperature continued to rise (+0.25º) from 2010-2017.

As well as looking at average temperature, Berkeley Earth (Berkeley Earth 2019) recorded the rates of change in these areas. From 1960-1990, all four areas had high rates of positive change (British Columbia, +2.34; Alaska, +3.42; Prince Rupert, +1.90; and Juneau, +2.76), but after 1990 Alaska was the only place to have a positive rate (+0.65), the rest had negative rates of change (British Columbia, -0.04; Prince Rupert, -1.59; and Juneau, -0.85), meaning that the weather was getting colder again, but at a slower rate than it had warmed up in the past.

Using Climate Explorer (KNMI Climate Explorer 2019), results show that temperature varied between a neutral trend throughout the whole recorded period and a warming trend (from 1990/2010 to 2017). The graphs from Hartley Bay, Holland Park, Hoonah, Juneau downtown, Kake, Ketchikan, and Klawock were all interpreted as not experiencing many changes throughout the history of the record. The stations with warming records showed that temperatures had gotten warmer between 1990-2010, except for Prince Rupert, whose data set ended in 1962, but the weather had showed slight warming from 1944-1962. The stations with a warming trend include Craig (since 1990), Juneau Airport (since 2010), Prince Rupert A (since 2000), Masset A (since 2010) and Sandspit (Skidegate, since 1998). These data match peoples' perceptions in interviews of the weather changing more in the last 8-20 years (section 3.3.1), between 2008-1994. Masset Airport was the only graph that indicated that there was a very slight cooling trend, but the measurements were overall about the same through the history of the data, so this cooling trend is inconclusive. See table 3.2 below for comparison of weather station data and interviewee observations for each community.

Seventeen interviewees, primarily in NSE (Hoonah (4), Kake (4), Juneau (1), but also in SSE (Craig (1), Klawock (1), Hydaburg (1)), MBC (Metlakatla (2)), and HG (Old Massett (1), Skidegate (2))[10], commented that with the reduction of snow, the air was warming up. Three people in both NSE and SSE, Hydaburg (Anthony Christianson), Juneau (A9), and Kake (Wilbur Brown), specifically commented on the warmer water as well. The effects of this warming trend ranged from noticing more

[10] Arnie Bellis (Old Massett), Diane Brown (Skidegate), Wilbur Brown (Kake), Wanda Culp (Hoonah), A11 (Kake), Adam Greenwald (Hoonah), John Hillman (Hoonah), Michael Jackson (Kake), Owen James (Hoonah), Evans Kadake (Kake), Ernestine Kato (Klawock), Vickie Le Cornu (Hydaburg), Harold Martin (Juneau), Fanny Nelson (Metlakatla), Robert Nelson (Metlakatla), Harvey Williams (Skidegate), Myrna Yates (Craig)

rain instead of snow, warmer water temperatures driving salmon to swim at deeper levels in the ocean, and milder winter conditions allowing flowers to bloom earlier, leading to a disjunction between flowers and their pollinators. The complexities around the observations of rain as a result of warming temperatures is discussed in section 3.2.3, and in the relevant case study chapters.

Table 3.2. Weather station trends (Climate Explorer) and interviewee observations for temperature in each community.

Region	Northern Southeast			Southern Southeast				Mainland British Columbia		Haida Gwaii	
Community	Juneau	Hoonah	Kake	Ketchikan	Klawock	Craig	Hydaburg	Metlakatla	Hartley Bay	Skidegate	Old Massett
Western Science	Warming since 2010	No conclusive direction of temp change	No conclusive direction of temp change	No conclusive direction of temp change	No conclusive direction of temp change	Warming since 1990	No weather station data	Warming since 2000 in one station, and warmer also from 1944-1962 for the dataset that ended then	No conclusive direction of temp change	Warming since 1998	Warming since 2010 (Massett Airport – slight cooling, but overall, about the same
Community Observations	Direction not noted	Getting warmer	Getting warmer	Direction not noted	Getting warmer	Getting warmer	Getting warmer	Getting warmer	Direction not noted	Getting warmer	Getting warmer

3.2.2 Snow

Snow levels have been recorded as showing a mix of trends, but the majority of the evidence points to an 'overall' decrease in snow amounts (Kunkel *et al*. 2016). As well, the amount of snow in each part of the year has been observed as changed, with a slight increase of snow in the autumn, and a decrease in snow in the spring. This is due to the increased amount of moisture in the air, which still falls as snow, instead of having switched to rain. The impacts of less late spring snow, and thus less available melt water, is further discussed in Chapter 5, with regards to salmon. Despite recording a decrease in overall snow, there has been an increase in very low temperatures (Cohen *et al*. 2014; Kunkel *et al*. 2016) and number of days below freezing (Cohen *et al*. 2014), which corroborates local observations of more isolated snowstorms. See Table 3.3 below for comparison of weather station data and interviewee observations for each community.

Using the data from Climate Explorer (KNMI Climate Explorer 2019), it was found that almost every community with nearby weather stations with records showing decreasing snowfall starting from approximately 1975-1990 (Craig, Hartley Bay, Juneau downtown and airport, Kake, Prince Rupert and Prince Rupert A, Masset A and Sandspit (Skidegate) The stations that differed from this broad trend of decreasing snow were: Hoonah, which was represented in the dataset as only having a little less snow now, but some very low snow years between 1981-1986; Masset AP, which appeared to have about the same amount of snowfall and depth as in the past; and Kake, where the snow decreased since the mid 1970's, except for one year (1982) with a large isolated snowfall event. Ketchikan, despite having no recent data and thus hard to match with current comparisons, showed more snow in 1956-1989 than between 1910-1942, which corresponds to other station readings showing more snow at times between 1910-1980s (Craig, Juneau Airport).

Almost every elder interviewed commented that, overall, the amount of snow had drastically decreased since their childhood (between 50-70 years ago, or from about 1934 to 1954). While there were reports of occasional recent years with major snowfalls – in particular a couple deep snows affecting the deer in Hoonah, discussed in Chapter 4 – snow was generally not as deep now as in the past. Many people shared stories regarding ponds and sloughs becoming covered with ice in the winter and being used for ice-skating, and snow being very deep, sometimes even coming up to the eves of houses – as Harold Martin (Juneau) described: 'the snow actually got up to our roof…we had a lot of snow then'. For the amounts of snow seen, Wanda Culp (Hoonah) said 'you wouldn't even see the ground until springtime, you know there'd be that much snow' and Ernestine Hanlon Abel (Hoonah) noted that there was 'a lot of snow, and it would be piled up…and what we would do was, in the wintertime, we would even be able to jump off our roof…we could never do that now, not and be safe'. Now, people describe that it will barely snow in a year, or snow and melt several times. While people feel that winter precipitation still abounds, as A9 (Juneau) comments: 'it seems like it's changed from snow to rain', implying that it is the type of precipitation that has changed, rather than the amount.

Several species were listed as being severely impacted by snow absence or presence. Deer and salmon were found to be highly affected both in feeding and movement patterns, but the nuances around these will be covered in their separate chapters (Chapters 4 and 5). Another species affected, but not included in the keystone species chapters, is yellow cedar (*Cupressus nootkatensis*). Yellow cedar, an important material for basket makers, has been reported as dying off throughout

Southeast Alaska, from Hoonah (Donald Bolton, Wanda Culp, Ken Grant, A12), Kake (Lionel Bean, Nancy Bean, Michael Jackson), Ketchikan (Delores Churchill, Merle Nancy Hawkins) and Hydaburg (Anthony Christianson, Vickie Le Cornu), due to a lack of snow not providing insulation for its root systems; thus, if a freeze does happen in winter, the exposed roots may die, killing the tree: "the snow used to insulate the root system, from the freeze, and now without that snow at those higher elevations when it does freeze the roots are exposed…it's what they [are] hypothetically theorizing…is that is happening with yellow cedar… so the exposed roots are getting damaged as the deep freeze comes on without that insulation" (Anthony Christianson, Hydaburg).

Table 3.3. Weather station trends (Climate Explorer) and interviewee observations for snow in each community.

Region	Northern Southeast			Southern Southeast				Mainland British Columbia		Haida Gwaii	
Community	Juneau	Hoonah	Kake	Ketchikan	Klawock	Craig	Hydaburg	Metlakatla	Hartley Bay	Skidegate	Old Massett
Western Science	Decreasing snow since 1980-90	Very little decreasing snow now, low snow years 1981-1986	Decreasing snow since 1980-90, but with a bigger extreme of snowfall in 1982	No recent data (since 1989), but more snow in 1956-1989 than 1910-1942	No snow data	Decreasing snow since 1980-90	No weather station data	Decreasing snow since 1980-90	Decreasing snow since 1980-90	Decreasing snow since 1980-90	Decreasing snow since 1980-90 (Masset A), Masset Airport – same amount now as in past
Community Observations	Decreased snow since childhood (1934-1954)	Decreased snow since childhood (1934-1954)	Decreased snow since childhood (1934-1954)	Decreased snow since childhood (1934-1954)	Decreased snow since childhood (1934-1954)	Decreased snow since childhood (1934-1954)	Decreased snow since childhood (1934-1954)	Decreased snow since childhood (1934-1954)	Decreased snow since childhood (1934-1954)	Decreased snow since childhood (1934-1954)	Decreased snow since childhood (1934-1954)

3.2.3 Rain

According to the Climate Explorer data from my sampled communities, changes in rainfall patterns are not consistent across the region, with the number of communities recording more rain (Hartley Bay, Hoonah, Juneau Airport, Prince Rupert R and Prince Rupert Mont Circ), less rain (Craig, Holland Rock (Hartley Bay), and Juneau downtown), and no change in the amount of rain (Kake, Ketchikan, Klawock, Prince Rupert, Massett Airport and Sandspit (Skidegate) being roughly equal. Cohen *et al*. (2014) reports that "the amount of precipitation on very wet days has increased from 160 to 185 mm" across the Northern Hemisphere, indicating potentially there are days with more precipitation falling, rather than a higher number of rainy days. See Table 3.4 below for comparison of weather station data and interviewee observations for each community.

Living in a temperate rainforest, people acknowledged that in the past there had always been significant amounts of rain but reported that there was now more rain in both the summer and the winter than before. Since, according to the climate data, rain does not appear to have increased as dramatically as many people describe, one possible explanation is that, due to local microclimatic variations, the weather stations may have captured different mixes of snow and rain than people experienced. Or it may be that people had a heightened perception of increasing ratios of rain to snow, or that the number of days without rain was decreasing, and thus there was more rain overall concentrated in a smaller number of days. On a cloudy, rainy, windy spring day, during an interview, one respondent commented: 'we get this kind of weather all summer…feels like it…[only] once in a while we get sunshine' (A1, Old Massett). A9 (Juneau) commented that 'when it rains [and thus becomes warmer in the winter], and then gets cold, it affects the plants'. This refers to the phenomenon of plants starting to sprout and flower in the warmer, rainier weather occurring earlier in the year, and then if a cold snap comes later in the yar, the plants and blossoms die, leading to a dearth of edible fruits, such as berries (further elucidated in Chapter 6). As seen above, the perception of increased rain, in a combination with decreased sun, also affects peoples' abilities to process food.

Table 3.4. Weather station trends (Climate Explorer) and interviewee observations for rain in each community.

Region	Northern Southeast			Southern Southeast				Mainland British Columbia		Haida Gwaii	
Community	Juneau	Hoonah	Kake	Ketchikan	Klawock	Craig	Hydaburg	Metlakatla	Hartley Bay	Skidegate	Old Massett
Western Science	More rain in recent times in Juneau Airport, less rain recorded in recent times for Juneau Downtown	More rain in recent times	No change in rain recorded	No change in rain recorded	No change in rain recorded	Less rain recorded in recent times	No weather station data	More rain in recent times in Prince Rupert R and Mont Circ, no change in rain found in Prince Rupert	More rain in recent times for Hartley Bay, less rain recorded in recent times for Holland Rock	No change in rain recorded	No change in rain recorded
Community Observations	More rain	More rain	More rain	More rain	More rain	More rain	More rain	More rain	More rain	More rain	More rain

3.2.4 Sun

The number of sunny days, and the intensity of the sun, as separate from a warmer temperature trend, are hard to quantify, both in existing climate data and in interviewee data from this study. Cohen *et al*. (2014) reported that that in the northern hemisphere "the percentage of warm days had risen from 10% before 1980 to 16% at present", but it is unrecorded if this refers to days that are actually sunnier, versus just having a warmer temperature. Interviewees responded to questions regarding the 'amount of sun' in two ways.

On one hand, 13 people, mostly on Haida Gwaii (Old Massett (4), Skidegate), and then in NSE (Hoonah (2 people), Juneau, Kake), but also in SSE (Klawock) and MBC (Metlakatla (2), Hartley Bay), noted a change in the number of sunny days[11]. Even though the weather was seen as having warmed up in temperature (a separate issue), people described that the presence of sun was declining or becoming more inconsistent: there were 'less sunny days' (Ernestine Kato, Klawock), and more rainy or overcast days. Respondents were attentive to this because a reduction in sunny days impact food drying and processing, as further elucidated below.

On the other hand, 21 people, primarily in NSE (Hoonah (7), Juneau, Kake) and secondarily in HG (Old Massett (3) and Skidegate (3)), but also in SSE (Craig, Hydaburg, Klawock), and MBC (Metlakatla (2)), commented on the changing of the intensity of the sun at certain times of the year, saying that even though the amount or intensity of sun isn't optimum for drying and processing, a hotter and more intense heat is being found on the few days the sun is out[12].

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[11] A2 (Old Massett), A13 (Juneau), Helen Clifton (Hartley Bay), Margaret Edgars (Old Massett), Adam Greenwald (Hoonah), Captain Gold (Skidegate), Charles Jack (Hoonah), Michael Jackson (Kake), Ernestine Kato (Klawock), Fanny Nelson (Metlakatla), Robert Nelson (Metlakatla), Emily Watts (Old Massett), Rolly Williams (Old Massett)

[12] A2 (Old Massett), A3 (Skidegate), A5 (Skidegate), Catherine Bolton (Hoonah), Anthony Christianson (Hydaburg), Wanda Culp (Hoonah), Reg Davidson (Old Massett), Adam Greenwald

People variously described the days as: being rainy or overcast when it used to be sunny, particularly in the spring, but sometimes in the summer; having days that were so much hotter than in the past that the sun was 'burning' plants and berries (specifically Captain Gold (Skidegate) and A13 (Juneau)); and sometimes even burning people (specifically in Skidegate and Old Massett (A3, Captain Gold)). Only Jack Litrell (Old Massett) contradicted this, explicitly noting that people used to burn more in the 1970s than they do now. As Captain Gold (Skidegate) described: 'we'd be swimming all summer long, nowadays when you get the sun burning though the clouds, that's the worst time, you get sunburned very quickly'. These nuances of experienced temperature and sun are not captured in instrumental climate data.

The greatest impact of not having as much sun in the late spring and early summer, seen throughout the entire study region, has been on the processing of food. For example, the lack of sun can make it hard to process 'dryfish' (sundried salmon or halibut), to dry mashed berries to make fruit leather, or to dry seaweed, all key traditional foods. Several interviewees were glad of modern techniques of being able to freeze seaweed to wait for a sunny day (A9 (Juneau), Helen Clifton (Hartley Bay), Michael Jackson (Kake), Ernestine Kato (Klawock)), and Adam Greenwald (Hoonah) described his self-designed indoor smoking process for halibut due to not being able to depend on the availability of sunny days:

> 'Victoria: …for drying halibut, you modified it?
> Adam: yeah…we've hauled numerous amount[s] of…bags full of ruined halibut up to the garbage dump…because we ruined it [by trialling out techniques], and I've talked to many people, and they say it just can't be done, but I know it can be done, because my grandmother did it when I was a little kid, and…I worked with it now until I got it down to a fine art…where sun

(Hoonah), Captain Gold (Skidegate), Ester Greenwald (Hoonah), Ken Grant (Hoonah), Cora Joseph (Klawock), Charles Jack (Hoonah), Michael Jackson (Kake), Owen James (Hoonah), Harold Martin (Juneau), Fanny Nelson (Metlakatla), Robert Nelson (Metlakatla), Rolly Williams (Old Massett), Myrna Yates (Craig)

> dried halibut, it takes you about 4 days, to do a sun dried…but this year, when you do it like I do it now [the] last three years, I haven't lost one batch of halibut [using the smokehouse]'

3.2.5 Storms and unpredictable weather

According to Cohen *et al*. (2014), storms have increased in frequency and intensity in the northern hemisphere in several ways, which is a similar finding to what the interviewees in this study mentioned. This increase has been occurring faster since the 1990s and is not only restricted to storms with warmer temperatures and torrential rainfall, and also storms with extreme cold temperatures.

11 interviewees throughout all four geographical regions (from the communities of Hartley Bay, Hoonah, Hydaburg, Kake, Ketchikan, Old Massett, Skidegate) commented either that storms seemed to be more frequent and/or intense[13], the 'storm season' of the autumn was pushed later in the year (Anthony Christianson, Hydaburg), or there was more lightning and thunder happening (Catherine Bolton (Hoonah), Merle Nancy Hawkins (Ketchikan)), as expressed in the following quotes: 'we seem to have more intense storms these days, like last week there's one blowing a 100 miles an hour' (Arnie Bellis, Old Massett), and 'we've always gotten big storms, but it's become more frequent…and…a lot harsher…like we've had stormy weather before, but it just seems like it's a lot more wilder' (Sherri Dick, Old Massett). Only three people in each of the three regions of SSE, MBC and HG (Fred Hamilton (Craig), Robert Nelson (Metlakatla), Harvey Williams (Skidegate)) noted the opposite, that they either couldn't tell if storms were worse, or that the storms were not as big now as they had been in the past.

[13] A2 (Old Massett), A5 (Skidegate), Arnie Bellis (Old Massett), Catherine Bolton (Hoonah), Anthony Christianson (Hydaburg), Vickie Le Cornu (Hydaburg), Reg Davidson (Old Massett), Merle Nancy Hawkins (Ketchikan), Michael Jackson (Kake), Carol Young (Skidegate), Rolly Williams (Old Massett)

Peoples' observations were divided when considering whether the weather was becoming more unpredictable in terms of when to expect stormy weather. Of the ten respondents that commented on this specifically, people in SSE (Klawock) and HG (Old Massett)[14] said they had not noticed any unpredictability, while the eight others in the regions of NSE (Hoonah, Juneau (2), Kake), SSE (Klawock), and HG (Old Massett (2), Skidegate)[15] felt that the weather had become more unpredictable in recent years, making it harder to know when calm weather would allow for safe travel:

> 'it seems like the weather has gotten more unpredictable, it used to be kinda like a pattern, every year, you know, and now…it fluctuates, and storms come up, it seems like all of a sudden, without expecting it, I lost…a nephew and his son in Angoon, because in March one year, he went across to Baranof Island, did some halibut fishing, and on his way across it was pretty nice, and half way across he got hit by a north wind, swamped the boat, and they both perished…they drowned in the straits…so, it's unpredictable and comes up all of a sudden…and it seems to me like we used to have long stretches of calm weather, when I was [little]…I grew up purse seining with my dad' (Harold Martin, Juneau)

However, three interviewees in NSE, SSE, and HG said the weather had always been unpredictable, and they knew how to adjust to it – if they watch the weather, they can still adapt to it, both in the past and today (Anthony Christianson (Hydaburg), A7 (Old Massett), Owen James (Hoonah)):

> 'well, you can pretty much tell here…I mean we live on the ocean, it's one island away… I've always had a knack for weather…I mean…you know, being a fisherman…and subsisting…you're tied to the environment, you have to kinda know…but things change fast, and there's been weird [weather lately]' (Anthony Christianson, Hydaburg)

[14] A7 (Old Massett), Mary Guthrie (Klawock)
[15] A2 (Old Massett), A9 (Juneau), Cora Joseph (Klawock), Evans Kadake (Kake), Harold Martin (Juneau), Harvey Williams (Skidegate), Rolly Williams (Old Massett), TerryLee Fiske (Hoonah)

Table 3.5. Table of basic weather observations.

Observation	Changes seen	Impacts	Responses	Local Experiences of Weather
Temperature	➢ air and water getting warmer	➢ changing the behaviours and distributions of animals and plants ➢ sun is hotter now when out	➢ traveling further to get things ➢ adapting harvesting techniques ➢ people getting sunburned	"it used to freeze outside, and that was before we had really freezers, you know, so I know it's a lot warmer, there's not as much snow, if there is snow, it rains and it disappears" (A11, Kake)
Snow	➢ overall decrease in the last 40-60 years ago ➢ some isolated years - major snowfall	➢ less available water for plants, animals, streams, etc from snow melt ➢ in extreme years, species aren't adapted for cold temperatures anymore	➢ adaption techniques to moderate water levels in streams	"before snow come to eves of roof – now barely snow in a year" (Catherine Bolton, Hoonah)
Rain	➢ more rain overall ➢ more heavy rain events	➢ washouts and mudslides	➢ harvest other places, repair areas	"I'd say…about 30 years ago or so…there'd be a good summer and a bum summer, and it finally went to…now it's just too much rain" (Adam Greenwald, Hoonah)
Sun	➢ fewer sunny days	➢ harder to dry food because of lack of sunny days	➢ drying indoors or with fans, or stoves ➢ freezing seaweed until there is favourable weather	"used to get good sunshine in summertime" (A10, Hoonah)
Storms	➢ becoming more unpredictable and frequent	➢ people don't know when the weather will stay fine to make it safe to stay out harvesting, or even know when they will be able to go harvest at all.	➢ people delay harvesting, and miss opportunity, or risk going out and get caught in inclement weather	"yeah, I think there's usually some overlap, and some set back, might go a couple of weeks thinking alright we're in the heart of spring, and then all of a sudden it gets cold, and some snow falls, and there's a storm" (Anthony Christianson, Hydaburg)

3.3 Weather patterns

In addition to separating out the weather changes into the abiotic factors seen above, people also noticed how the patterns of the weather and seasons were shifting. The observations in this section have been ordered to reflect people's comments on firstly, the rates of change and to match a timescale of approximate dates to the changes in the general weather, and secondly, how the timings of the characteristics of each season had changed. This finetuning of the temporal scale in terms of rates and timings allows me to also potentially extrapolate these weather changes into the future, as to how they will continue to affect the ecosystem (Chapter 7).

3.3.1 Rates and timescale of change

Observations about rates of change concerning weather or other phenomena can be difficult to document as not everyone is conditioned to consider rate measures. To place observations into a framework, I chose two distinct periods in which to contrast their observations: childhood versus today. The age of the informant was also factored in to get measure of change over specific time periods.

Eight people from all four regions, primarily in SSE (Klawock (3)) and NSE (Hoonah (2), Kake), followed by HG (Old Massett), and MBC (Hartley Bay) stated that there had been a gradual change[16] so that they had hardly noticed it until they compared today with their childhood:

> 'you know, when I think about it, and it's so gradual that it's hardly noticeable, because we have years of lots of snow, deep snow, we had 20' a few years ago, of snow here… so it's hard to tell, and you probably have to graph it and get the climatology people to graph it, and maybe there's a trend you know' (Ken Grant, Hoonah).

[16] A2 (Old Massett), A11 (Kake), Helen Clifton (Hatley Bay), Alma Cook (Klawock), Ken Grant (Hoonah), Mary Guthrie (Klawock), Charles Jack (Hoonah), Ernestine Kato (Klawock)

Eight other interviewees, primarily in the regions of NSE (Hoonah, Juneau (2), Kake (2)), but also in SSE (Ketchikan, Hydaburg) and HG (Skidegate) thought it had started out slowly and the rates of change had accelerated in more recent years[17]: 'yeah, the change of weather is happening a lot quicker now, and the unpredictability of it, you know' (Michael Jackson, Kake).

While not everyone could place a timescale on the weather changes, of those that did comment on shifting patterns, eight people, primarily in NSE (Hoonah, Kake (2)), and Haida Gwaii (Old Massett (3)), but also in SSE (Ketchikan), and MBC (Hartley Bay)[18] observed that the weather had changed more in the last 8-20 years. Four people based in SSE (Kake (2)) and HG (Old Massett (2)) observed that the main weather shift had started about 30-40 years ago[19]. Elders, especially, felt that in the early period of their lifetimes (50-70 years ago), weather was more predictable and stable, and people often referred to the unpredictability of weather primarily in NSE (Hoonah, Kake, Juneau), but also SSE (Ketchikan, Klawock), MBC (Hartley Bay) and HG (Old Massett), which most people said was new (see section 3.2.5 above). This was expressed as either people feeling that there wasn't a storm-free stretch of weather to harvest in, that storms affected harvesting (A1 (Old Massett), A2 (Old Massett), Helen Clifton (Hartley Bay), Rolly Willams (Old Massett)), or storms came up rapidly (A9 (Juneau). Thirteen interviewees[20], primarily in NSE (Hoonah

[17] A13 (Juneau), Wilbur Brown (Kake), June Degnan (Juneau), Adam Greenwald (Hoonah), Captain Gold (Skidegate), Merle Nancy Hawkins (Ketchikan), Michael Jackson (Kake), Vickie Le Cornu (Hydaburg),

[18] A11 (Kake), Arnie Bellis (Old Massett), Helen Clifton (Hartley Bay), Reg Davidson (Old Massett), Sherri Dick (Old Massett), Merle Nancy Hawkins (Ketchikan), Michael Jackson (Kake), Owen James (Hoonah

[19] Lionel Bean (Kake), Robin Brown (Old Massett), Wilbur Brown (Kake), Margaret Edgars (Old Massett)

[20] A1 (Old Massett), A2 (Old Massett), A9 (Juneau), Robin Brown (Old Massett), Wanda Culp (Hoonah), TerryLee Fiske (Hoonah), Merle Nancy Hawkins (Ketchikan), Michael Jackson (Kake), Owen James (Hoonah), Ernestine Kato (Klawock), Harold Martin (Juneau), Harriet Williams (Kake), Rolly Williams (Old Massett)

(3), Juneau (2), Kake (2)) followed by HG (Old Massett (4), and then SSE (Ketchikan, Klawock), also mentioned that you could no longer predict what the weather would do like you had been able to do in the past, and that the weather not only changed throughout the years, but also in a span of days or hours, as seen in the following quote:

> 'well, I'd say if…you're talking of a period of 40 years, it would be fast, but if you are talking about weeks or months…that makes the difference. Just in my lifetime, we went from an average, I'd say, in the wintertime, of 4 to 5 feet of snow, now, this past February, last February, February was…always the worst month of the year, it was not only the coldest, but it was blowing and snowing and it's just a miserable month. This past February, I don't recall any day in the whole month, that we had more than 4 inches of snow. Most of the time, we got one or two inches of snow, a couple days later it turned to rain, and it was gone; we had one period we got about 4 inches, in that whole month, that was the deepest snow we had in the month of February. That was the best February I ever seen in my life.' (Adam Greenwald, Hoonah)

These differing perceptions, perhaps also affected by people's ability to remember, make it hard to identify a consistent trend in weather change. This is probably also partly due to the range of micro-climates experienced across this region, and how different places were exposed to different winds and temperatures depending on sheltering patterns, as mentioned above.

3.3.2 Timings and definitions of seasons

Other changes to observed weather patterns included that the timings of the seasons had shifted, and that there was less definition and fuzzier boundaries between the seasons. The former comment refers to observations that weather typically considered autumnal, storms and rain, and the associated floral and faunal behaviours, were occurring mostly earlier (but sometimes later) in the year than before, as well as the lengths of each season shifting in duration, and when each season traditionally started and stopped - sometimes seasons are shorter temporally then they used to be, sometimes longer. The latter refers to observations that people also noticed less definition between each season, so instead of four distinct seasons, the boundaries between each season are blurring. For example, Arnie Bellis (Old Massett) commented on the shifting of spring into summer: 'it's not so pronounced now…one kind melts into the other, without…any visible change'. Correlatively, Ernestine Hanlon Abel (Hoonah) remarked that she even had a beading design that represented each of the four seasons with a flower or leaf that exemplified each season, and stated that: 'so we had a lot more snow, we had our very definite 4 seasons, very defined…and our 4 seasons aren't even defined the way they used to be, I mean, we even have…in our [Hoonah Peoples] beadwork, my auntie Jess Grey…[did] the '4 season flowers' [pattern]… and it is not as defined anymore…like one winter we had nothing but rain, it was just brown all winter, we didn't get any snow'. Ernestine commented that it was an old design, and that everyone had their own variations. She did not fully describe which plants were depicted as it was variable between artist, and she seemed uncertain of the identification because of the age of some of the floral designs but mentioned that some people used forget-me-not for a spring identifier, and alder for the autumn.

While these observations cannot be easily quantified, people made comments such as the spring weather feeling more winter-like, the end of summer feeling autumnal, and autumn blending in with winter weather patterns. Since the weather patterns of each season affects how plant resources develop and ripen, and when animal species are ready to harvest, it was noted that the timing of harvesting had changed accordingly. This will be discussed in the resources section. More than simple, gradual shifts in global or regional climate (e.g., warmer winters in a whole bioregion), increased local variation and unpredictability of weather may pose more difficult adaptation challenges.

3.4 Landscape changes

People reported numerous changes in landscape composition, structure, and function due to climate shifts, such as increased rains or higher tidal levels (Table 3.6). These changes to the landscape, which can also be exacerbated by land use changes (in varying degrees), affected how people navigated their territories (e.g., shallower water caused by isostatic rebound made it harder to follow known boating routes) or affected the abundance and distribution of resources (e.g., erosion of slopes caused by increased storms). While the overall weather trends and observations were similar throughout the entire study area, as seen above with the observations on rain, sun, and snow, with only subtle differences between sub-regions, likely attributed to the microclimatic differences affecting each community, quite a few of the changes observed in the landscape did vary over the study region. These changes are described in more detail below, but broadly speaking, melting glaciers, sea ice, and isostatic rebound were observed in Southeast Alaska (NSE and to a smaller extent, SSE) and sea level rise and sea-influenced erosion (wave and tidal erosion) was observed in British Columbia (MBC and HG). Erosion of land from hillsides and stream banks caused by rainfall, rivers, and streams, was observed throughout the entire study area.

3.4.1 Glaciers and floating ice

Glaciers were observed to have a bigger impact in the northern part of the research area. This is because in the southern region (Coast Mountains, BC) the glaciers tend to be higher in elevation, but in the northern regions glaciers not only are known to go all the way to the waterline in bays (called saltwater glaciers by Wanda Culp, Hoonah, such as Glacier Bay) and lakes (such as the Mendenhall Glacier in Juneau), but there has also been a drastic decrease in glacial extent noted only in the region of NSE (Hoonah (4), Kake (6), Juneau (4))[21] , and retreat has been seen in peoples' lifetimes – 'when we moved here in 1980, that glacier [Mendenhall] was right by the waterfall…and it covered pretty much that centre cliff there…it's receded so much since I've been here' (Harold Martin, Juneau). Because many glaciers originally went down to the waterline (particularly mentioned in Glacier Bay, AK), it was commented upon that as the glacier retreated, they were left 'hanging off [the] land now' (Wanda Culp, Hoonah). This retreat of the glaciers away from the waterline also meant there were fewer icebergs and chunks of floating ice observed in the nearshore regions (a product of glaciers calving into the water) near Kake (2) and Hoonah (3)[22].

As well, Wanda Culp (Hoonah) stated that the glacial meltwater contained silt and thus an important change seen was that increased silt is threatening to make the nearshore areas and lakes around glaciers shallower:

> 'another thing that's changing our landscape, which is huge, I wonder if it's being monitored, it must be, [is] all the silt coming down from all the glaciers…in Lynn Canal, for a huge example, I'm sure Glacier Bay, is…nothing but silt, and you just see it coming in to the canal…from all the mountains on both sides, and silt is just visibly there, so, years ago, when I was…commercial fishing on one of their big boats, and we went into Glacier Bay, and according to a five-year old chart, there should have been 11 fathoms of water beneath us, and we got stuck in silt…and there was no mountains around where it could have flowed from, so all that silt filled up that little bay from where…must have been major! But it filled it up, and we had to wait for the next tide to get out of there…the captain knew enough to wiggle it around again so that it didn't…you know…yeah, but it was amazing to me, 5 feet! We should have had 11 fathoms of water under us, instead it was filled with silt…so that's

[21] A9 (Juneau), A11 (Kake), Lionel Bean (Kake), Nancy Bean (Kake), Wilbur Brown (Kake), Wanda Culp (Hoonah), George Davis (Juneau), Agnes Davis (Juneau), Ken Grant (Hoonah), Adam Greenwald (Hoonah), Ester Greenwald (Hoonah), Joel Jackson (Kake), Marvin Kadake (Kake), Harold Martin (Juneau)

[22] Lionel Bean (Kake), Nancy Bean (Kake), Wanda Culp (Hoonah), Adam Greenwald (Hoonah), Ester Greenwald (Hoonah)

what's happening, anywhere where there's glaciers, the land is going to be changing because of that silt…you see it when you're heading to Juneau, and the Mendenhall Glacier, you see all the silt coming out…and you see it in the water, that's changing everything…that's going to close up the channel' (Wanda Culp, Hoonah).

While there are significant negatives of the nearshore areas silting up from glacial melt water, this melt water (as well as snow melt) is an important input into the coastal ecosystem, cooling down the nearshore water in the spring. A reduced run-off amount, along with the lack of floating ice described above, will mean an increase in the nearshore temperatures. Therefore, as glaciers become smaller there will not only be less available water input, but less cool water as well. The impacts of warmer water are discussed further down in this chapter, and in chapter 5, regarding salmon.

3.4.2 Isostatic rebound

An important change that was noted in the NSE region is isostatic rebound as a result of glacial retreat. As weight pressure is released by the retreat of glaciers, the land is rising, causing both a decrease in nearshore water depth, as described solely in Hoonah (Ken Grant, Adam Greenwald, Ester Greenwald, Lori Kay Guinard) and a higher shoreline, described primarily in Hoonah (Wanda Culp, Adam Greenwald), with one instance in Kake (Joel Jackson).

With regards to water depth, two kinds of observations were made. Firstly, it was described that water-covered areas were becoming shallower in Hoonah (Ken Grant, Adam Greenwald, Lori Kay Guinard): 'there's some places up the bay where I used to run in and out of, oh I ran through there, it's shallow here! You know, it's getting shallower…yeah…that's uplift…and it is climate change, it's a long one, the glaciers are retreating you know…and it's all part of the picture' (Ken Grant, Hoonah). Secondly, interviewees noted that rocks were 'appearing' where they didn't used to be, again observed in Hoonah, indicating that the depth of the water is less (Adam Greenwald, Ester Greenwald, Lori Kay Guinard): 'but as far as around here, it seems like it's less water because the land is rising, they have proven that…with the reduction of glaciers and things…so places out here that didn't used to have rocks, are just littered with rocks and things' (Ester Greenwald, Hoonah).

Secondly, the shoreline was observed as being 'higher' in several ways. Adam Greenwald (Hoonah) noticed that an old boat mooring cradle was no longer at the shoreline, but back in the woods:

> 'my dad had a boat, the Mabel G, and he used that to haul all the produce and everything, you know, and then there was times when he wouldn't have to use his boat for maybe two weeks, three weeks, something like that, so rather than anchor out and watch for the weather, he had a cradle, he called it his Mabel G's cradle, and at high tide he could run in and run up on to the cradle, and tie it up, and then he steps to go down, and then he'd get off the boat, and it wasn't too far from our farm, in fact, it was on the property, anyway, that cradle, he used it for years and years, and when he sold the property, that cradle was still there…when we got married, I showed Ester where the cradle was, and the cradle is still, well, about 2 years ago there were still portions of it…still there, but it was way back in the woods…there was big spruce trees out, way up…where the tide used to come, and where we used to run the boat in on the cradle, the whole cradle was setting back in the woods there, and, the tide don't come within a 100 yards of it.'

'The land around here [Kake] is relatively new' (Joel Jackson, Kake), one participant commented, while others in Hoonah noted, 'the whole country [Hoonah] has risen' (Adam Greenwald, Hoonah), and there's 'more and more land [in Hoonah]' (Wanda Culp, Hoonah). Furthermore, this "new land" changed the topography of traditional harvesting places in Hoonah (Ken Grant, Catherine Bolton, Donald Bolton). Linda Kruger (Juneau) of the US Forest Service, corroborated the observations of the villagers, commenting on the phenomenon of isostatic rebound in Juneau's Mendenhall forelands, where 'the land is rising, and so tide lands, what used to be tidelands are becoming dry uplands now, and trees are coming in …around the Mendenhall River, and… [its] outflow'.

Isostatic rebound was also tied to observations about changing tide levels primarily in NSE (Hoonah (3), Kake)[23]. Joel Jackson (Kake) observed that the upland is 'still raising up…in some places you can see it, and I see it in the tides, where the tides used to come up so high that they were right next to the road and you don't see that [now], even with a big tide'. Similarly, Adam Greenwald (Hoonah) commented about traveling in areas that used to (but no longer) flood on high tides:

> 'places that were called the First Slough, and the Second Slough, and then there was Nellie's Creek, where the First Slough was, big tides came up in it, right where a wagon road went, and sometimes when we were going with the wagon up to the farm, the potato fields and stuff, the water [came] up to the belly of the horses you know, and boy, to the bottom of the wagon you know…riding up to go to work, and man you had to sit on the sideboards you know, to keep from getting your feet wet…and now, the biggest tide doesn't come even close to going up in there…it's all grass and trees growing there, and I've been past there many times, where…First Slough was, then Second Slough, on the biggest tides you couldn't even go though, we had to go around it'

These comments are interesting, as three people in NSE (Hoonah (2), Kake)[24] still felt the tide level was rising, and covering land, despite seeing isostatic rebound as well. For example, Wanda Culp (Hoonah), who commented very briefly about rebound, also spent a lot of time in the interviews talking about the high tides (showing their interaction):

> 'Wanda: and also, the land that the ice was on is still rebounding, so that there's more and more land
> Victoria: so, the tide, would you say that the sea level is going up or down here?
> Wanda: oh...it's going up' (the tide levels)

Thus, in the region of NSE, many changes in the land-sea interface are being seen, between the higher tides covering land experienced by a few people, and the isostatic rebound, uncovering land, observed by a larger number of people. Both of

[23] Adam Greenwald (Hoonah), Joel Jackson (Kake), Lori Kay Guinard (Hoonah), Wanda Culp (Hoonah)
[24] A11 (Kake), Wanda Culp (Hoonah), Ernestine Hanlon Abel (Hoonah)

these observations relate to a loss of land for the original harvesting purpose, and forces the ecosystem to change, regardless of whether the land is covered by water or not. For example, isostatic rebound can create an uplands area from what was formerly an estuary (seen noted by Linda Kruger, Juneau), and land (including traditional harvesting sites) can be lost to high tides and sea level rise (Johnson *et al*. 2019), such as part of the culture camp in Kake being lost to the sea (A11, Kake). This change in available land influences many plant and animal species, and in turn changes how people interact with the landscape. These same changes were not seen in the region of SSE, nor in MBC or HG.

3.4.3 Sea level rise

Along with isostatic rebound in northern communities, sea level rise was an important change seen in all four regions. While many participants in NSE observed both phenomena (rising tide levels and isostatic rebound as seen above), some interviewees in NSE (Hoonah (2), an observation from near Sitka (June Degnan (Juneau)) and Kake (2)) and SSE (Hydaburg (2)) only mentioned tide levels (as resulting from sea level rise) as being impacts[25]. In the regions of MBC (Metlakatla (2)) and HG (Old Massett (6), Skidegate) nine interviewees mentioned sea level rise[26] (none had mentioned isostatic rebound).

Wanda Culp (Hoonah) expounded on how she has been keeping records of tidal levels and is noticing that tides are getting larger:

> 'Wanda: so what I've been doing is keeping track of the tides for the last several years, because they've been increasing, we've got 20 foot tides now, which we never used to have, 18 foot tides used to be the big tides…and now we've got…what is it, 2014, so for 2013 we had 3 20-foot tides, and 24 19

[25] A10 (Hoonah), A11 (Kake), Anthony Christianson (Hydaburg), June Degnan (Juneau), Ernestine Hanlon Abel (Hoonah), Michael Jackson (Kake), Marvin Kadake (Kake), Vickie Le Cornu (Hydaburg)
[26] A1 (Old Massett), Robin Brown (Old Massett), Sherri Dick, Reg Davidson (Old Massett), Jack Litrell (Old Massett), FN, RN, PP, Emily Watts (Old Massett)

foot tides last year…and 5 10 foot tides, that's more…and then 2012 – we had 8 20-foot tides, and 23 19-foot tides, and 9 10-foot tides…and 2011, 42 18-foot tides, 26 19-foot tides, 9 20-foot tides, so 2011 was a big…'

People commented that a rising sea level was making it trickier to disembark from boats:

'one time I was going out on the ferry, and the ferry came in, and I was thinking alright for the first time we're going to be on time…and…there [were] problems, and I finally went and asked, what's going on? They said the tide is too high…they build it for a certain tide, and they weren't taking into consideration [these environmental changes] and the tide would go up…so the tide was high when they came in, and they couldn't lower the ramp…so we had to wait for a while for the tide to go down before the ramp could go down' (Ernestine Hanlon Abel, Hoonah)

As well, it was noted that access to waterside smokehouses have been impacted:

> 'The tide…it's so high, I mean the ramp is just flat…and it's almost like, it goes right out, all the way down, and almost a little passage to go through here, a lot of water…I mean, there's a boat down, my ex's old boat down there, and my smokehouses, almost close to the water, I couldn't even get down there to start a fire in the smokehouse' (Fannie Nelson, Metlakatla)

As well as seeing changes in the tidal levels, some interviewees also commented on the levels of water in the rivers (even at the mouth). However, they typically attributed fluctuations in river levels to increased rain and snow fall amounts, rather than sea level rise, and the greatest impact of this was noted with salmon (covered in chapter 5). Finally, four interviewees, in the regions of NSE (Kake (2)), MBC (Metlakatla) and HG (Skidegate), stated that they had not seen any changes in either the tides or water levels[27].

In the region of HG (mainly in Old Massett), but also in SSE (Hydaburg) and MBC (Metlakatla), much of the discussion around tidal levels was linked to observations of erosion, as these people are experiencing rapid rates of coastal erosion and deposition on their land – this is further elucidated in section 3.4.4 directly below.

[27] A3 (Skidegate), Doris Auckland (Metlakatla), Lionel Bean (Kake), Nancy Bean (Kake)

3.4.4 Erosion

Erosion was seen in all four regions of the study area and was attributed to two major driving forces. Firstly, 12 people, primarily in Haida Gwaii (Old Massett (4), Skidegate), but also in the other three regions of NSE (Hoonah (2)), SSE (Craig (2), Hydaburg), and MBC (Hartley Bay) noticed that due to increased rainfall, mudslides were becoming more frequent in steep areas, such as the hills and mountains that the villages often back onto[28]. The higher frequency of slides noticed was thought to be instigated by heavy rain saturating the soil, and making it act 'like a sponge' (Fred Hamilton, Craig). This then causes the top layer of the soil to be heavier as it has soaked up water, and slide away from the bottom layer of soil, down the hill, causing landslides. Logging practices specifically commented upon by five interviewees, primarily in HG (Old Massett (3) and Skidegate), but also in NSE (Hoonah), were also a big factor in promoting erosion, due to the stabilizing vegetation layer having been removed[29]. A2 (Old Massett) added to this, by saying that 'since logging practices changed, all the coastlines are…cleaner than they used to be, so there's no logs there to buffer the waves [from the upper reaches of the beach]…to slow down the erosion problems [of the cliffs]…so we got more erosion, more erosion now than we ever did'. As well, he thought that logging practices, and the lack of stabilizing vegetation, were mostly to blame for slides, not heavier rain.

Secondly, as mentioned above, coastal erosion was noted, typically tied to rising sea levels, in all four regions. People commented that they had seen the tides and sea levels rise to such an extent that areas used for harvesting had changed/disappeared, or been covered by water, primarily in HG (Old Massett (3)),

[28] A2 (Old Massett), Arnie Bellis (Old Massett), Helen Clifton (Hartley Bay), Anthony Christianson (Hydaburg), Wanda Culp (Hoonah), Sherri Dick (Old Massett), Captain Gold (Skidegate), Lori Kay Guinard (Hoonah), Fred Hamilton (Craig), A7, Myrna Yates (Craig)
[29] A2 (Old Massett), Arnie Bellis (Old Massett), Wanda Culp (Hoonah), A7, Captain Gold (Skidegate)

but also in NSE (Hoonah, Kake) and SSE (Craig, Hydaburg, and Ketchikan)[30]. Beaches were recorded as eroding mostly in HG (Old Massett (2) and Skidegate), but also NSE (Kake)[31]. In other cases, parts of the villages (near the beach) or roads had been washed away (or logs blown up on them) especially in HG (Old Massett (7)), but also in SSE (Hydaburg)[32]. It was also noted by three people that cultural sites were being lost due to erosion in SSE (Hydaburg), MBC (Metlakatla) and HG (Old Massett)[33]:

> 'well for us it means a lot [of] historic sites and all of our cultural property are right at basically the tide line…and we've had mass erosion not only here in our community, but also in cultural property sites…so we're losing cultural heritage, you know, petroglyphs, burial sites, village sites, old canoe runs and things like that…they're washing away' (Anthony Christianson, Hydaburg)

Haida Gwaii, particularly Old Massett, is known for large amounts of erosion and deposition on the beaches on the north end of Graham Island, primarily due to changes in sea level and storms. Regarding erosion of their North Beach strawberry (*Fragaria spp.*) patch, now drastically decreased, Old Massett resident Emily Watts said: 'where we used to pick strawberries…where we walk on the beach to North Beach…it's washed straight out, there's nothing there now, because of the tide, [it] goes right in there'. Erosion was also discussed at Tow Hill by Robin Brown and A1 (Old Massett): "Robin: Tow Hill is a great example of that…A1: yeah…that's eroding too". A1 also noted that this erosion at Tow Hill had led to buried trees being uncovered: "we can see the trees that were buried many, many years ago are starting to show up in the sand".

[30] A11 (Kake), Delores Churchill (Ketchikan), Wanda Culp (Hoonah), Reg Davidson (Old Massett), Margaret Edgars (Old Massett), Emily Watts (Old Massett), Vickie Le Cornu (Hydaburg), Myrna Yates (Craig)

[31] A1 (Old Massett), Robin Brown (Old Massett), Captain Gold (Skidegate), Michael Jackson (Kake)

[32] A2 (Old Massett), A7 (Old Massett), Anthony Christianson (Hydaburg), Reg Davidson (Old Massett), Sherri Dick (Old Massett), Margaret Edgars (Old Massett), Jack Litrell (Old Massett), Emily Watts (Old Massett)

[33] Anthony Christianson (Hydaburg), Fanny Nelson (Metlakatla), Rolly Williams (Old Massett)

Robin Brown and A1 (both Old Massett) also described how the tide was getting higher, in this instance at North Beach: “Robin: yeah…the only thing that’s different that’s developing here, is the rising of the water…yeah, like out at North Beach…A1: down that far end there, our beaches are getting shorter and shorter, and the water is coming right up to the trees now”. As well, A2 (Old Massett) described that waves were getting much higher along Highway 16 (near Tlell), with the only road south to the main town of Skidegate often being covered by surges and logs in the winter time: ‘so when we get 23 foot tides now, and if you go down to Tlell, you can see where they’ve roped the driftwood across the roads on those big tides…we’ve never had waves like that, just up to I think 3 years ago they started coming up on the road there so…you can tell the water difference in the last 3 years, it’s still rising’. He also had several pictures showing the houses and beach along the eastern side of Old Massett. As can be seen from the following description, quite a few of the houses had been lost: “A2: you can see right where the tide is, [where] it used to be, now we got a seawall, way up back where the houses are…Victoria: and the road that we have now, is that back here?.A2: right in between these houses”. The current road (Raven Road) is drawn in the picture (Figure 3.1) using a yellow line – the houses and land to the left of the line have been lost to erosion, and it is now a beach.

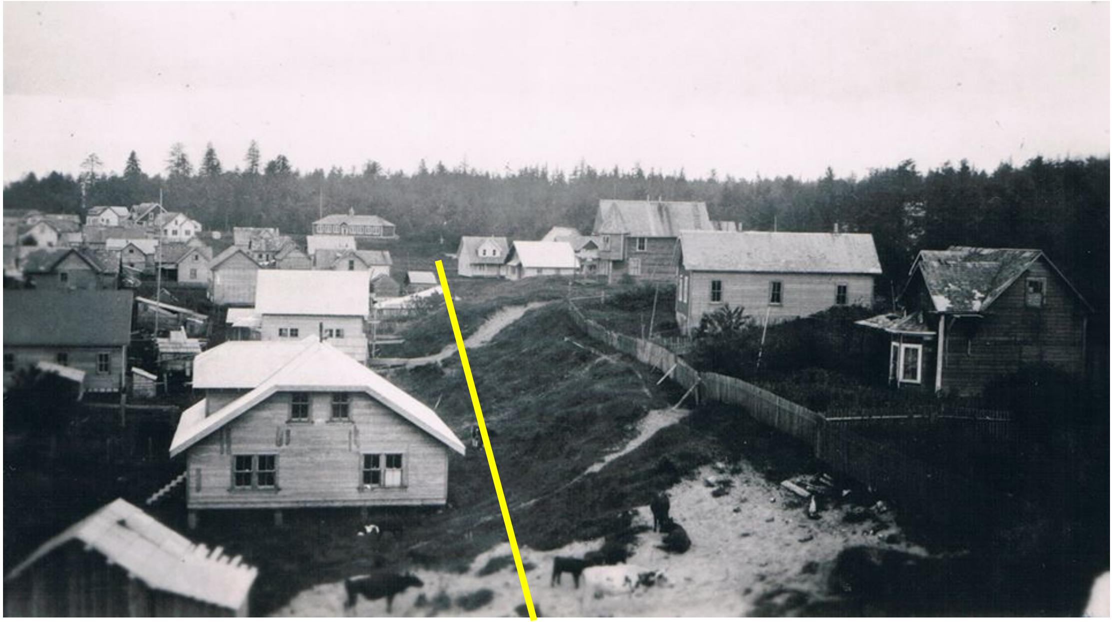

Figure 3.1. Picture taken by A2 (Old Massett), dated 1945-1950, showing where the current road (Raven Road) is, which currently goes right along the edge of the beach and the houses. Thus, all the houses and land to the left of the line have been lost, and it is now only beach.

Table 3.6. Table of observed changes in the landscape.

Observation	Changes seen	Impacts	Responses	Quotes
Glaciers and sea ice	➢ less floating ice ➢ sea glaciers have retreated onto the land	➢ warmer temperatures ➢ less water available in the spring, glacial melt in streams	➢ adaption techniques to moderate water levels in streams	"now there isn't enough ice to make a cocktail, there's nothing" (Adam Greenwald, Hoonah)
Isostatic rebound	➢ more in Alaska, esp. northern Southeast ➢ coastal bays getting shallower	➢ boats being damaged, motors hitting rocks ➢ less ice floating	➢ moving boat moorage sites ➢ changing travel routes	"with the ice receding, the land has risen quite a bit" (Adam Greenwald, Hoonah) "you could walk across to Graveyard Island, and when I was a kid, they used to anchor seine boats there!" (Adam Greenwald, Hoonah)
Tide Levels	➢ higher tide levels ➢ increased number of 'high' high tides (yearly maximum high tides)	➢ losing land (under water) ➢ harder to harvest clams, cockles and other beach resources	➢ moving houses/usage areas (the culture camp in Kake, A11)	"So, what I've been doing is keeping track of the tides for the last several years, because they've been increasing, we've got 20-foot tides now, which we never used to have, 18-foot tides used to be the big tides" (Wanda Culp, Hoonah) "it varies, but even the fact that we have 19- and 20-foot tides is something" (Wanda Culp, Hoonah)
Erosion	➢ because of heavier rainfall (and decreased plant cover from deforestation) ➢ beach erosion from higher tides	➢ plants and soil washed away ➢ shoreline changing (in conjunction with deposition, Old Massett)	➢ adjusting uses and access to the area	"so, there's been erosion, there was two contributing factors to that, they did dig up our sandbar, and pulled a bunch of sand out of there, but also I believe the water is rising slightly" (Anthony Christianson, Hydaburg)

3.5 Linguistic context of weather and landscape observations

In all three languages and the five dialects (Tlingit, Tsimshian, and Alaskan, Old Massett, and Skidegate Haida) encompassed in this study area there are individual words and language phases (both nouns and verbs) that relate to the weather observations noted by participants in this research, including snow, sun, rain, extreme temperatures (both cold and hot), storms, and tides, the existence of which further illustrate the knowledge of weather patterns across the region (Anderson 2018; DeVries 2014a; DeVries 2014b; Edwards 2009; Lachler 2010; Roberts 2009). In addition to a variety of words and phrases referring to these phenomena occurring in general, some specific terms were also used, and these are detailed below. In both Tlingit and Old Massett Haida, there were phrases that related to snow being quite deep, relevant to the heavy snows and cold spells noted, and in Old Massett Haida there was a phrase for people getting sunstroke from the heat, which could indicate that the temperatures on sunny days could get quite warm, even potentially burning people, another observation noted. All five dialects detailed terms for storms, rough waters, wind/rainstorms, squalls, gusty, and blowing hard. Tlingit and Tsimshian additionally had terms for snowstorms and these two languages, plus Skidegate Haida, had phrases around being unable to travel due to storms and finding shelter from storms, another noted observation. Surprisingly, erosion was the only landscape change which was not noted in all dialects/languages. There were no terms identified relating to erosion in Alaskan Haida, and a term for 'landslide' was the sole term found referring to erosion in Tsimshian and Skidegate Haida. However, phrases around mud, soil, and dirt were found in Tlingit, Old Massett Haida and Skidegate Haida, and Tlingit and Old Massett had specific terms for the ground being softened by rain and turning to mud, Old Massett and Skidegate Haida had terms for washouts, whether by gullies, rivers, or wave action, and Tlingit also had terms for snowslides, avalanches and rockslides. Finally, while not every dialect was listed as having a term for red tide, Old Massett and Skidegate Haida did acknowledge its presence with specific phrases, and the particular reference to something being ‘poisonous from red tide’ (Old Massett) shows people’s awareness of the severity of red tide (see 3.6.5 Biological hazards and threats for ethnographic information). Terms for weather were also linked to biological resources. On two occasions phrases were used to relate food processing to weather patterns. In Tlingit, Tsimshian, Old Massett Haida, and Skidegate Haida, there were phrases describing foods being dried in the sun, and in Tlingit only there was also mention of fish air-dried in freezing air. Old Massett and Skidegate Haida both link words describing rain with two birds, sandhill crane and black oyster catchers, both said to make a lot of noise when it is going to rain, showing an association between weather and an indicator species.

3.6 Changes in resource abundance, distribution, and use

In this section I discuss the changes observed as they apply to the broader ecosystem and its constituent species, and then I delve more deeply into the changes affecting each of the CKIS examples, and the connections and impacts of these changes, in the chapters that follow. As might be expected, with the variation in temperature and precipitation due to weather changes, knock-on effects have cascaded down to affect the local flora and fauna. Local residents across the region have observed these changes, ranging from broad-scale landscape composition shifts, to finer scale observations concerning behavioural adaptation, and individual size, abundance, distribution, quality, and quantity of resource (Table 3.9). While many people noted that the above weather changes had affected resources in such a way as to make them harder to harvest, two interviewees had differing opinions. Marlene Johnson (Juneau) stated that in her experience, even though the weather had changed, she thought development (such as road building and clearcutting) had a greater impact on the availability of resources than weather. Mary Guthrie (Klawock) felt that the weather had not changed very much, and that changes in resource supplies were due primarily to new laws and mismanagement that affected the harvest of key fish, wildlife, and other resources.

3.6.1 Species composition, distribution and migration

There were several factors identified as affecting species composition, distribution, and migration. According to three interviewees (Marlene Johnson (Juneau), Adam Greenwald (Hoonah), Mary Guthrie (Klawock)) logging, development, fishing, pollution, and other anthropogenic influences tended to amplify the base impacts of how climatic change influenced plants and animals. For example, many berry species grow well in clear-cuts and along roadsides, where they can get plenty of light, which temporarily increase their distribution (until forest succession forms a new canopy), a result not tied to climate change (described more in Chapter 6). Also, deer often move into the mountains to escape the housing and coastal development, which in turn impacts people’s ability to hunt them (although new logging and other access roads can create a vector to increase harvesting, as described in Chapter 4). One of the largest changes due primarily to the weather alone, was the connection between the warming temperature of the water (due to warmer air and lack of snow melt input) to changes in salmon migration, but this is explored in depth in the salmon chapter (Chapter 5).

In addition to the CKIS examples, other species found to have changed migration patterns were small migratory birds (commented upon in NSE (Juneau), and MBC (Hartley Bay)), which had been blown off course, or stayed in their northern distribution because it was warmer now (Helen Clifton (Hartley Bay), Jacque Martin (Juneau)), and seven people noted that fish that had come up from warmer areas in more southerly habitats to primarily SSE (Craig (2), Hydaburg (2), Ketchikan), but also NSE (Kake), and HG (Skidegate), with unusual currents[34]. Respondents in the region of NSE (Hoonah (9), Kake (8))[35] reported that the range of moose had expanded from only being on the mainland to also cover Kupreanof (Kake), Chichagof (Hoonah) and Baranof islands, as well as the surrounding smaller islands. As Agnes Davis (Juneau) said: 'that's something that wasn't available there years ago…for some reason it just started migrating there'. As well, dragonflies were an interesting case, as one participant reported that they were decreasing (A2, Old Massett), while another reported that they were increasing (Catherine Bolton, Hoonah). However, because these observations were in diverse locations, specifically Northern Southeast Alaska, and Haida Gwaii, this could be an observation that differs regionally, similar to the isostatic rebound versus sea-level rise observations.

Overall, there were many species of mammals, birds, insects, fish, and small plants commented upon in the interviews, but the individual species and functional groups that have either drastically reduced/disappeared or appeared are described in further detail in the next two sections.

[34] A3 (Skidegate), A11 (Kake), Anthony Christianson (Hydaburg), Fred Hamilton (Craig), Merle Nancy Hawkins (Ketchikan), Vickie Le Cornu (Hydaburg), Myrna Yates (Craig)

[35] A11 (Kake), Catherine Bolton (Hoonah), Donald Bolton (Hoonah), A9 (Juneau), Wilbur Brown (Kake), Wanda Culp (Hoonah), Agnes Davis (Juneau), George Davis (Juneau), Ken Grant (Hoonah), Adam Greenwald (Hoonah), Ester Greenwald (Hoonah), Lori Kay Guinard (Hoonah), Ernestine Hanlon Abel (Hoonah), Joel Jackson (Kake), Michael Jackson (Kake), Cliff Johnson (Juneau), Marlene Johnson (Juneau), Evans Kadake (Kake),

3.6.2 Species appearance

Twenty-three functional groups or species were noted as 'appearing', including new plants or animals that moved into areas as pioneers or in larger numbers, and species that had been both introduced by humans and/or migrated on their own. A listing of the species/functional group, locations, and people that observed them can be found in Table 3.7 below.

Table 3.7. New species that have appeared in the study region.

Organism/Functional Group	Location(s) and interviewee(s)
Ticks	Hoonah (Catherine Bolton)
Dragonflies	Hoonah (Catherine Bolton)
Bugs	Hoonah (Donald Bolton)
Giant squid	Juneau (but observed in Kake-A9), Hydaburg (Anthony Christianson)
Farmed fish in wild streams	Old Massett (Robin Brown)
Starlings	Hydaburg (Anthony Christianson, Vickie Le Cornu), Old Massett (Sherri Dick, Reg Davidson, A2, Emily Watts, A7)
Pigeons and Doves	Hoonah (Adam Greenwald), Kake (Joel Jackson, Michael Jackson, Evans Kadake, Marvin Kadake), Klawock (Mary Guthrie, Ernestine Kato), Old Massett (Sherri Dick, Reg Davidson, A2, A7, Jack Litrell)
Elk (moving onto islands)	Hoonah (Wanda Culp)
Cougars (moving onto islands)	Hoonah (Wanda Culp)
Tall invasive grass (hits people in the face when picking berries)	Hoonah (Wanda Culp)
Invasive plants on roadside and logging areas	Hoonah (Wanda Culp), Old Massett (A2)
Migrating birds not leaving (specifically mentioned Robins) (specifically mentioned Hummingbirds)	Hartley Bay (Helen Clifton), Juneau (Jacque Martin), (Juneau (Kake) (George Davis, Agnes Davis) Juneau (Kake) (George Davis, Agnes Davis), Kake (Evans Kadake)
Tropical Fish	Juneau (A9, Harold Martin), Kake (A11)
Mackerel	Old Massett (A2)
Blue Whale	Hoonah (Ernestine Hanlon Abel)
Tuna	Craig (Fred Hamilton, Myrna Yates), Hydaburg (Anthony Christianson, Vickie Le Cornu), Old Massett (Reg Davidson), Ketchikan (Merle Nancy Hawkins), Skidegate (A3)
Sunfish	Ketchikan (Merle Nancy Hawkins)

Turtle	Ketchikan (Merle Nancy Hawkins)
White shark	Old Massett (A2)
Wolverine	Kake (Evans Kadake)
'blue' glacier bear	Hoonah (Wanda Culp)

While tuna was a species that was seen to be appearing in numerous communities, Anthony Christianson (Hydaburg) thought that maybe it is a reoccurring species, so potentially it comes up north periodically: 'I've read some history that the Haidas used to fish tuna before…so I think this is a species that comes regularly or routinely here…[the last time I saw mention of them] it was in the March of 2014, [a] National Geographic article'[36] . While the presence of tuna near Haida Gwaii appears to only be documented in fishing websites (The West Coast Fishing Club 2014) with regards to coming up on warmer currents, it has been shown in the scientific literature that in the Atlantic Ocean that tuna are shifting further north with warmer water in recent years (MacKenzie *et al*. 2014). The only website with any scientific basis of tuna further north was that of the Pew Trust, which delimited the range of tuna species as coming up to Haida Gwaii, but no explanation or description of range shifting was given (Pewtrusts.org 2019).

Another species which was only commented upon once as appearing more frequently (Wanda Culp, Hoonah) was the 'blue' glacier bear (*Ursus americanus emmonsii*).

> ' [A] hard to see species, that you hardly ever saw, was what they call the blue bear…which is a glacier bear, and now you see…not a lot, but you see them, where they were so elusive…you were lucky if you ever saw one, they live by in the mountains, and in the snow, they are blueish, they are actually black bears…but they are greyish blue…they call them Glacier bears…or blue bears…here, they were not sighted a lot…now more people see them'.

[36] In this article, they only briefly describe tuna near Haida Gwaii, opining that the Haida People have hunted tuna for thousands of years, based on finding these bones in their middens, and don't discuss its migration patterns, or any changes to the pattern that would make it come more frequently now, such as warming water or change in currents (Brower, 2014).

Glacier bears are a subspecies of black bears, and is it thought that this species, which developed in isolation during the last ice age, will interbreed with other black bears, and this recessive dark grey colour gene will be dominated by the black gene (Bear Conservation 2019). The observation of more bears being noticed likely has to do with people moving closer to the bears' territory, rather than an actual increase in population.

Many of the sightings of new species were made in Hoonah, as generally the more people interviewed in a community, the more observations of new species were logged – 16 people were interviewed here, more than any other community, except Old Massett (20). However, in Old Massett, rather than documenting a greater number of new species, many people corroborated sightings of the same species, those of starlings, pigeons and doves. It was also interesting to note that these three birds were not limited to one community but were appearing throughout almost the entire study area (except MBC), ranging between Hoonah, Hydaburg, Kake, Klawock and Old Massett.

3.6.3 Species reduction

Thirteen functional groups of species were observed to have reduced numbers or ranges. Fewer species disappearances than appearances were noted by people. In general, many reductions of species' ranges and populations were noted, but there were few complete disappearances of particular flora or fauna. The disappearances and reductions mentioned by participants are listed in Table 3.8.

Table 3.8. Species that have had a reduction in the study region.

Organism/Functional Group	Location(s) and interviewee(s)
Violets and Lady slipper orchids	Ketchikan and Old Massett (Delores Churchill)
Herring (don't spawn anymore)	Craig (Fred Hamilton), Hoonah (AG, A12), Kake (Evans Kadake, Marvin Kadake), Klawock (Mary Guthrie), Juneau (A9, George Davis, Jacque Martin), Metlakatla (Fanny Nelson, Robert Nelson), Skidegate (Harvey Williams, Group interview)
Dungeness crab	Old Massett (Robin Brown)
'a lot of marine species'	Hydaburg (Anthony Christianson)
Migrating ducks and geese	Hoonah (Wanda Culp)
Hummingbirds	Klawock (Earnestine Kato)
Bees	Juneau (Agnes Davis, George Davis) Old Massett (Reg Davidson, A2, Gwaii Edenshaw, Margaret Edgars, Emily Watts)
Horseflies	Old Massett (A2)
Dragonflies	Old Massett (A2)
Frogs and Toads	Hartley Bay (Helen Clifton), Hoonah (Ken Grant, A4), Hydaburg (Vickie Le Cornu), Ketchikan (Merle Nancy Hawkins)

For the marine resources that were listed (herring, Dungeness crab and 'a lot of marine species'), the main cause of disappearance was thought to be overfishing rather than climate change, although these two effects compound to increase the negative consequences (further explored in Salmon, Chapter 5). The highest number of appearances and disappearances were noted in Old Massett (28% for each), but this may be skewed by the larger sample size of interviewees (15 people), as people didn't appear to indicate in interviews that they felt like they were losing a large amount of biodiversity. The next highest number of appearances (17%) and disappearances (15%) were noted in Hoonah (although if you add in the elders in Juneau originally from Kake, Kake overtakes with 26% appearances and 22% disappearances). Overall, every community noted more appearances (53 total) then disappearances (32 total), except Skidegate (1 appearance and 2 disappearances), Metlakatla (0 appearances and 2 disappearances), Hartley Bay (both 1), Klawock (both 2) (Figure 3.2).

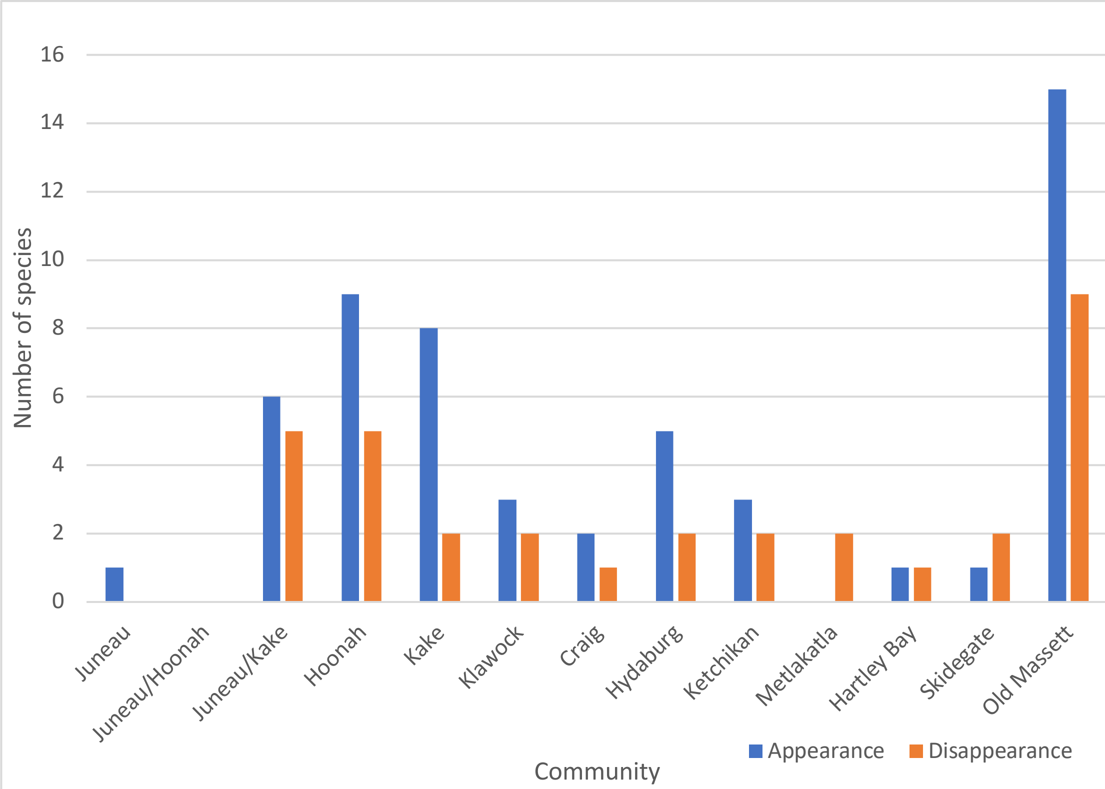

Figure 3.2. Species appearances and disappearances in each community.

Delores Churchill (Ketchikan) mentioned violets and orchids as species that had drastically disappeared in recent times. She was attuned to the presence of these species as they used to grow in great abundance near the spruce roots that she harvests for making baskets. She stated that she wouldn't harvest spruce roots where there were orchids so as not to disturb them. People tended to notice the species that they either harvested themselves or were associated ecologically with their target species; thus, fishermen noted changes in fish species and other marine organisms associated with their catches, and plant harvesters noted plants, both used and unused, associated with their gathering. One species which had not disappeared but was doing quite poorly is yellow cedar (*Cupressus nootkatensis*), and declines were noted primarily in

NSE (Hoonah (4), Kake (3)), followed by SSE (Hydaburg (2), Ketchikan (2))[37]. One cause of this 'yellow-cedar decline' (USDA Forest Service 2012) is a lack of insulation from snow, which exposes roots to freezing, thereby killing the tree. This mechanism was also described by interviewees as a causal factor in the reduced growth and loss of yellow cedar and was discussed with regards to snow in section 3.2.2.

3.6.4 Behavioural change

Most observed behavioural changes were associated with examples of the CKIS, especially deer and salmon (chapters 4 and 5). The next most commonly identified species exhibiting behaviour changes were humpback whales and killer whales. Even though killer whales commonly occur throughout the North Pacific Coast region, they were specifically noted to be traveling further north of Old Massett (A1, Arnie Bellis, Robin Brown), and their presence close to shore were cited as an indicator of stormy weather (Helen Clifton, Hartley Bay, quote in Table 3.9 below), which occurs more frequently now (they are known to come close to shore in stormy weather). Humpback whales were observed to be overwintering in Hoonah when they had not previously (Adam Greenwald, Ester Greenwald, both Hoonah), a phenomenon also noted in reports from Sitka (Straley *et al*. 2018; T. Thornton pers. comm. from J. Straley). As well, at Hartley Bay, humpback whales were said to 'have come back into the area' (Helen Clifton), which may also be tied to increased frequency and severity of stormy weather from which the whales are seeking refuge. In addition to whales appearing more frequently closer to the shore, some

[37] A12 (Hoonah), Catherine Bolton (Hoonah), Wanda Culp (Hoonah), Ken Grant (Hoonah), Lionel Bean (Kake), Nancy Bean (Kake), Michael Jackson (Kake), Anthony Christianson (Hydaburg), Vickie Le Cornu (Hydaburg), Delores Churchill (Ketchikan), Merle Nancy Hawkins (Ketchikan)

interviewees also noticed increasingly large congregations of humpback whales, although it is unclear whether the whales are actually ‘aggregating together’ or simply increasing in population, and thus being more commonly seen. Adam Greenwald (Hoonah) noted that whales were more common, perhaps increasing in population, then when he was a child: “you see whales all the time out here, go to Pinta Cove, and it’s full of whales…and they’re increasing…probably 4 times more than when I was a kid”, and Helen Clifton in Hartley Bay noted:

> “our people had never seen such a congregation[38] of humpbacks…when we talked about it as elders, we’d see maybe three together, maybe 4, but, more like 2, or a mother and a young one, but this was like a whole, they were having a big meeting of some kind, there was about 30 or 40 of them…we had never seen this, and everybody…was, sitting there, watch[ing] for it, and discuss[ing] it” (Helen Clifton, Hartley Bay)

Helen Clifton (Hartley Bay) also commented “that there’s something going on in the waters, why these whales are so free, in their own environment”, but it was unclear if this was due to storms, and they were coming in to the nearshore, or if some hunting or predation pressure was lifted off them. Fred Hamilton (Craig) also noted a behaviour change and found it surprising that whales had come all the way into shore, but he didn’t know the species, and just called them ‘little whales’. It has been noted in the literature that in addition to a population increase after the whaling ban was implemented, if humpback whales are unable to eat enough to allow them to complete the migration to Hawaii, they will stay in Alaska, so limited prey may be both affecting people’s observations that whales are still present in the winter, and also impact their predation on herring (Straley *et al*. 2018).

[38] the term congregation here may either refer to an increasing population, meaning more whales are seen together, or they have grouped together without the population expanding.

3.6.5 Biological hazards and threats

Many of the diseases, pathogens, contamination, and pests commented on were noted primarily in the CKIS examples, and thus are covered in those chapters. In addition to these, participants noted diseased trees, red tides/harmful algal blooms, degradation to totem poles and the presence of shipworm (*Teredo navalis*) and bitter crab syndrome (*Hematodinium spp*.).

Overall, the biggest issue that people found to be affecting species of interest was the higher spread and frequency of red tide affecting invertebrates in more communities throughout the study area. Participants thought the poisonous tides to be due to warmer ocean temperatures, and there is scientific evidence that increased levels of red tide have been linked to warming events (McKibben *et al*. 2015; Moore *et al*. 2011; Ryan *et al*. 2017) or that warm-water species that can cause red tide to be moving further north with warm currents (Shimada *et al*. 2016). Red tides are more appropriately labelled Harmful Algal Blooms (HABs), as not all phenomena that cause shellfish poisoning are red, and some 'red tides' are not harmful (Woods Hole Oceanographic Institute 2017), but I will continue to use the term 'red tide' in this chapter and thesis, as that was the term used by all of my interviewees. Seven people, mostly in MBC (Hartley Bay, Metlakatla (2)), but also in NSE (Hoonah, Kake), SSE (Ketchikan), and HG (Old Massett) noted this observation of increased occurrences of red tide[39]. Reg Davidson (Old Massett) mentioned that there was an indicator to judge when red tide would be affecting the shellfish, and to stop harvesting, as it was dangerous to eat them after that: 'I remember one guy went digging for butter clams, something to do with the blossoms, berry blossoms, not to go…digging butter

[39] Catherine Bolton (Hoonah), Helen Clifton (Hartley Bay), Reg Davidson (Old Massett), Merle Nancy Hawkins (Ketchikan), Ernestine Kato (Klawock), Fanny Nelson (Metlakatla), Robert Nelson (Metlakatla)

clams…because the butter clams can be affected by red tide.' In Newton and Moss (2009), they mention that one person determined the time to stop the clam harvest when the grouse hoots (in April).

In contrast to people that described more red tide occurrences, two people on Haida Gwaii (although in opposition to this, others on Haida Gwaii did note it as an issue) stated that they didn't think there was more red tide now. For example, Captain Gold (Skidegate) said that he didn't think there were higher incidences of red tide now across Haida Gwaii, although perhaps there was some more in certain bays and inlets due to a warmer localized ocean temperature, and A2 (Old Massett) felt that higher incidences of red tide had been manufactured by fisheries managers to prevent conflict between user groups:

> 'A2: and now we have all kinds of red tide things that are affecting it because they shut it down just for tourists to use it for crab dipping, and so the red tide is there so we can't dig clams…it just opens the beach up for tourism to come out and dip the crabs without interfering with clams
> Victoria: are there more red tides now than there used to be?
> A2: only because they want to…ever since we got this management of crabs and clams, red tide seems to be more, more evident, because they don't want this conflict between two user groups on the beach at one time…and I think that's why they created the red tide'

For the other three issues related to biological hazards and threats, only one to two people mentioned each one, and thus they are not considered widespread in the region, though they could grow to become larger issues. Firstly, Wanda Culp and Lori Kay Guinard, both in Hoonah, mentioned an unknown 'disease' that seemed to be killing off trees, including crabapples (*Malus fusca*), although both also mention the lack of water, so potentially they may be noticing die offs related to drought conditions, rather than a specific disease. Secondly, Catherine Bolton, also in Hoonah, mentioned the presence of a parasitic dinoflagellate (*Hematodinium spp*.) in crabs in Chatham and Stevens Passes (exact species was not given, but she was talking about king crab just above), called ‘bitter crab syndrome’. This disease is greatly damaging to crab fisheries around the world and has been found in the Atlantic and Pacific oceans in snow, or tanner, crabs (*Chionoecetes* spp.) for numerous years (Meyers *et al*. 1987; Morado 2007; Ryazanova *et al*. 2016; Shields *et al*. 2005) but it has also recently been reported in king crabs (all three species, *Lithodes aequispinus, Paralithodes camtschaticus* and *Paralithodes platypus*) in Russia (Ryazanova 2008; Ryazanova *et al*. 2016). Thirdly, Anthony Christensen in Hydaburg mentioned that shipworms (*Teredo navalis*), which live in all the world’s oceans except the Antarctic (Invasive Species Compendium 2019), seemed to be migrating north, and they monitor them as an indicator for acidification in the community:

> “shipworms, we’ve had our kids involved in shipworm studies, you know they’re an indicator of acidification…this is about as far north as they should be…showing up, and they’re real prevalent here, which is basically an indicator that the southern species are migrating north…[the] climate is becoming more…acceptable for their populations to sustain themselves”.

This observation is interesting, as I was only able to find literature saying that in the Northeastern Pacific they are only known to occur from southern British Columbia (off the coast of southern Vancouver Island) to southern California, and thus have not yet been reported from Alaska (Carlton 1992, Invasive Species Compendium 2019). In addition, apart from range and distribution information, its bioecological characteristics have only briefly been reported in the literature; Hendy’s (2012) graduate thesis discussed the importance of teredinid bivalves (the group shipworms belong to) in breaking down large woody debris and their empty tunnels (after dying) creating homes for other organisms and noted a greater species diversity correlated with a greater number of tunnels. In addition, Hendy (2012) reported a negative effect of acidification on calcium carbonate shells in general, and this will likely have an effect on teredinids (although noted it has not specifically been studied for them), which would in turn impact woody debris and the other species that utilise their tunnels. While this study was based in Indonesia, with the lack of any other evidence, it is feasible that this species could be a good indicator of acidification in my study region as well.

Reg Davidson (Old Massett) noticed that while poles carved 100 years ago had lasted for many decades, more recent poles were getting ‘green’ through vegetation and lichen growing on them relatively soon after they were erected, and they were rotting faster than would be expected. For example, he described this phenomenon “... from the 1800[‘s], there’s one that lasted 100 years before it fell...and now they removed one after what, 40 years”. Thus, because all poles were rotting faster in the last 10– 20 years, the new poles weren’t lasting as long as the older poles had. This is possibly an effect of climate change or, as suggested by Reg Davidson (Old Massett), air pollution. Along a similar vein, in a conservation report of totem poles in Ketchikan, Alaska, Sheetz (2008) noted a particular increase in decay, and of lichen, moss, and other vegetation growing out of the totem poles since the last conservation report 14 years previously in 1994 and suggests that this issue of epiphytic growth should be addressed by clearing branches away from poles to increase air circulation, or by applying a fungicide or water repellent compound. This shows that the observation of Reg Davidson (Old Massett) has been seen in other locations as well. Todd (1998) suggests one reason for the totem poles decaying faster now was due to moisture being trapped between the paint and the wood of the pole, as this is a very moist environment. However, this does not explain why there might be more ‘greening’ of the pole now versus in the past, unless this observation can be linked to the increased rain noted overall by participants in this study area, or different types of paint used for modern poles.

3.6.6 Growth and size differentiation

Comments on size of organisms were exclusively mentioned with regards to salmon and berries, and thus will be talked about in those chapters.

3.6.7 Quantity of resource

Comments on the quantity of resources were exclusively mentioned with regards to salmon, deer and berries, and thus will be analysed in those chapters.

3.6.8 Quality of resource

Comments on the quality of resources were exclusively mentioned with regards to salmon, deer and berries, and thus will be analysed in those chapters.

Table 3.9. Table of observed changes in resource use.

Type of Observation	Changes seen	Impacts	Responses	Quotes
Shift in species composition/ changes in migratory patterns of current species	➢ species shifting or expanding range more common than completely new species ➢ small migrating birds staying for the winter (robins and blue jays) ➢ moose coming from mainland	➢ new species present ➢ species moved from where usually are	➢ new species to harvest ➢ hard to find species when they've moved	"something's going on…difference in the air, and just last week…the robins are still here…crash into my bay window…I said 'you rascals,' you're supposed to be headed down south, what are you doing here?...and blue jays, and…I find that really, really strange, especially after that big thunderstorm, we had a little flurry of snow, about a month ago…everybody was shocked, and, so there's things happening in the air that [are] unexplainable…the birds are not leaving" (Helen Clifton, Hartley Bay)
New species appearing	➢ mostly linked to extreme weather events, such as 'unseasonably' cold or warm years ➢ See table in section 3.5.2	➢ can interfere with usual species ➢ new resources to hunt/fish for	➢ changes species harvested	"so, we are starting to see more fish from the south, from California, and we never did before" (Arnie Bellis, Old Massett)
Species disappearing	➢ more species declined than completely disappeared	➢ less available for harvesting	➢ limit harvesting	"Our birds are less and less…you don't see them in the flocks that we used to see them" (Wanda Culp, Hoonah)
Changes in behaviour	➢ whales coming closer to shore, behaviour they exhibit when it's stormy	➢ fewer salmon to harvest,	➢ changed resource use and sharing	"we're watching the whales down there, and the whales…for us, they are [a] weather…sign…and that would be blackfish or

	➢ salmon swimming deeper (because of warmer water temperatures, to get to cold water) ➢ declines in salmon fecundity due to lower water levels (Scannell, 1992) ➢ deer moving further away from human development and up mountains (less inhibited with lower snowfall), harder to hunt	shared and put up for winter ➢ harder to hunt deer	➢ changed ceremonies – not able to use deer, salmon or other traditional meats in potlatches	killer whale…so when they are going past the village, the old people will say they are headed out to the ocean, they are going to feed on the ocean…and they call the Pacific the big sea…in our language, and it's calm and now they are able to go out and gather, they got all the room in the world, and so then when they come in and go past the village, that means the Pacific is acting up…and they are coming in to feed…close to shore, because there's a storm coming, and so they're coming in" (Helen Clifton, Hartley Bay)
Biological hazards and threats	➢ higher levels of red tide due to warm water ➢ higher rates of worms and flies in deer and fish when preserving by drying and smoking, and in harvested berries, due to warmer autumn temperatures ➢ new varieties of pests around plant resources	➢ meat and berries of lower quality	➢ people can harvest/use less	"the sockeye, when, the warmer the water the more worms they get in their stomach" (Arnie Bellis, Old Massett)
Size of plant or animal	➢ fish getting smaller (also linked to overfishing and pollution, not just climate change)	➢ same limits, so overall less food	➢ people don't have as many fish to eat	"and they are getting smaller… one year they had 31 pounds, and then 29 pounds, last year it was 27 pounds won it, this year it's 26" (A9, Juneau)
Quantity of resource	➢ flowers blooming earlier, either vulnerability to frosts damaging flowers, or less	➢ fewer berries, deer and salmon	➢ don't go out to pick berries	"well, right now, it's kind of extreme, like, right now, we see [salmonberry] blossoms out and we're in January…and that means we

	pollination occurring, meaning less fruit ➢ deer are moving higher into the mountains due to less snow, and away from development ➢ salmon are moving deeper in the water, under the nets	➢ more difficult to harvest	➢ changed ceremonies – using store bought berries in potlatches instead ➢ drive into mountains, or hunt from boats, wait for a snow to drive deer down in elevation ➢ fishing closer to the river	won't have berries again…because there's no bees around" (Reg Davidson, Old Massett) "depends on the weather, eh? If there's not much snow, then all the deer's' up in the mountains… not too many people want to climb…and if there's snow we can get it on the beach, just travel on a boat and get our deer" (Wilbur Brown, Kake) "we've been having a hard time catching a lot of fish sometimes, because…they are staying deeper then they normally, and they aren't showing and jumping and behaving like they usually do, because the fresh water is so warm due to the lack of snowpack up there, melting" (Anthony Christianson, Hydaburg)
Quality of resource	➢ too much rain = fruit rot before ripening, or swollen with water and not fully ripening (not maximum sugar potential, no taste) ➢ not enough rain (or not at the right times) = berries shrivel up and desiccate ➢ with lack of food, deer are leaner, and have a lower quality meat	➢ fewer berries ➢ people don't want to harvest poor quality meat	➢ don't go out to pick berries ➢ changed ceremonies – using store bought berries in potlatches instead ➢ less deer eaten	"it did rain a lot this year, so I think that's made a difference in our berries, it's rotted a lot of them…mildew got to them" (Wanda Culp, Hoonah) Women like fatty meat, better for salting (Helen Clifton, Hartley Bay)

3.6.9 Intensity and temporality of harvest

As well as changes in animals and plants themselves, and their biogeographical distribution, peoples' intensity and temporality of harvest of these species has changed over time. Many people suggested they were taking fewer wild resources, and that harvesting was not being carried out as extensively or intensively by the younger generation. Interviewees attributed the phenomenon of lower harvests to a multiplicity of reasons. While climate change, and its unpredictable weather and fluctuating resources, is an important factor, patterns of resource harvest and use is also affected by social and technological change, competition, and scarcity due to other anthropogenic causes. Overall, however, in spite of these changes, and the changes in the weather, people generally felt important resources were still available in sufficient quantities, albeit often demanding more effort and inputs (e.g., petrol, time) to harvest. As well, at least some harvest survey data (Alaska Dept of Fish and Game Division of Subsistence 2019) suggest that harvests have not declined in all communities, and are either fluctuating, or even increasing in recent times. Although harvest levels and participation rates among younger generations are not captured separately in these data, it suggests that harvests can increase when resources are available to counteract the uncertainty of climate change (safer with larger boats, more money for fuel), and may potentially allow people to be more resilient in the face of climatic change.

Significantly, most of the observed impacts concerning animals referenced behaviour, abundance, and movement, while for plants, quality and quantity of berries and fruits tended to be discussed with relation to the weather. Plant distribution was also sometimes more closely attributed to landscape use (logging and land development) than weather changes.

3.6.10 Intensity and temporality of preparation

It was found that there was more variation in intensity and temporality in harvesting then in preparation, as going out to harvest is much more controlled by weather patterns and inclement weather then food preparation throughout the study area. However, as was seen above, the comparative lack of sun and excess of rain in particular did create challenges and limitations on food preparation, both with regards to drying foods (halibut, salmon and seaweed) and controlling flies and other (unidentified) insects (in chapter 5, salmon). The various adaptations that people have developed to adjust to changing weather and still preserve their food is further detailed in Chapter 7, Adaptation and Resilience.

3.7 Answers to Research Questions

The results of the data gathering on weather, landscape, and biodiversity changes in this chapter primarily answers sub-question 1. Sub-questions 2, 3, 4 and 5 are briefly touched upon with regards to non CKIS species that were mentioned. Overall, this chapter contributes to addressing the main overarching research question.

Sub-question 1 (Are Indigenous Peoples noticing changes in the weather and if so, what weather patterns (as indicative of climate changes) are happening?): This question can be answered with a definitive yes – people had noticed many large weather changes, such as decreased snow, increased rain, and storms being more frequent, intense, or unpredictable, as well as smaller changes, like definitions between seasons. These changes to the weather have also affected the landscape, resulting in less floating ice, more melting glaciers, sea level rise, and erosion, and biodiversity, in the appearance and disappearance of species, changes in resource abundance, distribution, and use, and biological hazards, threats, and diseases.

Sub-question 2 (Are observed weather changes affecting how people access, harvest and prepare resources in their territory?): This question is answered through the participants' observations of weather becoming more unpredictable and storms more frequent and/or intense. These weather patterns made it so that people couldn't always predict whether the weather would get stormy while they were out. As well, the weather was described as being 'more wild', so where they might in the past have been able to still harvest in a small storm, the storms are now too big and intense, or occur close together, to allow safe harvesting. Both of these observations will impact the duration and frequency of their harvesting trips, and thus the amount of food people can access and harvest. The observations regarding sun and rain amounts also impacted how people were able to prepare their resources, and their adaptations to overcome these obstacles were delineated for the CKIS examples and are thus described in those chapters, and in chapter 7.

Sub-question 3 (Which species (culturally and ecologically important and otherwise) were observed by people throughout this region to be experiencing change?): While this question was primarily answered in each of the CKIS chapters, this chapter did address it briefly, regarding other species that were discussed in addition to the CKIS examples. Multiple species had experienced changed migration patterns, including several species of birds, tropical fish, and moose, and a large number of species were observed to be either reducing/disappearing or appearing in the entire region.

Sub-question 4 (How do observed changes indicate broader shifts in biodiversity?): While this question was primarily answered in each of the CKIS chapters, this chapter did address it briefly, regarding other species that were discussed in addition to the CKIS examples. The disappearances, appearances, and range shifts of the specific species commented upon in this chapter all affect the overall biodiversity because as species composition shifts, there are changes in prey availability, habitat usages, and species interactions. For example, the presence of more small birds like starlings may prey more on native pollinators, thus effecting pollination.

Sub-question 5 (How can Traditional Ecological Knowledge and climate data be used in conjunction to present a comprehensive picture of local climate change effects and inform adaptive responses, including knowledge transmission between generations, and capability for resilience into the future?): This question is answered because TEK observations regarding shifts in weather, landscape, and biodiversity changes can all provide valuable insight to the ecosystems in this region, and contribute to how management policy makers manage future harvesting and managing of resources, particularly in an ecosystem based view to management and conservation.

3.8 Geographical trends

In this section, I analyse the weather, landscape, and biodiversity data into geographical trends, to explore if people were making the same type of observation in different sub-regions, or whether certain regions were experiencing different stressors, or observing different changes. In table 3.10 below, I have grouped the ethnographic data into main observations and sub-observations, along with the number of people that made that observation, in each region of my study. 13 observations were mentioned in all four regions:

- Warmer air temperature
- Decreased snow
- Increased rain
- Less sunny days, more overcast/rainy days
- Hotter and more intense sunshine when it occurs
- Storms more frequent and/or intense
- A gradual rate to climate changes
- Weather changed more in last 8-20 years
- Erosion cause by increased rainfall
- Species appearing
- Species disappearing
- Behaviour changes in non CKIS
- Increased red tide levels

Observations were fairly evenly split with almost the same number occurring in 1, 2, 3 and 4 communities, respectively, with 26% in only one region, 26% in two regions, 22% in three regions, and 26% in all four regions. The region with the most observations was NSE with ~45%. In this entire chapter the observation mentioned the most often were species appearing (33 appearing). However, I will go into the main regional trends for category of observations separately, because there is quite a large dataset and variety of type of observation and looking at it in smaller sections will better reveal inter-region variability.

For abiotic weather changes six of the 15 abiotic weather features were noted in all four communities, showing that there was a consensus on observed weather changes throughout the entire region. While there was variety on how hotter days affected people and ecosystems, and whether or not storms had actually become more unpredictable, overall, many participants agreed that there were warmer air temperature, decreased snow, increased rain, hotter and more intense sunshine, albeit on fewer sunny days overall, and storms were more frequent and/or intense.

The perception of rates and timescales of change, and how timings of seasons have changed was not as consistent in observations. The most common observation was that participants felt they couldn’t predict weather like they could in the past (13). Participants were split between observing that it was always a gradual rate of change, that it was slow at first and was now accelerating, and weather has changed more in the last 8-20 years (8 observations for each), although these observations were noted in at least three sub-regions, showing again some consistency across the region.

Changes in the landscape were largely split by region. Northern regions are primarily affected by isostatic rebound due to melting glaciers, with some effects of sea level rise, whereas southern communities are not affected by isostatic rebound at all, only by sea level rise. Exclusively in NSE, 14 participants noted that glaciers and floating ice are decreasing, and 13 participants noticed some effect of isostatic rebound on the land. Erosion causes and effects were seen in all four regions, with the primary cause being attributed to increased rainfall (11).

While the impacts on the CKIS examples by weather changes are fully described in the following chapters, a couple other species were mentioned as being impacted by the weather changes people were observing, particularly changed migration patterns in birds, tropical fish, and moose, and behaviour changes in whales (7 observations noted in all four regions). The observation that was the most widespread were appearances of species (33 observations, one or more species) closely followed by observations in reductions and disappearances of species (32 observations). Finally, biological hazards and threats were noted in all four regions with increasing red tide levels being the observation most noted (7) and in all four regions.

Table 3.10. Number of people making each observation of abiotic and biotic factors, divided into sub-region.

Main Observation	Sub Observation	NSE	SSE	HG	MBC	Total
3.2.1 Temperature	Warmer air	9	3	3	2	17
	Warmer water	2	1	0	0	3
3.2.2 Snow	Decreased	many	many	many	many	-
3.2.3 Rain	Increased	many	many	many	many	-
3.2.4 Sun	Less sunny days, more overcast/rainy days	4	1	5	3	13
	Hotter and more intense sunshine	9	3	6	2	20
	Burning plants and berries	1	0	1	0	2
	Burning people more now	0	0	2	0	2
	Burning people more in 1970s	0	0	1	0	1
	Hard to process food (without sun)	3	1	1	0	5
3.2.5 Storms and unpredictable weather	Storms more frequent and/or intense	2	2	6	1	11
	Unsure if storms have changed	0	1	1	1	3

	Weather more unpredictable	4	1	3	0	8
	Weather not unpredictable	0	1	1	0	2
	Weather always unpredictable	1	1	1	0	3
3.3.1 Rates and timescales of change	Gradual rate of change	3	3	1	1	8
	Slow rate at first, accelerating in recent years	5	2	1	0	8
	Weather changed more in last 8-20 years	3	1	3	1	8
	Weather changed more in last 30-40 years	0	2	2	0	4
	No storm-free stretches of weather to harvest	0	0	3	1	4
	Storms come up rapidly	1	0	0	0	1
	Cannot predict weather like in past	7	2	4	0	13
3.3.2. Timings and definitions of seasons	Fuzzier boundaries between seasons	1	0	1	0	2
3.4.1 Glaciers and floating ice	Decreasing	14	0	0	0	14
3.4.2 Isostatic rebound	Decreasing water depth	3	0	0	0	3
	Rocks appearing	3	0	0	0	3
	Higher shoreline	3	0	0	0	3
	Tides not coming as high up the shoreline	4	0	0	0	4
3.4.3 Sea level rise	Higher tide levels	5	0	7	2	14
	Can't access smokehouses close to water	0	0	0	1	1
	No changes to tide levels	2	0	1	1	4
3.4.4 Erosion	Caused by increased rainfall	2	3	5	1	11
	Caused by logging practices	1	0	4	0	5
	Harvesting locations impacted by erosion caused by rising tides	2	3	3	0	8
	Beaches eroding	1	0	3	0	4
	Roads and parts of villages washed away	0	1	7	0	8
	Cultural sites lost	0	1	1	1	3

3.6 Changes in resource abundance, distribution and use	Non-climate factors amplify climate change effects	2	1	0	0	3
	Changed migration patterns - birds	1	0	0	1	2
	Changed migration patterns - fish	1	5	1	0	7
	Changed migration - moose	17	0	0	0	17
	Species appearing	17	7	8	1	33
	Species disappearing	11	7	11	3	32
	Behaviour changes	2	1	3	1	7
3.6.5 Biological hazards and threats	Red tide levels increased	2	1	1	3	7
	Red tide levels unchanged	0	0	2	0	2
	Unknown disease killing off trees	2	0	0	0	2
	Bitter Crab Syndrome	1	0	0	0	1
	Shipworms changing distribution	0	1	0	0	1
	Totem poles rotting faster	0	0	1	0	1
Total Observations		151	56	104	27	338
Percentages		44.7%	16.6%	30.8%	8.0%	

3.9 Conclusion

In conclusion, it can be seen that that Tlingit, Haida, and Tsimshian Peoples are sensing changes and uncertainty about the climate, due to observed changes in the weather that are impacting their ability to harvest and preserve marine and terrestrial resources, the distribution and availability of these resources, and even people's confidence and ease in moving about their territory to hunt, fish, or gather, or visit other towns. For example, a mix of unpredictable weather (an access issue), and uncertainty in ripening (plant) and appearance (migratory species) times (a harvesting issue) have led to people having difficulties judging the best and safest time to harvest. People are less certain when to harvest anymore, as the timings are different from a generation ago. Consequently, they are having to expend more time, energy, and fuel checking the status of resources they may not be able to harvest yet, due to different maturation cycles and other ecological changes. Coupled with the uncertainty and increasing frequency of risky weather, and higher fuel costs, this can make harvesting less feasible. Beyond individual experiences, these risks and costs are also communicated amongst people, who may become more influenced by other peoples' experiences and thoughts about the impacts of changing weather conditions, and less reliant on their own observational skills and cost-benefit analyses than in the past. This means that people may be more swayed by tv and news weather reports for judging when to go out, rather than making their own decision based on their knowledge of how the environment reacts to pressures:

> "I think it's just more, we have radios, we got TVs, we got people, someone's always screaming oh it's going to blow 20, 30 miles an hour tomorrow, gusting a 100… and people hear that, before you never heard that… you know, you went by your own instincts, and you could read the clouds, and you know, the sky… and listen to the birds and animals and see what kind of reaction they got, that's you know, how they predicted weather before…now we depend on the radio, and news broadcasts, and weather things to find out what the weather is, so, you know, so, I think more, when somebody screams, you know, bad weather, I think everyone's going to get scared and hunker down and stay there" (Arnie Bellis, Old Massett)

While this uncertainty may make harvesting even more difficult, along with the other challenges described above, there is a convergence of opinion from a range of empirical observations over significant timescales and geographic locales, that many concrete impacts on communities are evident from changing weather patterns.

While this chapter presented a broad overview of the observations of changes in weather patterns, landscapes, and general biodiversity in the region, in the following three data chapters (chapters 4-6) I focus more on a suite of species identified through the interviews which illustrate my CKIS example. These species were identified in my interviews as being culturally and ecologically important, and impacted by weather changes, making them indicator species. Using these species takes us away from the whole ecosystem view to focus on what TEK of key species contributes to knowledge of management, harvesting, access, and use of species, while still understanding how these species fit into their ecosystems as a whole. In these each of these example species chapters, I will further explore how the changes described above influenced adaptation techniques, impact and change peoples' lives, the role of ceremonies and worldviews and how these cultural orientations can be used in management decisions, and the importance of bridging western science and TEK, as well as investigating how people see themselves continuing to adapt into the future in a resilient lifestyle.

Chapter 4 Sitka black-tailed Deer (Odocoileus hemionus sitkensis)

"depends on the weather, eh? If there's not much snow, then all the deer's' up in the mountains… not too many people want to climb…and if there's snow we can get it on the beach, just travel on a boat and get our deer…the snow plays an important part, you know, [if] we have lots of snow up in the hills, we are going to get our meat" (Wilbur Brown, Kake)

4.1 Introduction

Regardless of the varied impacts of Sitka black-tailed deer (*Odocoileus hemionus sitkensis*) on the ecosystems within the region, it cannot be denied that it is a key ecological, cultural, and indicator species throughout the study area. I will firstly describe its biological characteristics and then elucidate its keystone and indicator importance (including why they were picked as a CKIS and their EKS, CKS, and indicator status from the literature and interviews), before moving into a synthesis of the observations from the interview data bridged with western science literature, and finally a summary of how research questions were answered with this data and an analysis of regional trends.

4.1.1 Biological Profile

Sitka black-tailed deer (*Odocoileus hemionus sitkensis*) is one of several subspecies of the mule deer (*Odocoileus hermionus hermionus*) of Western North America, which endemically occurs along coastal areas in Northern British Columbia and Southeast Alaska (BC Ministry of the Environment 2000; Schoen and Kirchhoff 2007). Sitka black-tailed deer tend to be smaller than mule deer, with darker coats (BC Ministry of the Environment 2000), and average approximately 54kgs for bucks and 36kgs for does (Schoen and Kirchhoff 2007). They inhabit the coastal forest, ranging in an annual pattern from the beaches up to the high elevation meadows of the coastal mountains above the tree line, depending primarily on snow-pack depth, and availability and digestibility of browse (Schoen and Kirchhoff 2007).

According to Schoen and Kirchhoff (2007), the deer lifecycle and spatial distribution can be viewed in the following order: first, during the fawning time (late May-early June) deer live from sea level to ~450m in a more open landscape of 'open-canopy stands, fens, tidal meadows, and young clear-cuts', eating the new plant growth for the year. As the snows retreat higher up the mountains, the deer ranges increase in elevation until they reach the meadows at a subalpine level (end June-early July), where they have an abundance of easily digestible forage. As the temperatures drop and frosts start appearing (mid to late September), the deer stay in the mountains, but move down from the meadows into the more heavily wooded areas, and as the winter progresses and snow deepens, they continue to move lower in elevation. As the rutting season begins (late October), deer are again between sea level and ~450m, but focused on the old growth forests, which are invaluable for limiting the snow depth. The prime canopy cover offered by old growth forests will be partially revisited later in this chapter, but it primarily offers several advantages that contribute to deer wellbeing in the winter: camouflage from humans and predators, retention of body heat, keeping snow off of foraging plants for access, and less energy being expended when moving through the snow (Bunnell 1990). As winter progresses (December-March) deer move slightly lower, to below 300m, staying in old growth forests, and then as the spring melts begin deer move slowly upward to their fawning distribution. The nuances of deer diets will be revisited later, when Adam Greenwald of Hoonah discusses deer die-offs in relation to diet and severe winters.

4.1.2 Ecological Keystone Species (EKS)

The ecological impact of deer on the landscape varies widely within the study region. On some of the larger islands (e.g., Admiralty, Chichagof, Baranof, Kupreanof, Kuiu, and Prince of Wales) and the Alaskan and British Columbian mainland, deer had always been present (according to oral histories) and thus the ecological systems was in relative equilibrium between vegetation and herbivores. However, numerous human-assisted transplantations have occurred in many regions in Alaska. Sometimes this was a result of glacial forelands having recently (last 100 years, since 1916) become exposed, creating more habitat for deer and allowing transplants to flourish (de Laguna 1972), or repopulating because of a population crash (Paul 2009). In addition, on the Alaskan islands, deer are now having to share their range with moose (*Alces alces*), a recently arrived species from the Alaskan mainland, now well established on islands such as Kupreanof and Chichagof. Moose sometimes compete with deer for resources, which could impact both vegetation and deer populations.

Unlike in other communities in the study region, however, I found a different situation on Haida Gwaii. Deer were introduced to the Massett area of Graham Island in the late 1800s (starting in the 1870s, Gillingham 2004) primarily as a hunting source for European inhabitants (Baltzinger *et al*. 2009; Gillingham 2004; Reimchen *et al*. 2003; Stroh *et al*. 2008). After several initial introductions, deer spread out over the archipelago and have increased dramatically in population, and this has led to a decimation of vegetation. Deer density is estimated to be much higher than on the mainland, approximately 13 deer/km^2 (Baltzinger *et al*. 2009; Stroh *et al*. 2008).

Due to their seasonal use of different ecosystems, landscape impacts, and role in the food chain, Sitka black-tailed deer are an important EKS. When they are removed from the system, the floral architecture and diversity, the processing of minerals such as nitrogen, and the local soil make-up (Cobb 2014) will often change. Deer are a highly sought-after prey item for humans and other large predators, including wolves, black bear, and brown bear (Schoen and Kirchhoff 2007). In fact, 90% of total faecal samples of wolves on Prince of Wales Island had deer as a component, and 45% were solely comprised of deer (Gillingham 2004). Bear diets have not been studied in the same way as wolf diets, but as there are limited wolves on Haida Gwaii, bears may play a larger role in deer predation (Gillingham 2004) and may emulate the predator pressure wolves exert in other locales, although Paul (2009) argues that bear predation does not limit the deer population enough to reduce intense population increases, which in turn can lead to overpopulation and a crash in numbers. Less predation pressure may also account for the high populations seen on Haida Gwaii and the resulting decimation of vegetation.

4.1.3 Cultural Keystone Species (CKS)

Deer are highly utilized by humans, as evidenced by harvest data from the Community Subsistence Information System (CSIS) (see section 2.5) in Alaska (Alaska Dept of Fish and Game Division of Subsistence 2019) including the communities of Craig, Hoonah, Hydaburg, Kake, Ketchikan, and Klawock. Deer harvest numbers have fluctuated in all Alaskan communities where deer harvest was reported (Table 4.1), however some trends in this fluctuation can be seen. In 1996 and 1997 when a reduction in logging pressure occurred, every community except Hydaburg saw the highest number of deer hunted in the dataset. This is likely due to an explosion of understory growth taking over the clear-cut areas when logging occurs, and these young clear-cuts being utilised by deer for this abundance of available forage, leading to a population explosion in deer as well.

However, while there are short-term benefits to clear-cut areas and the abundance of available forage for deer, these areas are best utilised in low snow years as the canopy does not provide shelter from heavier snow falls (Farmer and Kirchhoff 2007; Hanley 1993; Schoen and Kirchhoff 2007; USDA Forest Service 1997). As these second growth forests age, conifers slowly dominate, and it was suggested that within 30 years the forests were at the lowest value to deer as the understory vegetation has been shaded out, but the canopy is not tall nor robust enough to protect the deer from snow (Schoen and Kirchhoff 2007; USDA

Forest Service 1997). Another issue with the forage provided in clear-cut areas is that this abundant forage may not translate into prime habitat for deer, as deer 'foraging efficiency' is more strongly related to plant size and quality rather than plant density or biomass. Lower quality forage is not ideal for milk producing females, nor surviving harsh winters, and deer appear to have a preference for forest grown plants, in contrast to clear cut grown ones (Schoen and Kirchhoff 2007).

As mentioned in the biological profile, deer highly utilize old growth forests partially due to the quality and digestibility of forage, and partially due to its ability to shelter them from deep snows. While logged areas may provide some benefit in terms of forage, in order to have resilience to survive winters with heavy snowfall and mitigate the impacts of these 'extreme weather events', it will be vital to maintain some tracts of old growth so that deer populations can readily access forage and be protected from deep snowfalls (Farmer and Kirchhoff 2007; Hanley 1993; Schoen and Kirchhoff 1985, 1990, 2007).

The impact of the types of habitat available has been examined in the 'Deer Capability Model', most recently re-framed by Schoen and Kirchhoff (2007) from the model originally designed by Suring *et al*. (1992) and used extensively throughout the 1997 Tongass Land Management Plan (USDA Forest Service 1997). The most productive habitat overall for deer is 'high volume old growth', defined as having a timber volume average of 35,000 board feet per acre, with a canopy cover of 65-95% (USDA Forest Service 1997) due to high levels of snow interception and even though it only has a moderate amount of understory, it is of a higher quality than other habitats. The second highly utilized habitat was recent clear-cuts due to the abundant forage that is found in them from the opening of the canopy, however this landscape is only able to be utilized in months or years with low snow. These habitats have been evaluated based on their significance to deer in the winter season, using various characteristics (Schoen and Kirchhoff 2007; USDA Forest Service 1997).

As evidenced throughout this chapter, deer populations fluctuate in response to changes in weather (such as heavy snowfalls) or landscape change (such as loss of old growth forests) and thus the number of deer harvested in each year might be influenced by these population fluctuations. However, in table 4.1 it can be seen that the percentage of hunters has stayed relatively similar, around 50% of the population, for most of the years for which harvest data has been collected in each community. In Hoonah, Hydaburg, and Kake, the latest harvest record is an increase from the previous one, with the first two communities interestingly not tied to a year with decreased logging (causing a population explosion resulting in higher hunter numbers because deer are easier to hunt). This indicates that this species is not only a key resource in the past, but into the present as well.

Table 4.1. Deer harvest numbers from communities and years where recorded by CSIS.

Community	Year	Harvest (individuals)	% household harvesting	Rank in importance of resources	Logging Activities
Craig	1999	743	40.7%	only resource monitored	
	1997	963	46.8%	2nd (after salmon)	Reduction in Logging
	1987	600	51.5%	2nd (after salmon)	
Hoonah	2016	560	55.4%	5th (after herring roe, salmon, berries, halibut)	
	2012	470	47.5%	3rd (after salmon, halibut)	
	1996	829	55.8%	2nd (after salmon)	Reduction in Logging
	1987	786	65.0%	2nd (after salmon)	
	1985	584	52.0%	2nd (after salmon)	
Hydaburg	2012	283	52.1%	3rd (after salmon, halibut)	
	1997	175	33.3%	5th (after salmon, marine inverts, halibut, shrimp)	Reduction in Logging
	1987	203	37.2%	3rd (after salmon, marine inverts)	
Kake	1996	464	49.3%	2nd (after salmon)	Reduction in Logging
	1987	310	41.9%	2nd (after salmon)	
	1985	208	38.6%	4th (after salmon, halibut, vegetation)	
Ketchikan	1999	760	6.9%	only resource monitored	

Klawock	1999	475	47.8%	only resource monitored	
	1997	503	43.4%	2nd (after salmon)	Reduction in Logging
	1987	445	51.8%	2nd (after salmon)	
	1984	204	55.0%	2nd (after salmon)	

Notes: This table also includes the importance rank of deer in the total harvest for each year, as well the years that coincide with a reduction of logging activities from the intensive harvests between the early 1980s and the 1990s in the Tongass National Forest and ANCSA corporation lands.% of households harvesting in each year is also presented, showing amount of population harvesting and thus importance in community over time (green highlight indicates increase between first and last year recorded, and red indicates decrease). Rank in importance of resources indicates at what rank deer are at in harvesting important, and in brackets are listed the resources that are harvested more (then deer). In almost all cases, the only resource harvested more than deer were salmon, showing how important they are. Harvests were not recorded in every community in every year, hence the gaps.

Another impact on deer from the recent occurrences of moose spreading to the islands, in addition to the ecological impact on both deer and vegetation, is that moose can create another food source for people to harvest, and potentially alter the number of deer being harvested and thus its cultural importance. In the harvest record, moose were harvested by inhabitants in all Alaskan communities except Hydaburg, as early as 1985 (Hoonah), 1987 (Craig and Klawock), and 1996 (Kake). The 1997 records had the highest moose harvest, varying between 3 and 11 moose a year (Table 4.2). Due to low numbers of moose on the islands, especially Chichagof, it is likely that many of the recorded intakes in these communities could refer to people going to the mainland to hunt and bringing it back to their community, particularly hunters going to Gustavus which is located in Hoonah traditional territory (Thornton, pers comm). In interviews, people have described that moose were appearing on islands where they didn't occur before, including Chichagof and Kupreanof Islands, as moose are considered a mainland species[40]. This observation was also reported by Woodford (2015), although biologists note that while moose are present, they are not surviving on the islands for extended periods. It was suggested by both participants in this study and Woodford (2015) that moose were swimming over from Gustavus.

[40] A9 (Juneau), A11 (Kake), Ernestine Hanlon Abel (Hoonah); Wilbur Brown (Kake),Wanda Culp (Hoonah), George Davis (Juneau), Lori Kay Guinard (Hoonah), Adam Greenwald (Hoonah), Joel Jackson (Kake), Michael Jackson (Kake), Evans Kadake (Kake), Marvin Kadake (Kake)

Table 4.2. Moose harvest numbers from communities and years where recorded by CSIS.

Community	Year	Harvest (individuals)
Craig	1997	4
	1987	4
Hoonah	2012	0
	1996	11
	1987	0
	1985	8
Hydaburg	2012	0
	1997	0
	1987	0
Kake	1996	3
	1987	0
	1985	0
Klawock	1997	9
	1987	3
	1984	0

Another way of recognising the cultural importance of a species to an Indigenous group is to is to examine its role in the language, and the number of terms that appear relating to anatomy, life stages, and other resource characteristics (Turner 1988). The three Indigenous groups in this study, the Tlingit, Haida, and Tsimshian, all have their own languages, and it is this data which has been explored here to examine linguistic importance. To link this CKIS example to the linguistics literature I reviewed dictionaries for names for deer in each language (Table 4.3).

The language references (Anderson 2018; DeVries 2014a; DeVries 2014b; Edwards 2009; Lachler 2010; Roberts 2009) were searched for additional terms relating to this CKIS example (such as body parts, harvesting techniques, processing, etc). For deer there were a large number of terms found relating to the species and its use, indicating a high cultural significance, not just for harvesting, but in the social fabric more generally (Turner 1988). Deer had terms in all three languages that related to hunting and movement, life stages, anatomy, processing and preparing skin and meat, and diseases. The vocabulary revealed speaks not only to the keystone status of these species but also provides descriptions of environmental impacts such as diseases.

Table 4.3. CKIS names from the three languages throughout study area.

English name	Scientific name	Tlingit name	Tsimshian name	Alaskan Haida name	Old Massett Haida name	Skidegate Haida name
Deer	*O. hermionus sitkensis*	G̲uwakaan[1]	wan[2]; wa̲n[2]	k'áad[3]	k'aad[4]	k'aad[5]

[1] - Thornton 2008; [2] - Anderson 2018; [3] - Lachler 2010; [4] - DeVries 2014b; [5] - DeVries 2014

4.1.4 Indicator Species

Sitka black-tailed deer prefer to live in a mixed habitat throughout the year, because of their specific use of different habitats. Their general presence and movements between landscapes throughout the year indicate the quality of old growth forests, open younger forests, forest edges and floral diversity, as deer have a varied diet of herbaceous and woody plants, characterised by consistent features such as digestibility (Hanley 1996; Lee and Rudd 2003; Schoen and Kirchhoff 2007). Biologists (cf. Hanley 1996) consider deer an indicator species on the basis of the following characteristics: they have large home ranges which they migrate throughout in a seasonal pattern; they make use of different habitat types seasonally, including varied food sources and canopy cover options; and they are valued by local people, primarily as a food source, which makes them 'socially relevant' (Hanley 1996). Deer particularly indicate when undisturbed habitat is lost (Lee and Rudd 2003), because undisturbed habitat is essential to their forage and movement requirements, so if the habitat doesn't meet this requirement, they move elsewhere. Deer are also an indicator species from a management point of view. As discussed in Chapter 1, The United States Forest Service have identified deer as a MIS, which shows the high importance this species is held in, not only by local peoples (as seen in the rest of this chapter through the interviews) but also by the government as an indicator species.

People reported that many changes regarding the ecology and ethnoecology of deer could be tied back to the influence of climatic changes, although there was some discussion of how deer usage was also connected to the idea of social climate change described by Ken Grant (in Chapter 7). Beyond simply being a resource for subsistence harvesting, deer were also said to be an indicator of weather changes. Snow was reported to be the biggest abiotic weather factor affecting deer, primarily regarding their movements and access to food to sustain them, leading to population shifts. Warming air temperatures were identified as the leading cause of snow depth variation, resulting in differing amounts of browse being available, as well as increased occurrences of fleas and ticks. People also discussed changes to the timings of seasonal weather as related to timings of harvesting, quality of meat, and disease incidences, leading to variation in usage over a temporal scale, and linked to governmental rules and regulations around harvesting. These impacts, and the variation seen throughout the study region through influence in weather patterns, will be further delineated below.

4.1.5 Deer as a Cultural Keystone Indicator Species

Wilbur Brown's quote at the start of this chapter recognised the linkage between deer and weather, and how spatial distribution of deer is strongly indicative of weather patterns. This, alongside the background research and interview data in this chapter about deer being a key cultural resource, and ecological component, demonstrates that deer are a prime example of a cultural keystone, ecological keystone, and indicator species, and plays an important role in the biogeographical and cultural landscape, making it an excellent CKIS for analysis of climatic change.

4.2 Methodology

Interviews were conducted with 96 participants in Southeastern Alaska and Northern British Columbia. Participants were identified using a snowball methodology, which builds the data sample through referrals, and interviews were organised in a semi-structured format. The full methodology is described Chapter 2.

4.3 Results: Ethnoecological data

In this research, Sitka black-tailed deer were mentioned in approximately 90% of the interviews, regarding observations of population and distribution change, health of animals, and usage patterns and was demonstrated to be an important food for people throughout the entire region of study. As two of my participants stated, 'everybody harvested deer, because it sustained…our families all winter' (Michael Jackson, Kake) and 'deer, that was a big thing [that fed us all] when I was little' (Fanny Nelson, Metlakatla). Not only was it an important food source in the past, but up to present times as well. It is still used in feasts, potlatches, and lunches in senior centres, and in peoples' private homes. In fact, deer was so important that it was transplanted by Natives to places where it was not endemic, such as Glacier Bay National Park's Willoughby Island (G. Mills, pers comm to Thomas Thornton 1990), and the transplantations described above. Data from interviews is presented in depth in the following sections, and the key findings summarised in Table 4.7 below.

4.3.1 Population change

Deer population numbers are known to fluctuate significantly year to year in response to the weather patterns (Harper 2013; Schoen and Kirchhoff 2007), and these population patterns were also described through the interview observations. Overall, almost all interviewees noted population fluctuation, however, also commented that numbers generally appeared to be lessening. It was interesting to note that there was no significant geographical trend to the increases or decreases seen in the study area. The main exception to this trend includes Haida Gwaii, where deer have been intensively introduced and have few predators, and thus are greatly expanding their populations (discussed in section 4.3.2). Additionally, there were three people in Hoonah (Adam Greenwald, Ester Greenwald, Lori Kay Guinard) that mentioned that there had been an increase noted in number of offspring, primarily in reference to the occurrence of twins – "we're seeing a lot of twins in the does" (Lori Kay Guinard, Hoonah). Adam Greenwald (Hoonah) ties this observation to a recovery response from a bad winter: "the big ones survive and go on to reproduce more next year…instead of one fawn, most of them will have two fawns, you know, once in a while you'll see three, that's pretty rare, but you see a lot of doubles, two fawns, if they have a winter where they die off, the next year, two fawns".

However, in terms of overall population direction, and not yearly fluctuations, there were geographical difference in observations. Because deer primarily inhabit forested areas and often form scattered small groups, it is hard to gain accurate counts and population estimates (Gillingham 2004), not only through local knowledge systems, which do not conduct formal population assessments, but also from formal governmental surveys (Harper 2013). Governmental monitoring often uses hunting data, road-kill numbers, and sightings of deer to estimate populations (Gillingham 2004). The issues around the uncertainty estimating population numbers, and their influence on government hunting regulations (bag limits and seasons) was an important theme in interviews:

> "they [the state biologists] can't tell you, they fly over, and they count deer, well, you fly over an area and tell me how many deer you actually see…and they tell you, well, you can't hunt this area because we only seen ten deer, but you can hunt this area, because we [saw] 20 deer…well, you might have seen 20 deer out on the beach, but what about those 400 that's in the trees there that you didn't see" (Lori Kay Guinard, Hoonah)

4.3.1.1 No population change

Eight people, primarily from NSE (Hoonah, Kake (2)) and SSE (Craig, Hydaburg, Klawock), but also in HG (Old Massett (2)) did not note a direction of population change, and thus seemed to suggest that populations were relatively stable in numbers from the past until now, with only slight yearly variations due to weather[41]. This data indicates that there is no significant population change trend over a longer timescale than year to year. While they thought that deer populations had stayed the same over time, there was disagreement if the deer had always been abundant or had always been sparse. People also noted that population numbers were copious, and it was only the ease of finding them differed, for example: "there's also quite a few deer…I think there's still a lot of deer, you know, we just go up the road here, and we see them on the side of the road" (Michael Jackson, Kake), while others mentioned that deer were around but scarce to find - "they pretty much are, you know, they're there, but…you know, you really got to hunt for them" (Joel Jackson, Kake). The fact that both these comments were made by brothers, living in the same community, suggests that, while deer populations appear relatively unchanged, they may be harder to track, and the observed availability can greatly depend on an individual's interaction time with deer or accessible deer habitat, such as that afforded by roads.

Reg Davidson and Jack Litrell, both from Old Massett on Haida Gwaii, commented that the weather was not affecting the abundance of deer on the island, as they were already so abundant - "it does not seem to be affecting the deer here that much, you know, because mostly, there's [so] much deer here" (Reg Davidson, Old Massett). The dynamics between deer and the environment on Haida Gwaii is further discussed in section 4.3.6.1.

4.3.1.2 Population increase

Four people in NSE (Kake), SSE (Hydaburg, Klawock), and HG (Old Massett) noted increases in deer populations, which was mostly tied to warmer weather[42]. This was described to be occurring due to two reasons. Firstly, populations were recovering after rarely

[41] Anthony Christianson (Hydaburg), Reg Davidson (Old Massett), Ken Grant (Hoonah), Cora Joseph (Klawock), Joel Jackson (Kake), Michael Jackson (Kake), Jack Litrell (Old Massett), Myrna Yates (Craig)
[42] Arnie Bellis (Old Massett), Anthony Christianson (Hydaburg), Mary Guthrie (Klawock), Marvin Kadake (Kake)

seen severe winters and heavy snows, such as the winters during the 1960s, 2006-2008, and 2013-2014 described in interviews, which often caused mass die offs further explained below (section 4.3.1.4). From the weather graphs from Climate Explorer, it was not possible to look at the scientific numbers behind the observations for these three snowy periods, as the stations closest to the communities of Hydaburg, Kake, Klawock and Old Massett were either missing snow depth/fall data for the years of interest, or there were no stations at all (Hydaburg), but ADFG reports (Harper 2013) were able to be used to place these extreme snow falls into the scientific literature as well. There was some data during these missing snow data years regarding precipitation and temperature from Climate Explorer for this area, which under closer examination could be combined to be a proxy for snow fall, as more moisture in the air can fall as snow if the temperature is cold enough, and lead to extreme snow fall years (explained in Chapter 3). However, when looking just after these cold periods on the temperature graph for warmer temperatures that might led to population increases, unfortunately almost all the time periods and stations were either missing data or showed no temperature, except for Old Massett after 2014, which was recorded as having warmer temperatures. Regarding increases, Mary Guthrie (Klawock) stated: "no more snow…more deer than I've ever seen, actually the deer are eating around on the roads, they did not used to do that…there's a lot of roadkill laying on the side of the road, because people are bumping them with their cars, and ruining their cars…that did not used to be." Marvin Kadake (Kake) referred to the fluctuation, but ultimate increase, of deer as follows: "deer are often…it depends on the winter…yeah, the winter before, we had a severe winter [2013-14], now, the latest report, the deer are coming back again…so it's off and on you know". Secondly, a general warming trend from a reduction of snow levels (as described in Chapter 3) and warmer air were leading to more available forage and higher survival rates, which for deer meant populations were increasing: "well, with the warming trend, a lot of things have been benefiting, I mean the land animals, they sure like it when they don't get a deep winter…and several feet of snow, I mean the survival rate of deer and other game is high…most of the land species seem to be doing well…I mean everything has a little more opportunity to grow a little longer" (Anthony Christianson, Hydaburg).

4.3.1.3 Population decrease

Twelve people, primarily from NSE (Hoonah (3), Kake (4)), but also in HG (Old Massett, Skidegate) and MBC (Hartley Bay, Metlakatla) referred to either a decrease in population numbers, or deer moving further away from villages, and thus reducing the huntable population close at hand (further discussed in section 4.3.2)[43]. While land use changes, especially logging, were seen as playing a part in these changes, here I focus on participants' observations of climatic changes on the landscape, noting cases where logging was said to exacerbate these climatic effects, rather than the direct impact of logging[44]. Weather effects were seen as a major constraint on deer populations and forcing deer to move away from close proximity to communities, which previously allowed easy access. Wilbur Brown's (Kake) comment was typical: It [the weather] "killed off our deer…it's coming back [the deer], but…we used to be able to just get on the boat and go a little way and get our limit and come home…we cannot do that anymore…I know here people drive out the road for months [i.e., repeatedly] …trying to find a deer". The statement about driving for 'months' explains the effort involved when people have to drive out multiple times to find a deer, which has a large impact on people harvesting because of time and monetary expenditures.

[43] A9 (Juneau), A11 (Kake), Catherine Bolton (Hoonah), Donald Bolton (Hoonah), Wilbur Brown (Kake), Helen Clifton (Hartley Bay), Sherri Dick (Old Massett), Captain Gold (Skidegate), Owen James (Hoonah), Evans Kadake (Kake), Robert Nelson (Metlakatla), Emily Watts (Old Massett)

[44] The management plans produced every two years by ADFG discuss deer population changes, including their response to clearcutting (new vegetation growth for positive food choices and lack of shelter from deep snows for negatives), and as the opening matures (how the forest structure changes as the vegetation grows back, and less forbs and shrubs are available from browse) (ADFG 2014).

Robbie Nelson (Metlakatla) also noted that “I know deer’s gone, I [haven’t] seen [any] deer from around our community probably for the last 3 or 4 years”, indicating deer are making use of habitat further away from human habitation, again pointing to the effort involved in hunting.

4.3.1.4 Massive die-offs

In addition to these decreases and movements away from villages, seven people, exclusively in NSE (primarily in Hoonah (6), but also Kake) specifically mentioned that deer had experienced massive die-offs[45] (Table 4.4).

Table 4.4. Comparison of deer die-off dates from interview data and climate data from Hoonah and Kake.

Year	1960s	2006-2008
Community	Kake	Hoonah
Scientific observation	No climate data	large snowfalls, 1250-1350mm avg
Interview observation	Deep snow, cannot drink frozen water, go to beach, eat kelp, die	Deer died due to deep snow, found frozen on beach

In Kake, Wilbur Brown thought an extreme snow event in the 1960s had caused a die off - “that was back in the 60s I think…a lot of snow…deer will die if there’s 5, 6 feet of snow and the waters frozen, they cannot drink water…they cannot get their food…they’ll go down to the beach when there’s a lot of snow…and live on kelp and stuff, but…they’ll die off real fast”. In Climate Explorer, Kake’s snow depth graphs were missing data for this time period, so a direct comparison with oral sources was not possible, but deep snows were reported in Game Management Unit (GMU) 3 (which includes Kake) by the Alaska Department of Fish and Game (Harper 2013) in the late 1960s-early 1970s.

[45] A12 (Hoonah), Catherine Bolton (Hoonah), Donald Bolton (Hoonah), Wilbur Brown (Kake), Wanda Culp (Hoonah), Adam Greenwald (Hoonah), Lori Kay Guinard (Hoonah)

In Hoonah, an extreme snow event was described in six interviews from ~2006-2008 that caused so many deer to die due to deep snows and starvation that populations were still trying to recover during 2014 when the interviews were conducted, leading to some management schemes further described in section 4.4.2.1[46]. In fact, the Alaska Department of Fish and Game (Harper 2013) reported severe winters in 2006-2007 and 2007-2008 with large snowfalls in GMU 4 (which includes Hoonah), which places the descriptions in the interviews into the scientific data as well. Climate Explorer data also supported the observations of there being lots of snow in Hoonah during 2006-2008, measuring depths of 1250-1350mm despite only being a normal year in terms of average snow fall amounts (approximately 300mm/day). The snow depth is likely deeper due to the temperature being quite cold (-12°C to -14°C, the coldest winters since 1980), which would lead to more snow being retained, and thus not melting off. Some of the interview descriptions of this deer die-off was that some deer were even found "frozen on [the] beach, facing [the] water" (Catherine Bolton, Donald Bolton, both Hoonah), and Adam Greenwald (Hoonah) gave a very detailed account of this starvation incident in these years:

> "Adam: oh! Well, it fluctuates quite a bit, but…I do not think you have the winter kill like you used to have…there was times when it was pathetic, you get this deep snow, and then big tides, and it was sorta sad, you go…out to Flynn Cove, or any of the bays, you go in there, and then the low tide, and the deer, they come out of the woods and they'll have one trail, they'll build a trail, and, at the low tide mark would be 30, 40, 50 deer, down there eating kelp…and then when the tide comes in, they get paralyzed, their hind legs, and…here they are pulling themselves out, dragging their hind legs behind them like this, so when you get up to the high tide mark, the snow is, just a wall of snow, because the tide comes up, the snow falls off…and so they cannot get up over the snow, and here they are in the high tide, the water washing up on them, and the poor things iced all over and freezing, and they just lay there then die
> Victoria: this is a long time ago?
> Adam: oh, not too long ago, there was a few, but you do not see it much now
> Victoria: why did they get paralyzed?
> Adam: I do not know, there must be something in the kelp…whether it's iodine in the kelp, or just what it is, but it paralyzes them

[46] A12 (Hoonah), Catherine Bolton (Hoonah), Donald Bolton (Hoonah), Wanda Culp (Hoonah), Adam Greenwald (Hoonah), Lori Kay Guinard (Hoonah)

Adam also demonstrated the interconnections between deer and their chosen food sources, perceptively noting the sensitivity of deer to different forage types and their willingness in stressful conditions to consume forage that is ‘toxic’ to them due to the bacterial make-up of their digestive system:

> Adam: you can kill a deer, and we killed quite a few of them, by feeding them cabbage, or lettuce, or something like that…they, [have] not got the digestive juices like we have, they got to acquire a bacteria, that dissolves the cabbage leaves, without that bacteria, you feed them cabbage, they are not used to eating cabbage…and they’ll just lay there and die, and…
> Ester: and bloat too…it causes them to bloat quite often
> Adam: oh yeah, bloat like crazy…poor things…if you want to go in the woods and chop off some hemlock boughs, and go and feed them, that’s fine…and the Department of Fish and Game did not realise that in Alaska, ‘til one year, they got talking…shipping in a bunch of alfalfa, bales of alfalfa, fly along with a helicopter over these bays that the deer were dying off on the beach, so they dropped this alfalfa, and the deer’s ate the alfalfa, and it killed them…the next year there was hardly any, in the areas where they bombed it with alfalfa, there was hardly any deer left, it took 4 or 5 years before they finally built up a crop of deer again…and it was during this period that they discovered that they, give them any other food than what they have acquired the germ, the bacteria for, you killed them, so they are better off not feeding them anything…unless they send out guys to chop a tree down, fall a tree, and the deer’s can eat off that tree…they are used to eating hemlock boughs…so they do not do much feeding anymore, because [of that] factor, people, a lot of people say you got too many trees falling down, you’re falling too many trees, and then others say you better start falling trees, cause the deer are dying off, you know…so you got the two arguing against each other, and, so they do not do it hardly at all anymore
> Victoria: yeah…so when did they stop feeding the animals?
> Adam: well, it depends on the deep snow
> Victoria: oh ok…so a while ago they would feed it if it was very cold that winter
> Adam: yeah
> Victoria: but now they realise that it’s not good
> Adam: right, they do not do it anymore

Adam Greenwald’s observation regarding the forage sensitivity of deer is corroborated by the scientific literature. For example, Henderson *et al*. (2015) found that while there is some overlap between bacterial groups in all samples they looked at worldwide (over 700 samples), diet was a key factor in the abundance of many bacteria species in each ruminant species, because ‘physical and chemical characteristics of the feed determine the different microbial niches available" (Henderson *et al*. 2015). Applegate and Gray (1995) describe that populations of coastal ruminants may find it difficult to meet their complete nutritional needs in the wintertime, as there may be a decrease in appropriate food. They showed that seaweed is not the most nutritious feed, but that it has higher digestibility and protein content than other feed, and thus deer may make use of marine flora. This may explain why deer were found frozen near the beach in Hoonah (Catherine Bolton, Adam Greenwald) – perhaps they were trying to find forage. Numerous reports illustrating the concept of supplemental feeding, and the dangers in doing this have been published in recent years (Dougherty 2013; Maine Department of Inland Fisheries and Wildlife n.d.). Very similar to Adam's story, when there are heavy snowfalls and browse are covered, people are tempted to bring out other foods like hay, corn, cabbage, and lettuce. However due to gut flora biodiversity being tied to diet (Henderson *et al*. 2015), when deer change feed, they need several weeks to adjust to the new food source and can die of malnutrition in the meantime (Maine Department of Inland Fisheries and Wildlife n.d.), as was also noted by Adam Greenwald with the deer starving to death despite supplemental feeding. Adam also recognised that deer could adjust to a new diet if it was introduced gradually:

> "like I say, if you took them and gave them one leaf of cabbage, and the next day give them two leaves, they make it…they acquire the bacteria they need to dissolve the food, but we give them a big head of cabbage you know, and it kills them, so…but we do not get those types of winters much anymore, we get some that the little winter kills, but it's usually the fawns or the young ones, you know, that die, but the big ones survive and go on to reproduce more next year."

In the above paragraph and quotes, it can be clearly seen how extreme and sudden weather changes can cause devastating effects in the modification of a deer's diet, and their ability to forage, leading to die offs.

In addition, creating supplementary feeding 'stations' also causes other problems. They can encourage deer to stay close, perhaps preventing them from finding a suitable and nutritious winter browse habitat, make them dependent on humans, and by increasing density, encourage diseases (Maine Department of Inland Fisheries and Wildlife n.d.). While predation was a high cause of death, even greater was starvation (Farmer *et al*. 2006) due to deer being unable to find adequate overwintering habitat and being constrained to eat food to which they were not adapted. It was found that if people wanted to help the deer, the best thing to do, as Adam suggested, was to fell branches of native shrubs, berries, and conifers so that the deer could eat them (Maine Department of Inland Fisheries and Wildlife n.d.). Despite there being greater deaths in this situation, Adam's comment also discusses that since fawns will die at a greater rate than the adults who will continue to reproduce, it can be deduced that populations may not be as greatly affected in the longer term.

Overall, particularly through the die-off events, it can be seen that population change is strongly linked to weather patterns, particularly extreme snowfalls causing a temporary decrease in deer, though as seen in the self-management section below (section 4.4.2.1), when hunting pressure is released populations tend to recover quickly. Less snow in recent times and warming weather patterns facilitate growth of vegetation for deer browse thus increasing the amount of food available and increasing populations[47]. The effects of clearcutting on deer were not mentioned in the interviews except as a vector to increase (temporarily) the amount of berry growth, which will indirectly provide more forage, and may increase deer populations[48], but also as the forest fills in, decrease the amount of browse available. From both of these situations, potentially, the larger populations occurring from more forage may be more vulnerable to bigger die-offs when high snow fall events occur, which are further exacerbated by lack of cover in clear-cuts (Harper 2013).

[47] although there are other environmental factors, such as logging which increase browse and populations too, but often only in the short run.
[48] as noted in interviews and further expanded in Chapter 6, berries

4.3.2 Spatial distribution and behavioural change

In addition to the snow impacting population levels as seen above, the way deer travel around their landscape and their distribution patterns are also impacted by weather, particularly snowfall, which was commented upon in the interviews in both NSE (Kake) and HG (Skidegate). If there is not much snow in the mountains, the deer will escape from more heavily human populated areas, occasionally due to logging (A3, Skidegate), but if there are heavy snow falls, they will come down to lower elevations (Wilbur Brown, Kake; A3, Skidegate) which makes them easier to hunt: "we'll wait until a little bit of snow up on the mountains bring the deer down…so…that too depends on the weather, eh? If there's not much snow, then all the deer [are] up in the mountains… and if there's snow we can get it [deer] on the beach, just travel on a boat and get our deer…get our limit…yup, it depends on the weather" (Wilbur Brown, Kake). Sometimes, people (all in NSE, Kake)[49] said deer would even escape onto the beach during the heaviest snowfalls: "they can't get their food…they'll go down to the beach when there's a lot of snow…and live on kelp and stuff, but…they'll die off real fast" (Wilbur Brown, Kake). The observations of deer coming down to the beach were recorded in Kake and Hoonah. This behaviour is consistent with that described by deer biologists in terms of what causes deer to go looking for browse in old growth forests during heavy snows, and how they change their behaviour to take advantage of different habitats to find food (Schoen and Kirchhoff 2007).

Another land use change noted in interviews was that clear-cut logging was creating mudslides especially in steep areas where root structure is needed to bind the soil, making deer move to find browse (Lori Kay Guinard, Hoonah). However, when mudslides do occur, deer often appear to like the openness of the habitat and the new browse that flourishes within it, similar to the descriptions by Marlene Johnson (Juneau) of deer liking the

[49] Catherine Bolton (Hoonah), Donald Bolton (Hoonah), Wilbur Brown (Kake), Adam Greenwald (Hoonah)

prevalence of new browse on cleared roadsides. These observations are consistent with scientific studies of deer that show where on the landscape deer are situated, and what forage they have access to, is crucial to cushioning the impact of winters with heavy snowfall. While cleared areas provide the tender browse needed by deer for maximum nutrient absorption, cleared areas are susceptible to heavy snowfalls, and not suitable for deer to live in all seasons (Harper 2013; Schoen and Kirchhoff 2007).

One of the most interesting things about deer in this PNW region, however, refers to its introduction to Haida Gwaii (Margaret Edgars (Old Massett), Captain Gold (Skidegate)) in the 1870's to provide meat for local people (Gillingham 2004; Reimchen *et al*. 2003) - "those are introduced species, we never used to have deer here" (Margaret Edgars, Old Massett). It has been described in the literature (Paul 2009) that deer were introduced to areas even in Alaska, however this introduction has had the most long-term impact on Haida Gwaii. While initially this may have seemed like a good idea at the time, an unintended consequence of this action is that deer have drastically over-browsed in this area, the impact of which is further discussed in section 4.3.6.1, over-browsing.

4.3.3 Timing of harvest

Timing of harvest was discussed in two ways. Firstly, six people from NSE (Juneau (3)), SSE (Klawock), MBC (Metlakatla), and HG (Old Massett) commented on the appropriate time to harvest deer within the seasonal cycle[50]. George and Agnes Davis (Juneau), and Fanny Nelson (Metlakatla) all mentioned that deer were hunted during rutting time, as well as Harold Martin (Juneau) commenting on seasons "just like the deer, I never bother them in the spring, it's late fall and winter…well, late fall mostly, and wintertime they

[50] Agnes Davis (Juneau), George Davis (Juneau), Reg Davidson (Old Massett), Mary Guthrie (Klawock), Harold Martin (Juneau), Fanny Nelson (Metlakatla)

are already pregnant…so we… don't [hunt]". Reggie Davidson (Old Massett) noted that "when the alder leaves fall, I was told, you go hunt for them, for the deer". These harvest timings are also linked to when the quality of the meat appears to be higher because of the fat content (see section 4.3.4). However, Mary Guthrie (Klawock) stated that she felt that people could "have deer any time of the year we want". While the government delineates the hunting season, Mary Guthrie does hit on a good point – that it is slightly arbitrary that you have a deer hunting season at all, as apart from self-management, deer are able to be hunted year-round. Indigenous hunters often self-regulated to avoid hunting when does were with fawns or before deer had put on winter fat, which again would delay hunting until the fawns had grown – both of which have to do with not interfering in the reproductive cycle. Additionally, hunters self-regulated when population crashed, often in response to heavy snows.

The second way timing of harvest was examined was by discussing how it matches to legal restrictions. These observations were only made in NSE (Kake, Hoonah)[51], so it was overall more limited geographically than the previous harvesting discussion. Likely due to deer responding to a changing climate, there was now a mismatch between the deer being ready to harvest, and the regulated opening: "the season opened a little later than it does now, they open it way too early now" (Adam Greenwald, Hoonah). Wilbur Brown (Kake) explained the link between deer harvesting and amounts, and timings of snow:

> "Yeah, people will say why…wait until the snow, the openings are the same, but the timing to go hunting is different, we have to depend on the snow…to get our fill of 6 deer…and, usually, when the snow flies we get a couple feet of snow, everybody will end up…the weather's calm, everybody [will] rush out…and…sometimes we have snow in… October, late October…November, sometimes we don't have snow in December, you know, Christmas time, when we had snow [before], was, yeah…it's very different…and sometimes it is here in November…and…sometimes [not] until late December or early January we'll have snow".

[51] Wilbur Brown (Kake), Adam Greenwald (Hoonah)

Since snow will drive deer lower in elevation, it is more desirable to hunt after the deer have come down the mountain, so the early season, starting before the snow, would mean people are having to harvest further away, at higher elevations, and use more effort. As well, the lower amount of fat, and thus lower quality of meat discussed in section 4.3.4 can be tied to the mismatch with regulations – because people have to adhere to legal restrictions, which are not adjusted along with weather changes, deer are not at an optimum harvesting stage. Currently, according to ADFG (Alaska Dept of Fish and Game 2019g) hunting regulations, the seasons in Game Management Units that include the communities in Northern and Southern Alaska aren't open past mid-late December. While people didn't specifically suggest alternate harvest dates to change the policy, with the snow fall not occurring until later in the autumn (November-January, as described by Wilbur Brown (Kake)), this perhaps suggests they are not able to make as much use of the season in the months of August to October as they did in the past.

4.3.4 Quality of meat

One reason to harvest the deer at certain times, as described in section 4.3.3, is that the quality of the meat varies throughout the year, according to deer's diets. Five people in NSE (Hoonah, Juneau (2)), SSE (Klawock), and MBC (Hartley Bay), discussed the relationship of meat taste to timing of the kill[52]. George and Agnes Davis (Juneau) felt that the deer harvested in Kake tasted better than the ones from Yakutat due to diet, and Ernestine Kato (Klawock) noticed that even though the deer had been "eating a lot of the plants I notice, but the deer are skinny…a couple of the ones I've seen on the road, they are constantly eating…but they never gain any weight". Both Adam Greenwald (Hoonah) and

[52] Helen Clifton (Hartley Bay), Agnes Davis (Juneau), George Davis (Juneau), Adam Greenwald (Hoonah), Ernestine Kato (Klawock)

Helen Clifton (Hartley Bay) isolated that higher quality meat was indicated by the fattiness of the meat, and thus was a good trait to show you have meat that will be good for salting and preserving: “the season opened a little later than it does now, they open it way too early now…and…they haven’t even put on their fat, you know or anything…they let it go for another month or two, the deer get a lot fatter…we used to go up the mountain, and when you get up in the alpine up there, you’re up in big buck country you know” (Adam Greenwald, Hoonah). The observations of fattiness correlate with Schoen and Kirchhoff’s (2007) findings that deer attain peak fat content and weight in September and October, and this is likely the reasoning behind the official ADFG season opening the season between August and September. However, if deer are modifying their fat accumulation responses to the changing climate to be later in the year, perhaps this has not been picked up by the scientific reports yet, and thus there are no recommendations for modifying the hunting season dates. Reg Davidson (Old Massett) further delimited an indicator of harvest, saying that deer were preferentially harvested ‘when the alder leaves fall’, after a summer of putting on weight.

4.3.5 Diseases

The spread and impact of disease can be affected by climate change, but not very many diseases were identified in deer populations in this study, and diseases and parasites were only briefly mentioned by interviewees living in Hoonah, Juneau, and Old Massett. Catherine and Don Bolton (Hoonah) felt that warmer temperatures would result in more ticks and fleas, but only had definite knowledge of new ticks appearing. Brucellosis, a disease initially commonly found in reindeer, was mentioned by one elder (Jacque Martin, Juneau). She thought her husband, Harold Martin (Juneau), had killed a seal with symptoms, although in his interview he did not specify which disease he thought he had seen: “we’ve been noticing more disease in harbour seals [*Phoca vitulina*]” (Harold Martin, Juneau). Brucellosis is not currently a major concern for either marine or terrestrial mammals in this region but may need monitoring in the future. While I could not find any literature linking a prevalence of brucellosis to temperature change, in terrestrial environments it was thought to increase in frequency with higher densities of animals, such as that found around supplemental feeding programs (Godfroid 2002) in deer[53]. To date, humans are not thought to be affected by marine brucellosis, but polar bears have been known to express antibodies, without actually manifesting the disease, and thus it may be passed to humans in the future (Godfroid 2002).

4.3.6 Non-climatic factors

While deer are highly impacted by non-climatic factors, such as logging and food sources changing, these are tightly woven into how they are able to adapt to weather changes, rather than impacting the species independently of this. The main issue that was raised in the interview that was not directly tied to climate was the issue of over-browsing.

4.3.6.1 Over-browsing

Over-browsing was mentioned as an issue only on Haida Gwaii. Because deer populations are not held in check by predation by wolves and cougars, competition with other herbivores, and relatively low hunting demands, they have rapidly multiplied and a major effect of that on Haida Gwaii is the over-browsing of the native vegetation, sometimes even decimating species or areas (Baltzinger *et al*. 2009). While they are still an important food source on the island, there are compounding issues where deer are over browsing native and/or rare vegetation leading to loss of biodiversity, illustrated in the last entry in Table 4.7

[53] While brucellosis has been known to be in seals and other marine mammals in California and Scotland (species *Brucellosis pinnipediae* and *B. cetaceae*), and in moose (*B. suis* biovar 4) from the Northwest Territories in Canada, and in northern Alaska (transferred from reindeer in the arctic region of Alaska) (Godfroid 2002), there have not been any reports to date from the waters and land in the nearshore coastal environment in northern British Columbia or Alaska region. In marine environments, it is still unknown how brucellosis may be transferred, or what may cause it to increase (Godfroid 2002).

below, and showing a negative effect of this species. Six people exclusively in HG (Old Massett (5), Skidegate) mentioned in particular that crabapple shoots and saplings, and huckleberry, blueberry, and salmonberry shoots were being eaten. Jack Litrell (Old Massett) commented that he hunted to keep populations in check: "so, when I hunt, [I'm] trying to restore the balance here [talking about hunting the deer that eat the berries]". In addition, high bush cranberry (*Viburnum edule*) has been almost wiped out by grazing[54]. Only a handful of individuals were known to still be growing on Haida Gwaii in the wild: "they [high-bush cranberry, *Viburnum edule*] used to be common around here…it's getting extinct because of the deer browsing…I was working on the land use planning at one time…and we investigated, we looked and looked and looked all over for high bush cranberries, and nobody seen them around for a long time…there's a couple guys that know where there's some, but…it used to be plentiful…but not anymore" (Margaret Edgars (Old Massett)) and Leo Gagnon (Old Massett) commented that the deer were moving out of the forest and depleting the plant life as they were eating everything.

Jack Litrell (Old Massett) noted how excluding deer from certain areas might be beneficial for biodiversity and floral preservation:

> "I have a fenced area that had some old fruit trees, I put in there, that got ignored for too long… it's like a deer exclosure…that scientists build and study, well, I have one, it was built in the 70s, and the deer have never been in there, and it's just like, incredibly dramatic…if you look at this side of the fence, and it's like ferns, sword ferns on this side, huckleberries, salmonberries that are 10 feet high, that I can't get rid of… other plants, foamflower I think it's called…and then on the right side of the fence it's just brown and grey, there's almost nothing, there's like elderberry and some little things, cleavers or something, some little thing, crawling".

To this end, there have been several scientific experiments in creating deer enclosures to see if browsing can be controlled, and they have come to the conclusion that biodiversity

[54] A6 (Old Massett), Diane Brown (Skidegate), Margaret Edgars (Old Massett), Leo Gagnon (Old Massett), Jack Litrell (Old Massett), Emily Watts (Old Massett)

and biomass could in fact be increased when deer were excluded from an area (Baltzinger *et al*. 2009; Stroh *et al*. 2008).

These observations do not tie directly to impacts of climate change, but loss of biodiversity and biomass may exacerbate the inability of local flora to rebound from the additional effects of climate changes. While fencing is not feasible on an island-wide scale on Haida Gwaii, perhaps in areas of particular interest, or of ecological/cultural importance, some exclosures may have to be employed to conserve other CKIS in this area.

It is worth noting that in this study area, the evidence for the inclusion of deer as a culturally important species, and thus an example of CKIS, is not as strong in Old Massett and Skidegate, Haida Gwaii, as it is in the other communities in this research area. The main reasons why the evidence for this is weaker is because the deer are an introduced species on Haida Gwaii (Gillingham 2004) and are considered pests by many people, particularly due to their devastation of the local flora through over browsing (which was frequently mentioned in interviews from this study). Despite being an invasive species however, some people have come to rely on deer as an important source of meat, and in interviews noted significant behavioural, phenological and population observations. As May Russ (Old Massett) commented, “but, you know…on one hand people want to get rid of them, because they’re not indigenous to the island, and then on the other hand, there are people…it’s becoming a food source for them”. Thus, over time, deer may continue to rise to full CKIS status in Haida Gwaii and become highly valued, although it is not currently as strong a CKIS example as it is in the communities in Alaska and mainland British Columbia.

4.4 Adaptations

Adaptation was expressed in several ways through the interviews. Firstly, people mentioned how harvesting had changed over time, which was tied to both changes in the weather and changes in land development. For harvesting being affected by weather, this has been touched upon in earlier sections, regarding deer movement in response to deep snows, how governmental regulations may not be adjusting harvest seasons to correlate to these changes in the deer population, and regarding optimum time for quality of meat. In addition, it was also discussed that the road network has facilitated harvesting. When the snow is lighter and the deer are higher in elevation, the road network was used by hunters, as well as using boats and hunting from the beach in heavier snows (see the beginning of section 4.3.2).

Secondly, people discussed how the weather impacted processing of food and the adaptations they had made. Elders in NSE (Juneau (2))) and SSE (Hydaburg) described relying heavily on the use of freezers to preserve in the modern day[55], and Wanda Culp (Hoonah) delineated a few specific adaptations in response to drying deer in an unfavourable climate: "You gotta get creative (laughing), oh man, it depends, like some people have a furnace room that's nice and warm, and provides that consistent warmth, so that area would become used, rather than the sun…[or] woodstoves…you see racks, hanging over woodstoves…to dry deer or fish". It was also mentioned in the widely separated regions of NSE (Hoonah) and HG (Old Massett) that people would rather go to large grocery stores rather than eat their traditional food (Adam Greenwald (Hoonah), A6 (Old Massett)), but trade between people harvesting was still considered an important practice: "I do a lot of trading myself, cause I can go get beach asparagus, or at least I was able to this year, and I can pick berries, and so I make a lot of jam, and jarred beach asparagus, and so I trade with the hunters for deer meat" (Merle Nancy Hawkins, Ketchikan).

[55] Agnes Davis (Juneau), George Davis (Juneau), Charles Nakong (Hydaburg)

4.4.1 Respect and Ceremonies

Ceremonies and respectful practices associated with deer were mentioned by ten people, located primarily in NSE (Hoonah (2), Kake (3), Juneau (3)), but also in SSE (Craig) and HG (Skidegate)[56]. While ceremonies and respectful practices were not said to be directly impacted by climate change, they illustrate the cultural importance of deer and that population change impacted by climate change will also affect cultural knowledge and practices in relation to this key species.

First off, people mentioned that they used all parts of the deer and didn't waste any[57]: "there was very little waste for the natural resources, like with the deer, you get almost everything, of course you eat the liver and the heart, and even the stomachs, cleaned it all off" (Fred Hamilton, Craig), and that you would only take what you need (A3, Skidegate). Secondly, people were expected to respect the deer throughout the process of hunting and butchering, in order to renew the lifecycle, or as phrased by one person: "[we] show respect to get more" (A9, Juneau). Harold Martin (Juneau) described talking to the deer with great respect to "send it back to the spirit world", and Joel Jackson, A9, and Wilbur Brown (all three from Kake) commented on the specific tradition of cutting off the deer head and leaving that in woods as a mark of respect and means of renewal, to encourage a continuing deer harvest. Joel Jackson (Kake) explained: "When we go after deer, we usually cut the head off, and we'll set it, you know, we're not trophy hunters, so we cut the head off and leave it…and we usually try and leave it some place out of sight…put it some place where you know, it's far away, you don't just discard it…just showing respect to it, you know…you killed it, it's providing food for you". In the interviews, I asked several questions that addressed

[56] A3 (Skidegate), A9 (Juneau), A11 (Kake), A13 (Juneau), Wilbur Brown (Kake), Adam Greenwald (Hoonah), Lori Kay Guinard (Hoonah), Fred Hamilton (Craig), Joel Jackson (Kake), Harold Martin (Juneau)

[57] A13 (Juneau), Wilbur Brown (Kake), Lori Kay Guinard (Hoonah), Fred Hamilton (Craig)

knowledge around how resources were taken care of, and what prescriptions, prohibitions, ceremonies, and protocol were in place for harvesting and care of resources. However, people often did not directly answer this question, and those that did address it, focused primarily on the importance of respect for the environment and resources. It can be seen in these responses that even though respectful behaviour and its consequences (and conversely people recognised in general the consequences of disrespect potentially bringing bad luck) was engrained in people's worldviews and outlooks on hunting practices, they didn't specifically state the mechanics behind these observations. Not everyone mentions worldviews and cosmological features for several reasons, such as conversion to Christianity in the past, having their potluck culture outlawed, and disconnection from generational knowledge sharing. However, the fact that some people did discuss the respect and protocol mentioned above, seeming to imply that a deer's spirit would inhabit other deer and that the respect from these protocols would encourage more deer to come in to be hunted, shows that even if this view is not easily expressed, people did incorporate it deeper into their mindset and view of the world.

Thirdly, A11 (Kake) commented that she had been taught not to harvest does, as they have "a chance of having more, can have more deer from this one female, [so] we'll leave it". Finally, Adam Greenwald (Hoonah) described the place deer have in the worldview of the Tlingit, in this case talking about his son carving a totem pole, and how the symbols on the totem represent how teaching and passing on knowledge to people about respect helps you to provide for yourself and your family. While not described in this research, de Laguna (1972) discusses deer as a symbol of peace, and its role in peace making ceremonies.

4.4.2 Management

Because deer are living higher in the mountains due to a lessening amount of snow, hunting may require more effort than the preferred methods of beach or lowland hunting, and thus people are changing hunting practices in response to environmental change. However, primarily in NSE (Hoonah (2), Kake), but also in SSE community of Klawock, interviewees noted that it was much easier to travel into the mountains to hunt today than in the past because of the access provided by the network of logging roads[58] - "In the old days you had to hike, and pack your deer out [and now they can go on the logging roads]" (Ken Grant, Hoonah), and "nowadays, they jump in the car and they go hunting, they drive back and forth on the road…that's hunting" (Adam Greenwald, Hoonah). So, while deer may be in places traditionally considered more inaccessible due to lessening amounts of snow in the mountains, logging road developments assist the hunters to reach more distant upland and higher-elevation deer. As people spend more time and energy searching for resources and going farther away, two people, both in NSE (Kake), mentioned that it is expensive to hunt on the roads (Wilbur Brown, Joel Jackson) – "I know here people drive out the road for months…trying to find a deer…[and it's a lot of money to do that] about $6 a gallon for gas" (Wilbur Brown). The weather also affects the need to harvest deer on other islands than the ones the interviewees came from. For example, both A11 (Kake) and A9 (Juneau), with observations again from NSE, discussed the need to travel to other islands to get deer: "we had to go across, there are no deer on the islands, so we had to go [north] to Admiralty [across Frederick Sound] on a boat" (A9, Juneau)). As was seen in chapter 3, stormy weather is becoming more frequent and much less predictable, which will impact people harvesting from boats. People cannot always cross bays and sounds to go hunting - as Sherri Dick said: "we don't really harvest in stormy weather". This means people have to judge the weather

[58] Ken Grant (Hoonah), Adam Greenwald (Hoonah), Harriet Williams (Kake), Mary Guthrie (Klawock)

carefully, and sometimes will not be able to harvest meat. Another factor on local hunters, which is not climatically controlled, is the overharvesting by 'outside hunters''. Three interviewees, primarily in HG (Old Massett (2)), but also in NSE (Hoonah), mentioned that not only were non-local hunters leaving with a lot of meat, but they are also unsafe in their hunting techniques[59]. People were frustrated by this as they saw their valuable meat leaving their traditional territories, and also felt the outside hunters increased the risks involved in hunting as some of them engaged in reckless behaviours, Wanda Culp (Hoonah) simply stated of this subgroup: "it's unsafe, they're idiots".

4.4.2.1 Self-management initiatives

When deer populations crashed, as described in section 4.3.1.4, six people, exclusively in NSE (mostly in Hoonah (5), but also Kake), commented that local hunters adjusted their hunting quotas independently of the state regulations of harvest limits, creating self-managed hunting limits until conditions improved and populations stabilized[60] – Donald Bolton (Hoonah) said that Hoonah People voluntarily stopped hunting to let the population recover - giving up hunting deer completely for two years, after which they resumed taking males, and then a year later resumed taking females. Wilbur Brown (Kake) stated that "we're allowed to hunt, but only take one deer or one buck, that's it…and people are really careful, you know, they're not out there just killing them". Charles Jack (Hoonah) was not convinced that The Department of Fish and Game was managing deer well and thought that local people should be consulted more – for example, he said that local people would say not to shoot pregnant does, but Fish and Game did not care if you did. While ADFG do allow does to be hunted at certain times of year and in certain locations, they also alter their management

[59] Wanda Culp (Hoonah), A2 (Old Massett), Sherri Dick (Old Massett)
[60] Catherine Bolton (Hoonah), Donald Bolton (Hoonah), Adam Greenwald (Hoonah), Ester Greenwald (Hoonah), Charles Jack (Hoonah), Wilbur Brown (Kake)

recommendations season to season depending on what their population data and models tell them. These changes can include not allowing the harvest of does, shortening the season (or closing it altogether, such as from 1975-1979), or lessening the number or type (only antlered) of deer to be harvested (Alaska Dept of Fish and Game 2019g).

4.4.2.1 Governmental management issues

Similar to people deciding to manage harvests themselves because Fish and Game were not providing adequate support, five people, primarily in NSE (Hoonah (3), Kake) but also in HG (Old Massett), also felt that they were more limited in the quantity they could harvest thanks to the government regulations and were unhappy with the ways that the rules were implemented, or the changes they felt were coming[61]. Lionel Bean (Kake) mentioned that "if I went out hunting now and got a deer, I'd be in jail for about 2 or 3 years" and Lori Kay Guinard (Hoonah) expressed frustration that when the Department of Fish and Game fly over and count the deer, they underestimate, often missing deer hidden in the trees, and then do not open the season because they claim there are not enough, whereas if they asked the local people, they could give them a more accurate representation, as seen in her quote above. Charles Jack (Hoonah) summed up well the differences between the harvesting rules in the past and present, and its current consequences:

> "a lot of the rules that they make is not that way, like the deer season, it's really, I can't stand it, no deer season, it opens up in August, don't close until January, sometime in January, when I was a young person growing up, it opened up the day after Labour Day…closed the 11th of November, and you were allowed 4 deer, 1 doe, or 4 bucks if you can't get a doe…and you can't take a buck with a horn less then 3 inches long…now, that's all gone, if they'd kept that, that part of it, it would have been ok…cause what happened when they did away with the antler-less deer, the, even the babies were being shot, you know…and then the season from…November on is not fair because you're shooting two for one, because you open the doe season too, so you're shooting the doe, and the doe is pregnant, so you're shooting two for one…so once you get that far you need to leave it alone so that the does can go on and

[61] Lionel Bean (Kake), Reg Davidson (Old Massett), Donald Bolton (Hoonah), Lori Kay Guinard (Hoonah), Charles Jack (Hoonah)

> bring their babies along…but you can't tell that to the Fish and Game, because they are the experts you know".

Charles Jack's (Hoonah) comment also speaks to the need to be responsive to environmental change, especially at the local landscape level, which perhaps governmental bodies are unable to do, or to respond as quickly as local people would like. This theme was expanded upon in section 4.3.3 looking at how the timing of harvesting may have changed, but the government regulations have not kept up to date.

4.5 Answers to Research Questions

The results of CKIS data gathering on deer in this chapter specifically answers sub-questions 2, 3, 4 and 5, and further contributes to addressing the main overarching research question.

Sub-question 2 (Are observed weather changes affecting how people access, harvest and prepare resources in their territory?): This question is answered because it was seen that the weather observations regarding snow presences and amount impacted the access and harvest of deer. Snow had impacted how people were able to access deer, because in deep snow years, deer are further away from villages, either in the mountains or beaches, while in light snow years they are closer to the villages. This affected how much people were able to harvest and how they harvested.

Sub-question 3 (Which species (culturally and ecologically important and otherwise) were observed by people throughout this region to be experiencing change?): This question is answered because through interviews, deer were identified as a species which was culturally important, and was experiencing change in several biometric parameters, such as population, distribution, harvest timing, and diseases. Throughout further background investigation into this species, it was found that in addition to being cultural keystone species, and weather indicator species, they are also ecological keystone species, making them good CKIS examples.

Sub-question 4 (How do observed changes indicate broader shifts in biodiversity?): This question is answered because the way deer move around the landscape in response to weather changes, namely snow levels, also demonstrates shifts in land usage and habitat variation, such as indicating a move from old growth to logged areas, or the recovery of logged areas to secondary growth, and the resulting biodiversity changes.

Sub-question 5 (How can Traditional Ecological Knowledge and climate data be used in conjunction to present a comprehensive picture of local climate change effects and inform adaptive responses, including knowledge transmission between generations, and capability for resilience into the future?): This question is answered because TEK observations regarding deer population shifts, both in distribution and numbers, along with longer term climate predictions in the region, can be vital information for management policy makers to manage future harvesting regulations. As well, the adaptations of local self-management schemes that people described in this research can be important for increasing their capacity for resilience into the future and respond to influence of climatic change on it, sustaining harvesting so that future generations understand how to use this resource.

4.6 Geographical trends

In this section, I analyse the CKIS results according to geographical trends, to explore if people were making the same type of observation in different sub-regions, or whether certain sub-regions were experiencing different stressors, or observing different changes. In table 4.5 below, I have grouped the ethnographic data into main observations and sub-observations, along with the number of people that made that observation, in each sub-region of my study. The only observation that was made in all four regions was about people's uncertainty in knowing when to harvest, and the observation with the highest number of people mentioning it overall was that deer populations were decreasing (11 observations). Just over half of the observations were noted in two or more regions (~58%), but by far the highest number of observations in total were noted in the NSE communities (including Hoonah, Kake and Juneau), ~56% of the observations. Since more participants in both NSE and HG were interviewed (~35% of the total participants in each region), it was expected that one or both of those would be a higher percentage of observations, but NSE having over 56% of observations is significantly more than expected.

Table 4.5. Number of people making each observation of changes influencing deer populations, divided into sub-region.

Main Observation	Sub Observation	NSE	SSE	HG	MBC	Total
4.3.1 Population Change	No Change	3	3	2	0	8
	Population increase	1	2	1	0	4
	Population decrease	7	0	2	2	11
	Die off	7	0	0	0	7
4.3.2 Spatial Distribution and Behaviour Change	Escaping snowfall	4	0	1	0	5
	Mudslides increasing	2	0	0	0	2
	Introduction to new area	0	0	2	0	2
4.3.3 Timing of Harvest	When to harvest	3	1	1	1	6
	Matched to legal restrictions	2	0	0	0	2
4.3.4 Quality of meat	Deer taste better with some fat on them	3	1	0	1	5
4.3.5 Diseases	More ticks, fleas, and other diseases	3	0	1	0	4
4.3.6 Non-Climatic factors	Over-browsing	0	0	6	0	6
Total Observations		35	7	16	4	62
Percentages		56.5%	11.3%	25.8%	6.5%	

I have also summarised the observations people made about how they had adapted to climatic and biodiversity changes, and other topics such as reciprocity, management, and hunting (Table 4.6). Again, most observations were made in two or three communities (70%), although this time no observations were made in all four regions. Overall, the observation that was reported by the most people was protocols around reciprocity, including various forms of respect and ceremonies (10). Surprisingly, there were no observations about adaptations in the MBC region, and the number of observations were heavily skewed towards NSE participants (almost 92% of observations). 12 observations were made regarding how people had adapted. People had changed their hunting techniques, including where they hunted and how they got there. For example, people either hunted on the beach, from boats, or used the road systems to get higher in the mountains to hunt deer that were moving further away from communities. People had also changed their processing techniques, so that they froze meat, or dried with more human assistance, like furnace rooms, rather than drying using the sun. Finally, people also described that they still traded amongst themselves, but were buying more at stores rather than relying as much on hunting. Participants in NSE also seemed to be more vocal about management decisions, potentially contributing to seeing more overall observations from NSE.

Table 4.6. Number of people making each observation of adaptation, reciprocity and management, divided into sub-region.

Main Observation	Sub Observation	NSE	SSE	HG	MBC	Total
4.4 Adaptations	Change in hunting techniques	4	0	1	0	5
	Change in processing techniques	3	1	0	0	4
	Buying more at stores	1	1	1	0	3
4.4.1 Respect and Ceremonies		8	1	1	0	10
4.4.2 Management and hunting	Easier to hunt (logging roads)	3	1	0	0	4
	More expensive	2	0	0	0	2
	Going to other Islands to hunt	2	0	0	0	2
	Outside hunters – unsafe and leaving meat	1	0	1	0	2
	Self-management	6	0	0	0	6

	Less harvest available then desired	4	0	1	0	5
Total Observations		34	1	2	0	37
Percentages		91.9%	2.7%	5.4%	0%	

4.7 Conclusions

It can be seen from the above that deer are important cultural and ecological keystone species, and that they are heavily influenced by weather changes, making them prime indicator species, because their distribution and population levels are influenced by the abiotic climate factor of snowfall levels. Amount of snowfall was the most important climate variable, with both their ability to access forage and travel around the landscape being reduced by periodic heavy snowfalls, leading to population decreases. Further reducing their capacity to utilise the landscape, plus leading to a decrease in population numbers, were non-climate variables such as logging old growth forests and increased rain causing mudslides. While initially there is a greater amount of forage from the openness, overall, the lower quality and lack of snow interception of this habitat makes them more susceptible to population reductions in response to higher snowfall. Explosions in forage may also lead to explosions in deer numbers which in turn have a negative cascade of effects in the ecosystem, including over browsing vegetation and ultimately also leading to deer decreasing again, in a boom-and-bust cycle.

Additionally, some participants felt that regulations had not adjusted to weather changes to allow for appropriate harvesting periods, and in addition to governmental regulations, they had also implemented self-regulating measures when hunters recognised the need to avoid overharvesting after observing drastic population decreases. It was seen from the harvest data that this is still a highly used species – in fact in almost all communities in almost all years, deer was the second most harvested resource in estimated weight (after salmon), even in communities on Haida Gwaii, where they were introduced more recently but have risen to being prominently used – and are thus vital for continuing traditional practices into the future. Drawing on their traditional knowledge, coupled with preserving existing old growth forests to increase this species' resiliency to adapting to climate changes, will allow it to continue as a key resource into the future.

In this chapter, I examined a terrestrial animal species for how they illustrated my CKIS example. In the next chapter, I use a marine animal species to demonstrate the CKIS concept.

Table 4.7. Table of observations relating to deer.

Type of Observation	Changes seen	Impacts	Responses	Quotes
Population change	➢ increased amount of food ➢ die off, starve and dehydration from extreme snows and ice ➢ found frozen on beach (Hoonah, Kathy and Don Bolton, Adam Greenwald)	➢ wolves have easy access to carcasses ➢ had to buy more meat in store ➢ not getting as much deer as used to	➢ Hoonah People gave up hunting males for 2 years, females for 3 years	"with the warming trend, a lot of things have been benefitting, I mean the land animals, they sure like it when they don't get a deep winter…and several feet of snow, I mean the survival rate of deer and other game is high" (Anthony Christianson, Hydaburg) "and that was because of, a lot of snow, cold…deer will die if there's 5, 6 feet of snow and the waters frozen, they can't drink water" (Wilbur Brown, Kake)
Geographical and behaviour change	➢ Lack of snow, deer living in higher elevation mountains ➢ Deer moving further away from human development and up mountains (less inhibited with less snowfall), harder to hunt	➢ harder for people to harvest	➢ travel and hunt from boats ➢ sometimes wait for a bit of snow to drive deer down in elevation	"depends on the weather, eh? If there's not much snow, then all the deer's' up in the mountains… not too many people want to climb…and if there's snow we can get it on the beach, just travel on a boat and get our deer" (Wilbur Brown, Kake) "the snow plays an important part, you know, we have lots of snow up in the hills, we are going to get our meat" (Wilbur Brown, Kake)
Hunting practices	➢ When use boats to hunt, sometimes too stormy to go out	➢ Can't get meat	➢ Have to wait for the weather to calm down	"we don't really harvest in stormy weather" (Sherri Dick, Old Massett)
Timing of Harvest	➢ harvest indicators are out of sync	➢ can't use proxy measure to know when to get deer	➢ may miss window of hunting	"like with the alders, when the alder leaves fall, I was told, you go hunt for them, for the deer" (Reg Davidson, Old Massett)

Quality of meat	➢ leaner with lack of food ➢ earlier hunting seasons, indicate deer haven't put on fat	➢ lower quality meat	➢ people don't want to harvest poor quality meat ➢ less deer eaten	Women like fatty meat, better for salting (Helen Clifton, Hartley Bay) "the season opened a little later than it does now, they open it way too early now…they haven't even put on their fat, you know or anything…[if] they let it go for another month or two, the deer's get a lot fatter" (Adam Greenwald, Hoonah)
Diseases	➢ Increased levels of ticks and fleas due to warmer temperatures ➢ DDT sprayed by loggers (illegally)	➢ meat not healthy/contaminated	➢ hunt less/can't use meat	New ticks have appeared, and think ticks and fleas will increase when warmer (Catherine Bolton, Donald Bolton, both Hoonah)
Over browsing	➢ Native and rare vegetation disappearing, eaten	➢ Some plant populations can't recover	➢ Studies done looking at deer exclusions (Haida Gwaii)	"deer has a lot to do with some of the [lack of berry] harvesting, like they eat a lot of the plants, the huckleberry bushes, the salal bushes" (Margaret Edgars, Old Massett)
Ceremonies and Respect	➢ Bury head in woods after shooting ➢ don't shoot all the deer ➢ don't throw carcass on beach	➢ lack of respect alienates animals, leading to declines, if respect and use all resources, will get more deer in future	➢ people think they should remember ceremonies	"When we go after deer, we usually cut the head off, and we'll set it, you know, we're not trophy hunters, so, you know, so we cut the head off and leave it…and we usually try and leave it some place out of sight…put it some place were you, you know, it's far away, you don't just discard it…just showing respect to it, you know…you killed it, it's providing food for you (Joel Jackson, Kake)

Chapter 5 Pacific Salmon (Onchorynchus spp.)

"when they go coho fishing…the river has a different smell up there, when …the dying salmon…there in the river, and we'll see the skeletons of salmon, rotting salmon, to go up the stream is just to watch…the cycle of life, and then when the salmon come back, and they are jumping out, in the river, and you'll hear the people holler to the salmon, they'll say, ***ay-oh***! ***ay-oh***! You'll hear them, wonder what, and so here it's just, they're so happy the salmon are back, and it's a greeting to the salmon, I'm glad you're back, I'm glad you're here…and so you'll hear that ***ay-oh***! And they just stand, it's just like you are blessed, it's an extension of yourself and the salmon coming back, and to see the life cycle up there." (Helen Clifton, Hartley Bay)

5.1 Introduction

Due to similarities in the ecological and cultural roles between salmon species, I am grouping all the Pacific Salmon species into one functional group for the CKIS example in this chapter. The salmon species included in this functional group are: *Onchorynchus gorbuscha* (pink/humpy), *O. keta* (chum/dog), *O. kisutch* (coho/silver), *O. nerka* (sockeye/red) and *O. tshawytscha* (chinook/king/spring). I will first address the biological and ecological characteristics of each species individually, and then elucidate their keystone and indicator importance as an entire functional group, including why they were picked as a focus functional group, and their EKS, CKS, and Indicator status from the literature and interviews, before moving into a synthesis of the observations from the interview data bridged with western science literature, and finally a summary of how research questions were answered with this data and an analysis of regional trends.

5.1.1 Biological Profile[62]

All five species of salmon follow the same generalised lifecycle, and species-specific characteristics are listed in table 5.1. Salmon return to their natal streams between spring and autumn to spawn (depending on the species and run), where the females will dig nests, called redds, into the gravel to deposit several thousand eggs to be fertilised by the male. The adult salmon die when they have spawned out. The eggs then hatch in the late winter or early spring after having incubated for several months and the hatchlings (called alevins) stay under the gravel for several days to several months, feeding off their yolk sac. These alevins then emerge from the gravel as fry, and live in estuaries, lakes, and rivers, feeding off a variety of riverine and estuarine insects, crustaceans, plankton, fish eggs, and other young fish. In this stage they often have distinctive 'parr marks' to camouflage themselves in a stream environment. The only species to not do this are the pinks as they have the shortest time between spawning and entering the sea of any of the salmon species. In order to facilitate this immediate movement from fresh to saltwater they often spawn very close to the fresh/salt boundary, sometimes even just staying in the saltwater to spawn, and thus are silver coloured from the end of the alevin stage.

As the fry migrate closer to the coast and prepare to leave the fresh water, they become smolts, losing their parr marks and much of their dark colourings. In this stage they stay in estuarine and nearshore coastal regions, and then move out into the open ocean as they continue to develop into adults. As they migrate into the open ocean all species continue to lose their dark colouring until they only have dark backs, and their sides turn silvery. These darker backs have led to sockeye having another common name of 'blueback' from their metallic green-blue back when they are at sea. The only species that doesn't move very far

[62] General lifecycle and species-specific information synthesized from species information on species profile websites of Alaska Dept of Fish and Game 2019a-e; Fisheries and Oceans Canada 2018; FWS 2013; Washington Dept of Fish and Wildlife 2019a-e.

into the open ocean are cohos, which predominately make use of the oceanic coastal areas and do not range far from shore, although they have been known to migrate several thousand kilometres into the open ocean on occasion. In the open ocean all species feed on a variety of plankton, marine shrimp, and krill, smaller fish (including specifically herring, sandlance, and pilchard but also others), squid, aquatic insects, copepods, tunicates, molluscs, and crustaceans while they travel throughout the North Pacific. The common names of two species of salmon, pink and red (sockeye, spawning colouration) refer to the presence of krill, shrimp, and other crustaceans in their diets.

As adults return to their natal streams they change physically again, often darkening again to have brown or black backs and sides or turning red. Additionally all species develop humped backs and prominent hooked jaws called 'kypes' as they enter fresh water to spawn. Several species develop other morphological traits unique to their species. These traits include chum salmon developing large canine-like teeth that the males develop as they mature, which has led to another common name for them of dog salmon, and humpback/humpies (pink salmon) referring to the extremely large humped back that the males develop as they mature. Adults return to the streams anytime between spring and autumn (depending on the specific run and species) where they travel to their preferred spawning location in the river system and proceed to lay their eggs. In general, both the literature (Alaska Dept of Fish and Game 2019a-e; Brock and Coiley-Kenner 2009; Fisheries and Oceans Canada 2018; FWS 2013; Washington Dept of Fish and Wildlife 2019a-e) and two participants[63] in this research agreed that sockeyes are the first to be caught, followed by the humpies, dogs and coho, however the exceptions to these well-known patterns has been noted and is described in section 5.3.6.

[63] Myrna Yates (Craig), Charles Jack (Hoonah)

Several of the salmon species also have some biological traits that are specific to them, which I will detail now:

Pink salmon are unique in the length of their lifespan as they only take two years before coming back to spawn. This has formed two distinct genetic populations, those in even years and those in odd, even in the same natal stream. The streams will often have one of the years produce more fish (either even or odd) leading to weak and strong years, but some streams have both years equally strong. While other species may sometimes return within two years, most individuals are out longer, and pinks are the only ones to have all individuals return in two years. The ethnographic literature also described that pinks, which are generally smaller, are able to make it up rivers in low flow conditions and thus are a very hardy species (Brock and Coiley-Kenner 2009).

When the maturing chum return to the streams they do not travel up the watersheds as far as the coho they often share the streams with, perhaps due to their larger size which needs deeper water or perhaps due to their poorer jumping ability, and instead spawn closer to the saltwater interface (Washington Dept of Fish and Wildlife 2019b). In the ethnographic literature it was reported that chums and pinks "cannot share the same stream" because chum are said to unintentionally dig up pink eggs during spawning (Brock and Coiley-Kenner 2009) and may perhaps illustrate a way that this habitat overlap may lead to competition in some cases. Obstacles such as waterfalls which don't stop the migration of other species, may block chum salmons' passage further limiting where they are able to spawn. For chum fry, the amount of time they stay in the riverine environments depends on the size of the streams. In shorter smaller streams that end closer to the coast, they tend to move quite quickly to the sea sometimes only spending one or two days in the fresh water, whereas in larger rivers the fry will often spend several weeks (occasionally up to several months) in the fresh water. While chum spawn in a broad range of habitats, they prefer slower flows in small to medium channels that are spring fed. Most chum runs spawn in the autumn but there are some earlier runs in the summer, making two diverse runs of chum, called 'summer chum salmon' and 'fall chum salmon'. This phenomenon of multiple runs is also seen in the ethnographic literature (Brock and Coiley-Kenner 2009).

Coho have the most 'distinct populations' of any of the salmon species, perhaps due to the need for narrow spawning habitat characterised by medium velocity, gravel that is small to medium size, and with woody debris in 'pooled' areas, leading to severe competition and the necessity for numerous streams, and thus genetic variability. Additionally, after hatching, the fry defend these territories using a succession of movements called the 'wig-wag dance'. Cohos have been described to force other fish out of a spawning area, even other cohos, if there are too many fish coming into the area to spawn (Brock and Coiley-Kenner 2009). There are also descriptions in the ethnographic literature that coho can adapt to spawn in other streams if their natal stream is blocked by natural or man-made impediments, such as downed logs or being blocked by earlier arriving salmon (Brock and Coiley-Kenner 2009), which could perhaps lead to even more genetic diversity. Because cohos have narrow habitat requirements, the extraction of water from the system for agricultural purposes, control of flooding, hydropower needs, and land use changes (linked to logging, construction of roads, development, mining, agriculture and recreation) have greatly diminished the availability and value of the habitat they can use. It is thought that between 80 and 90% of the riparian zone has been eradicated in many western states, and that in the last 200 years the wetlands in Washington and Oregon have decreased about 33%, and in California by about 91%. Additionally, physical blockages such as dams have intensified mortality as the coho migrate (Alaska Dept of Fish and Game 2019b).

A distinctive feature of sockeyes is that it is necessary for them to have access to a lake during their lifecycle, an aspect of the habitat which is more important than qualities of the substrate and water speeds, as sockeyes can adjust to a variety of situations. Another distinctive feature is their 'cyclic dominance', which refers to the four-year cycle sockeyes observe with regards to their abundance, an occurrence which has yet to be explained. While sockeye can mature anywhere between two and six years (depending on the amount of time they spend in both freshwater and saltwater), particularly in the Fraser River system there is a higher abundance in only one year of a four-year cycle, signifying that a majority of the offspring produced in a certain 'brood year' will spawn four years later, leading to a 'dominant' year with a larger population. The majority of the threats that impact them are anthropogenic and have intensified mortality. The threats include: the extraction of water from the system for agricultural purposes and control of flooding, habitat being lost through hydropower plants, mining, and anthropogenic development, and also becoming physically trapped in hydropower plants. These threats all affect the southern populations more than the Alaskan populations, mostly because the latter habitat continues to be primarily pristine, although future threats may involve habitat loss and degradation, climate change, and overfishing.

The amount of time a chinook spends in the freshwater depends on the water temperature and the latitude of the spawning grounds. In some areas in the southern part of their range they only spend three months in freshwater, while in northern regions they often spend a year in freshwater (Fisheries and Oceans Canada 2018; Washington Dept of Fish and Wildlife 2019e) due to less productivity in the streams, leading to slower growth (Washington Dept of Fish and Wildlife 2019e). Scannell (1992) also reported that chinook absorbed yolk and emerged from the gravel faster and had shorter developing times in warmer water. There are both advantages and disadvantages to this; developing sooner may increase ability to hold territory sooner but may also cause disadvantages such as a reduction in swimming and foraging ability, and potentially emerging before their prey (Scannell

1992). In addition to the temperature and latitude, the amount of time in freshwater is determined by the ‘type’ of fish it is: ocean type or stream type (Alaska Dept of Fish and Game 2019e). If a chinook is an ocean type, they migrate to saltwater within their first year, whereas if they are stream type they migrate to the ocean after having spent a complete year in freshwater (Alaska Dept of Fish and Game, 2019e). Illustrated in the example of Alaskan chinook, many of which are ‘stream types’ and spend more time in fresh water and linking this to the observation that in northern parts of their ranges fish stay in freshwater longer, it can be surmised that individuals in northern regions tend towards more ‘stream type’ and those in the southern range tend towards more ‘ocean type’ (Alaska Dept of Fish and Game, 2019e).

Table 5.1. Comparison table between all five species of Pacific salmon.

Scientific name	*Onchorynchus gorbuscha*	*Onchorynchus keta*	*Onchorynchus kisutch*	*Onchorynchus nerka*	*Onchorynchus tshawytscha*
Common names	pink, humpbacks /humpies	chum, dog, calico	coho, silver	sockeye, red, blueback, kokanee (landlocked)	chinook, king, spring, blackmouth, quinnat, chub, tyee (over 14 kgs)
Weight (kg)	1.4-2.5, max found 5.4	4.5-6.8, max found 15.0	2.7-5.4, max 14.1	2.3-3.6, min 1.8, max 6.8/7.3	4.5-6.8, often found 13.7-22.7, max 61.2
Length (cm)	45.7-63.5	61.0-71.1	61.0-76.2	45.7-78.7	usually 91.4, max 147.3
Spawning location	close to fresh/salt boundary, and not often more than 64km upstream, and sometimes even in saltwater	Share streams with coho, small-medium sized spring fed streams with slow flow, lower parts of larger rivers, spawn closer to entrance	small streams and tributaries, also lakes and larger rivers	rivers leading to lake systems	large rivers, smaller stream if have enough water, can travel a long way upriver to find spawning area, found both east and west of Coast and Cascade Mountains; populations going further upstream enter river in spring and early summer, and those spawning near ocean enter late summer and autumn
Hatching time	hatch late winter/early spring, incubate 5-8 months	incubate 3-4 months, depending on water temp	hatch early spring, incubate since autumn	hatch in winter	hatch late winter/early spring, dependent on when spawned and temp of water
Alevin stage (under gravel)	a few days	1-2 days, up to 60-90 days	until May or June	until spring	early spring
Fry stage (Estuarine/lake)	several months	several months	one to two years, sometimes up to three, may alternate between estuarine ponds in	move to lakes, spend 1-2 years, (up to 3 or 4 years), move to	3 months to a year, dependent on water temp and latitude

			summer and freshwater in autumn	ocean quickly if no lake	
Smolt/Adult stage (open ocean)	18 months	2 – 3 summers, up to 4 years	18 months, some only 6 months (called jacks)	1 – 3 years	1 – 5 years
Fry description	bright chrome or silver, no parr marks	dark greenish brown on backs, 'pale iridescent green under the lateral line', about 8-12 small dark vertical parr marks	bar-shaped parr marks	small, dark, oval parr marks, a little below middle of body, trace of blue on back	parr marks being well developed and crossing their lateral line when they are younger, marks are bigger than spaces between
Adult ocean description	bright greenish blue on top, silvery sides	metallic blue/green and silver, some black 'speckling' on backs in tidal waters, no black marks on deeply forked tail	backs a metallic blue colour with 'irregular black spots', black spots on the upper part of the tail fin, flashing silver sides	silver and metallic green-blue back (along with some black 'speckles')	parr marks shrink and they develop silver sides and a dark back with a 'greenish blue sheen'
Adult spawning description	large black spots on backs and tails; males = white belly, brown or black back; females = white belly, olive green back with lavender or dark gold bars/patches	'checkerboard or calico' colouring; males = dark olive or brown, with reddish-purple vertical stripes; females = grey or brown and develop a dark horizontal stripe down their sides running alongside their lateral line	males = brighter green on back and head, darker on the belly, bright red on sides female = similar, but less pronounced	red overall, with a green head	a darker body with a redder hue on belly and near the fins as they enter the spawning habitat - colouring can vary between red to copper to dark grey subject to the level of maturing and the location; Males = humped back (4-7 years old), redder; females = rounded nose, torpedo shaped, greyer
Diet	plankton, marine shrimp, krill, smaller fish, squid	copepods, tunicates, molluscs and other fish	fish, squid	plankton, insects, small crustaceans and	herring, pilchard, sandlance, squid and crustaceans

	and sometimes aquatic insects			sometimes squid and small fish	
Return to natal stream	late June – mid-October	autumn and summer, two diverse runs	July – November	June – July	spring, summer or autumn
number of eggs	1200-1900	not reported	2400-4500	2000-5000	3000-14000
Unique traits	➢ smallest species found ➢ two year lifespan ➢ odd and even year returns – distinct genetic populations ➢ most abundant	➢ spawn closer to entrance, due to larger size needing deeper water or poorer jumping ability to overcome obstacles e.g., waterfalls	➢ year-round access to clean cold water required ➢ can be found in urban streams ➢ narrow habitat for spawning, medium velocity, small to medium gravel, woody debris, 'pooled' areas ➢ mostly use oceanic coastal areas, not far from shore	➢ need access to a lake ➢ 'cyclical dominance' – higher abundance every four years	➢ flesh range in colour from white to pink to deep red ➢ multiple runs a year- spring, summer and autumn, timing of runs depends on how far up-river travelling ➢ size can vary widely, from 1.8 kg, mature at 2 years, and >22.7 kg, mature at 7 years ➢ females take longer to mature than males
Protection status	not monitored or protected under Endangered Species Act; generally healthy and stable stocks	threatened in Columbia River and Hood Canal summer run, declining in WA, OR, CA, stable in AK	threatened in the Lower Columbia River, species of concern in Puget Sound and Strait of Georgia, stable in AK	threatened in Ozette Lake and endangered in Snake River	threatened in Lower Columbia River, Puget Sound and Snake River (spring, summer and autumn runs), and endangered in Upper Columbia (spring run), abundant in AK
Threats	overfishing, habitat loss and degradation, potentially climate change reducing prey	overfishing, habitat loss, competition from hatchery fish (hatchery make about half of total catch), climate change	anthropogenic disturbances, climate change	anthropogenic	overfishing, dams, habitat loss and degradation and climate change

5.1.2 Ecological Keystone Species (EKS)

As ecological keystone species, salmon are pivotal to the ecosystem, and one main ecological impact as a functional group on the landscape is primarily as a connector – linking oceanic and freshwater systems, and up into the riparian zone. Their carcasses are often moved into terrestrial environments and broken down by detritivores to provide nutrients to the plants and enrich the soil, which provides a pathway for nutrients to connect the ocean and forest (Cederholm *et al*. 1999; Hocking and Reynolds 2012; Reimchen *et al*. 2003). The nutrient input of salmon into the coastal environment has influenced the structure and function in this ecosystem, and the yearly contribution affects entire ecosystem survival and reproductive capacity, particularly providing a source of nitrogen to nitrogen-poor habitats which increases primary productivity (Cederholm *et al*. 1999; Mathewson *et al*. 2003; Willson and Halupka 1995). This land-sea connection was also seen through the interviews, from Arnie Bellis (Old Massett) saying that his dad called "Salmon [the] creature[s] of the forest" and Helen Clifton (Hartley Bay) saying "they become part of the river, part of the whole system".

Another main ecological keystone impact is as a food – ranging from large predators (seals, sea lions, bears, and wolves), birds (including eagles), predatory fish, marine mammals, aquatic and riparian scavengers, and insects (Cedarholm *et al*. 2000; Hyatt and Godbout 2000; Reimchen *et al*. 2003; Willson and Halupka 1995), in addition to humans. They are preyed upon at every stage of their life cycle, from eggs to carcasses (Willson and Halupka 1995). At least 138 species have some kind of relationship with salmon throughout their lifecycle (Cederholm *et al*. 2000). In interviews they were specifically described as being eaten by seals, sea lions, bears, and eagles[64]. There was some discussion by Marvin

[64] Harold Martin (Juneau), Harvey Williams (Old Massett), Wanda Culp (Hoonah), A13 (Juneau), Marvin Kadake (Kake), Adam Greenwald (Hoonah)

Kadake (Kake) and Harvey Williams (Old Massett) that they thought sea otters might be affecting the salmon population as well, but no evidence of this has been found in the literature. Two participants, one located in each country, also reported that the governments used to offer bounties to kill predators of salmon: In Alaska, Harold Martin (Juneau) said that the local people used to get bounties on hair seal and eagles, because "the biologists decided that they are predators…the seals [and eagles] deplete the fisheries" and in British Columbia, Harvey Williams (Old Massett) noted that "when fisheries had a bounty on the seals…you know, the seals were killing too much salmon, so the…Department of Fisheries put a bounty on them". A13 (Juneau) also mentioned that predation by animals were affecting people's ability to harvest - "where we used to go fishing, we have to go out further…and there's so many sea lions and seals, if you get the salmon on your fishing line, they grab it…so it's getting harder for us to get some…they're not out there fending for themselves anymore". The last predation incident that people noted was that trout prey on salmon eggs - "sportsman covet the trout…we don't, because they are only there to eat the salmon eggs!" (Wanda Culp, Hoonah).

5.1.3 Cultural Keystone Species (CKS)

As a cultural keystone species, while not all species are equally valued by Indigenous People, are not equally abundant, or have different uses, all five Pacific salmon are as a whole integral to peoples' livelihoods, interactions with ecosystems and are a staple food source (Brock and Coiley-Kenner 2009; De Laguna 1972 Emmons and De Laguna 1991, Langdon 2006, Ratner *et al*. 2006, Turek *et al*. 2006). As Anthony Christenson (Hydaburg) noted "that's our primary concern, it's our primary subsistence, resources, the salmon, cause pretty much everything else relies on that stock". Harold Martin (Juneau) also thought that of all their resources, salmon had been the most affected, however, he did not attribute this to climate change: “probably our salmon? But it’s not because of climate change, it’s because of hatcheries…and fish farms”. However, even with Harold Martin’s observation, there is enough evidence in the rest of this chapter that while other factors such as overfishing and fish farms are factors in salmon abundance and use, salmon do indicate changes in weather and climate primarily, and are greatly impacted by climatic changes.

Using harvest data from CSIS, it can be seen how much salmon have been harvested in Alaska. As stated in Chapter 2, the Methods chapter, every government has a different way of reporting catch records, and unfortunately it is hard to access data from British Columbia due to the way the government records catch from Indigenous communities. However, in Alaska, salmon harvest is recorded by the Community Subsistence Information System (Alaska Dept of Fish and Game Division of Subsistence 2019). Harvest data for fish had been recorded every year since 1980, but not every community was recorded every year, and in the 2000’s the unidentified salmon catch was reported in pounds instead of individuals, which makes comparison difficult (Table 5.2). In the table below, it can be seen that both the total reported catch of each species in the communities, and the percentage of households that are harvesting each resource has fluctuated over the years and has not steadily increased or decreased across the board. Partly this could be due to not every community being recorded every year, particularly after 1996/97. However, using 25 possible datapoints (five species in five communities, comparing between years of collected data), it can be seen that in general there is an increase in harvesting. Comparing between the first and the last year that harvest data was recorded in each community, it can be seen while every community had both increases and decreases in the % of households that were harvesting each species, there were more instances of increased harvesting, with 15 increases and only 10 decreases. In contrast however, Brock and Coiley-Kenner (2009) reported that sockeye salmon harvests had decreased in recent times in Kake and Hoonah, although specific years were not mentioned.

In the CSIS data, Craig, Hoonah, and Hydaburg had the greatest number of increased harvests between the first and last years of harvest records, and chinook, sockeye, and coho were the species who had the greatest number of increased harvests in the communities (see red and green highlighting in table).

If comparing just between 1987 and 1996/97, as data from all studied communities were recorded in those two years, the same trend can be seen: there are 15 datapoints that increased, and 10 decreased. Ratner *et al*. (2006) analysed the CSIS data in terms of pounds harvested per person and found that harvest had increased between 1987 and 1997, and this, along with the data presented in the table shows that harvest is still an important aspect of people's lives and this vital resource has not reduced overall in harvesting levels.

Table 5.2. Salmon harvest numbers.

		Total Harvest (ind)										(lbs/ind)
Community	Year	Pink	% household harvesting	Chum	% household harvesting	Coho	% household harvesting	Sockeye	% household harvesting	Chinook	% household harvesting	Unidentified Salmon
Craig	1997	1694	19.7%	1399	12.7%	6590	52.6%	8371	35.8%	1979	42.2%	20,032 (ind)
	1987	1902	11.9%	277	6.6%	1814	39.6%	4062	33.4%	685	31.2%	8,741 (ind)
Hoonah	2016	615	23.1%	332	13.8%	2348	49.2%	1389	23.1%	828	32.3%	28,787 (lbs)
	2012	832	22.1%	722	20.5%	3489	51.6%	3592	22.1%	1311	36.9%	52,702 (lbs)
	1996	1622	32.5%	2822	35.1%	4135	54.5%	6069	42.9%	2069	55.8%	16,753 (ind)
	1987	1200	35.8%	3518	32.1%	2026	54.5%	1192	29.2%	1637	50.4%	9,572 (ind)
	1985	690	19.7%	1317	28.2%	1384	33.8%	580	16.9%	1152	46.5%	5,123 (ind)
Hydaburg	2012	1527	16.7%	712	19.7%	2221	41.7%	9780	62.5%	697	45.8%	71,235 (lbs)
	1997	552	17.6%	347	13.7%	873	43.1%	7824	58.8%	134	25.5%	9,730 (ind)
	1987	724	32.8%	661	19.4%	1632	49.3%	6477	49.2%	391	34.3%	9,885 (ind)
Kake	1996	184	8.2%	372	12.3%	392	19.2%	4902	41.1%	334	41.1%	6,187 (ind)
	1987	555	20.9%	1106	31.7%	483	36.8%	1497	31.7%	279	27.5%	3,921 (ind)
	1985	1810	31.4%	1981	40.0%	1177	30.0%	1368	34.3%	650	35.7%	6,987 (ind)
Klawock	1997	1452	19.8%	1709	17.0%	2901	53.8%	7458	37.7%	1784	36.8%	15,304 (ind)
	1987	1666	27.4%	518	16.9%	3120	44.3%	3844	40.8%	777	24.0%	9,925 (ind)
	1984	1063	36.1%	739	27.8%	1234	52.8%	1801	52.8%	295	33.3%	5,189 (ind)

Notes: these data are records from CSIS. This table includes the number of individuals reported for each species, and either pounds or individuals reported for unidentified salmon catch. % of households harvesting in each year is also presented, showing amount of population harvesting and thus importance in community over time (green highlight indicates increase between first and last year recorded, and red indicates decrease. Light green and light red indicate 1996/97 records if there are later years for that community, and grey indicates no change)

All five salmon species are used in similar ways which is one reason they are grouped into one CKIS. Different species of salmon and different life stages of each one (Ratner *et al*. 2006, e.g., fish are oilier in the ocean, which they lose as they ascend into rivers to spawn) results in slightly different characteristics that in turn lead to different cultural uses, such as fish with more oil are less desirable for drying (Ratner *et al*. 2006).

As detailed above, pink salmon are one of the most abundant species in the region, and as such, the literature shows that they are highly used for subsistence uses (Alaska Dept of Fish and Game, 2019a; Brock and Coiley-Kenner 2009), and mentioned by four participants. In contrast to the high abundance reported in the literature, two participants referred to it being scarcer: Myrna Yates (Klawock) said "a little bit of humpy, we don't use a lot, but I like it for boiled fish" and A11 (Kake) said that "the pinks are good once in a while…we like them for boiled fish…just lucky to get it, when we have it", although she also said later there's "less salmon in our house" since her husband passed so perhaps she consumes all species of salmon less, and it is not a reflection of how much she used pinks. In interviews, four participants specifically mentioned that pinks: they are "the best tasting fish of all fish…makes the best dry fish, makes the best canned fish for making spread or patties you know" (Charles Jack, Hoonah). Harold Martin (Juneau) recalled that he, and likely many Indigenous People, like pinks and contrasted this with their reception by non-Indigenous fishermen "I got a humpy, I tell my wife, fry it up! Yeah, it was good…it was really good, but to hear the non-natives talk, humpies are an inferior fish…they don't like it…[but] they are all nutritious…we grew up on that you know…they are all good".

In the literature, chum was recorded as being the second most abundant species and having a low oil content (making them harder when dry, Ratner *et al*. 2006), and while they are not the most desirable species to everyone, they are also considered a "mainstay food source" in the region (Brock and Coiley-Kenner 2009). They are highly valued for cold-smoking and dry fish (Alaska Dept of Fish and Game, 2019b, Brock and Coiley-Kenner 2009; Fisheries and Oceans Canada 2018). In the interviews four participants commented on all these uses. Harold Martin (Juneau) not only mentioned the low oil content – "so humpies and dog salmon, kept all winter, they didn't have a lot of fat in them" but also the smoking use - "we smoked mostly dog salmon", and Adam Greenwald (Hoonah) talked about smoking chum, but to use as a food at feasts. Wilbur Brown (Kake)) and A11 (Kake) commented on the usage as a dry fish: "[I] remember my grandparents also used to use the chums for dry fish, they completely dehydrated [them]" (A11, Kake).

Coho were viewed in two different ways, both as a desired food and also not being as preferred as other species. In the literature, cohos are reported as having an oil content mid-way between chum and sockeye (Ratner *et al*. 2006) and being used in a wide variety of ways (Brock and Coiley-Kenner 2009). Their versatility may perhaps be due to their oil levels. The literature did not note any specific uses (Alaska Department of Fish and Game 2019c), but five interviewees discussed the usage of cohos. Adam Greenwald (Hoonah) was proud that his neighbours really liked his pickled coho "in November, December, I'll take them out and leach them, and ah, cut them in strips, and then cut them in pieces and make pickled coho…they are good, people…get hooked on it, and then I don't know why, I'm sure there's others that know how to do it, but they…oh they get me to pickle the cohos" and Charles Jack (Hoonah) recalled that his father "used to love the late coho and boil it". Wilbur Brown (Kake) noted that they used cohos for smoked strips and fresh pack[65]. In two contrasting viewpoints, however, A11 (Kake) said that she felt that people used "all the five different species of salmon, but we use mostly the sockeye and coho", while Mary Guthrie (Klawock), who noted other issues with cohos (the fry eating sockeye eggs, described more below), said

[65] Fresh pack is when raw salmon is packed into tins or jars, sealed, and then cooked in a pressure canner to cook it to preserve it. Salmon is put in whole, with the skin and bones.

that cohos were not of the same quality because “you have to put up three cohos to get the nourishment from the sockeye”, and it wasn’t her “fish of choice”.

Sockeye are considered to be among the most economically and culturally important of the salmon species, in particular because of their higher oil content, colour, and texture of their flesh (including improved preservation of their nutritional value compared to other species), and they return for a longer period than other species throughout the summer with predictable (and less variation) in stock levels (Alaska Dept of Fish and Game 2019d; Brock and Coiley-Kenner 2009; Fisheries and Oceans Canada 2018; Ratner *et al*. 2006; Turek et al. 2006). Sockeye were mentioned by three of the interview participants. A11 (Kake) noted that sockeyes were widely used (in addition to cohos). Referring to the high oil content, Mary Guthrie (Klawock) stated “they have more of the oil we need in them than all the other species except king salmon” and Harold Martin (Juneau) said “sockeyes are fat…they won’t keep very long… nowadays you freeze them, so they…keep longer”, again referring to a high oil content.

Chinook are one of Alaska’s most important industries (Alaska Dept of Fish and Game 2019e) and are valued due to their large size, ‘good flavour’, higher quality of the meat after preservation, and a higher oil content (Brock and Coiley-Kenner 2009). Chinook was the least commented upon as a cultural keystone species and a food in this study, only being mentioned by one person: Michael Jackson (Kake), described how he dried chinook salmon, and then soaked it in oil.

Sometimes people would substitute other fish if they couldn’t get their preferred one, like Carol Young’s statement (Skidegate) saying that she remembers them using pink and dog (chum) salmon when they couldn’t get sockeye as much. While some participants displayed a preference for different species, some people just said they enjoyed all the salmon, like Harold Martin (Juneau): “we’d wait until they got up into the creeks, when they got in the creeks they couldn't feed, and so they are not so fat… and so humpies and dog salmon, kept all winter, they didn't have a lot of fat in them, somewhere along the way, somebody decided that sockeyes and cohos were…better, but I don't think they're better, I think they are all good" or Joel Jackson (Kake): "because you know, we depend on fish and it's a big part of our diet, we eat all the fish…some people don't want to eat the dog (chum) salmon or the pinks, or what we call humpies (pink) – we eat them, you know, we eat all the salmon, because that's what we grew up on".

Besides the salmon meat being eaten, eggs were also considered a delicacy, and turned into a traditional dish known in English as stink eggs or Indian Cheese (Brock and Coiley-Kenner 2009; Ratner *et al*. 2006; Turek *et al*. 2006). Six of the participants talked about the edibility of salmon eggs. Two of them, located in NSE, didn't specify the species[66]. However, the remaining four participants that did specify which species the eggs came from were split along a geographic boundary. The three from NSE specified coho eggs[67] and the one from SSE specified sockeye eggs[68].

In addition, two legends were mentioned by interview participants, one from Hoonah and one from Kake, both NSE. The first one is in the words of A11 (Kake), and describes the tribes that survived under the glacier, of which several stories exist in the literature (Swanton 1909), and how her clan ended up settling where they did because they wanted salmon. Mary Guthrie (Klawock) also said that her people had also settled near a sockeye river in her clan's origin story.

> "there's a song about the glacier that goes back thousands of years where the land was just covered with glacier, and, two ladies, with clan head, well, they were past the childbearing age, at the time, it was going to be their sacrifice…they were going to go under the glacier…and if we succeed it will make the traveling a lot easier for the rest of the clan, so…they succeeded going under the glacier…so you can imagine how

[66] A11 (Kake), Adam Greenwald (Hoonah)
[67] Wilbur Brown (Kake), Ernestine Hanlon Abel (Hoonah), Harriet Williams (Kake)
[68] Cora Joseph (Klawock)

much glacier there was…yeah, so they went just under the glacier, and they succeeded and the rest of clan followed…so there are songs like that, that tell the history, of what they went through…they were migrating…and wherever they stopped, wherever looked good to them, a clan would stop there and say, well this is where we are going to live, the land is good, the weather is good here, we can catch our fish and pick our sea [food], and pick our berries, and there's plants around that we can use, so that is where they would settle…like my clan…during the flood, they drifted inland, and they weren't just used to land animals…so they said, we want our salmon, we want our salmon, we want our seafood, so they said we are going to build canoes and drift down this river, and it should take us down to the sea…the salt water, so this is what they did, there, that's a long history"

The second story was by Owen James (Hoonah) and told the story of a young boy who was punished by the salmon people for killing their 'children' (baby salmon). I have retold his story in my words, as he did not want to be recorded in the interview:

A young boy who was naughty captured some baby salmon and brought them up in a clam shell. His mother told him he couldn't keep them, but he kept them anyway, and during the night the baby salmon died. This made him upset, and when he was crying, his parents said that they had told him to let them go, but despite these warnings he did it again, and caught more baby salmon. After this, the naughty boy was playing on the beach, and got his hand stuck under a rock, and started crying for his parents. As a punishment, his parents left him there, even though other people from the village kept asking if that was their son on the beach crying. All the other villagers eventually gathered on the beach to watch the boy, and this brought the parents down as well, where they explained the consequences of his actions – because he had kept catching baby salmon, he was now trapped under a rock. After a while, the tide was coming in, threatening to drown him, and so everyone tried to help him, such as putting a tube in his mouth to breathe under water, but after the tide fell again, the son was dead.

This legend shows peoples' close connection to their resources, and how integral salmon were to their lives – you don't play with your food, or you might be punished, or your food source might disappear. While the salmon people engineered him getting his hand stuck, so that he would get caught by the tide, his parents also left him to face his fate, as a lesson that if you mismanaged resources, or played with your food, you had to face consequences.

Another way of recognising the cultural importance of a species to an Indigenous group is to is to examine its role in the language, and the number of terms that appear relating to anatomy, life stages, and other resource characteristics (Turner 1988). The three Indigenous groups in this study, the Tlingit, Haida, and Tsimshian, all have their own languages, and it is this data which has been explored here to examine linguistic importance. To link the above CKIS example to the linguistics literature I reviewed dictionaries for names for salmon in each language (Table 5.3).

The language references (Anderson 2018; DeVries 2014a; DeVries 2014b; Edwards 2009; Lachler 2010; Roberts 2009) were also searched for terms relating to this CKIS example (such as body parts, harvesting techniques, processing, etc). For salmon, there were a large number of terms found relating their use, indicating a high cultural significance, not just for harvesting, but in the social fabric more generally (Turner 1988). All three languages had various terms relating to salmon in general. These included terms around seasons and locations of fishing, spawning, fishing tools, life stages, anatomy, processing, and mythology. There were also terms that related specifically to each of the five species. The three Haida dialects had the greatest number of terms: naming 10 terms specific to coho, 15 terms specific to chum, and six terms specific to sockeye. Both Tsimshian and Haida had a total of 6 specific terms for pink, and all three languages, Tlingit, Tsimshian and Haida, had a total of eight specific terms for king.

Table 5.3. CKIS names from the three languages throughout study area.

English name	Scientific name	Tlingit name	Tsimshian name	Alaskan Haida name	Old Massett Haida name	Skidegate Haida name
Salmon, chum	*O. keta*	téel'[1]	gayniis[2]	sk'ag[3]	sk'ag[4]	sk'aagii[5]
Salmon, coho	*O. kisutch*	l'ook[1]	üüx[2]; ẅaax[2]	táay[3]	taayi[4]	táay.yii[5]; táay.yiigaay[5]
Salmon, king	*O. tshawytscha*	t'á[1]	yee[2]	táa'un[3]	taawan[4]	taaGun[5]
Salmon, pink	*O. gorbushcha*	cháas'[1]	sti'moon[2]; stmoon[2]	ts'at'áan[3]	ts'at'aan[4]	ts'iit'an[5]; ts'iit'aan[5]
Salmon, red	*O. nerka*	Gaat[1]	misoo[2]; müsoo[2]	sGwáagaan[3]	sGwáagaan[4]	taaxid[5]

[1] - Thornton 2008; [2] - Anderson 2018; [3] - Lachler 2010; [4] - DeVries 2014b; [5] - DeVries 2014a

5.1.4 Indicator Species

In general, salmon was linked as an indicator species to three main abiotic factors – temperature, narrow or precise habitats, and water quality. As discussed in Chapter 1, The United States Forest Service have identified two species of salmon, pinks and cohos, as MIS, which shows the high importance these species are held in, not only by local peoples but also by the government.

In terms of temperature, sockeye in particular was singled out to be an indicator of temperature changes in a report by the Ministry of the Environment (MoE 2016) because they prefer colder water, and thus can indicate if the water is getting warmer, as warmer water affects their fitness, survival, and reproductive success. However, in Scannell (1992) there was discussion about how all five salmon species are affected by temperature. For all species, as the temperature increases the number of days in incubation decreases, causing the alevin to hatch sooner and the yolk to be absorbed faster, meaning if the alevin uses up all their yolk, they may start reabsorbing body tissue. This can cause several issues: smaller alevin and smaller fry in total body length, lower rates of survival in hatching, reduction in swimming or foraging ability, hatching before their prey is available, and easier for predators to eat them (Scannell 1992; U.S. EPA 2008). Salmon also have narrow preferred temperature ranges, mostly between 5°-14°C, and temperatures outside this range can greatly affect egg maturation, hatching rates, and alevin size as mentioned above. The influence of temperature on salmon from the interview observations is explained in section 5.3.2 below.

For narrow and precise habitats, both pinks and cohos were noted as having restrictive habitat requirements, meaning that they can indicate disturbances in the watershed that may affect the required habitat (Alaska Dept of Fish and Game 2019a; Alaska Dept of Fish and Game 2019c; Bryant *et al*. 2008). The full interviewee responses for salmon with regards to the indication of habitat changes is primarily in section 5.3.3 below. In addition to having a narrow habitat, pinks also have predictable population fluctuations, and thus indicate in two ways ecological, human, and hydrological effects on the system (Estes 2014).

Sockeye salmon were also singled out for being known as indicators of water quality because they spend much of their life in freshwater, and thus have been shown to decrease in population in lower quality areas (Washington Dept of Fish and Wildlife 2019d). In interviews, the need for salmon having clean, cold, shaded water was discussed, and the effects of landscape change on salmon from the interview data is further elucidated in section 5.3.3 below.

In addition to indicating the abiotic features above, such as temperature, and both quality and restrictiveness of habitat, salmon are linked to several other species as indicators of biotic interactions. Bears, whales, needlefish, salmonberries, and mountain ash berries were mentioned as indicating either the movement or presence of salmon. Two signs that the salmon were returning to the nearshore after their time at sea included whales making a certain sound – transcribed in the interviews as hquuu – which indicated to people that the salmon are underneath them (Wilbur Brown, Kake) and the presence of needlefish, which the salmon eat: "the coho, when the needlefish show up, [because] they feed on needlefish…a lot of times they show up then" (Fred Hamilton, Craig). Salmonberries and mountain ash were said to be watched, and when they ripened, the salmon were in the streams and people could go out fishing:

> "usually, when we see the berries turn red on the mountain ash…that's when the sockeye's ready to go to the rivers…we use that as our timing to go to the river, so that that timings never changed, [it's the] same now, and that's all we judge our time to go to the river, and when they're red, and usually by the amount of red berries on that bush that year, if it's thick and every one of them have got lots on them, loaded, then they always used to say it was going to be a good sockeye season" (A2, Old Massett)

> "then the fish goes up, salmonberries is the first blossoms you see…and when there are blossom[s], it means there is fish up the river, if you wait for the fireweed, it's

> kinda late you know, it's later than the salmonberry" (Charles Jack, Hoonah)
>
> "when the salmonberries, in the first part of June, are dusky, and they are not quite ripe…we know that around Portland Canal, and Dundas, we could go and get our sockeye…they're here, ready…and we knew that we could go to around Port Simpson…when the salmonberries were dusky, and we could go and get sockeye…when the salmonberries was nice, bright and ripe, it's still not the full run of salmon, we know if we go outside Metlakatla we can go get it, our sockeye" (Robbie Nelson, Metlakatla)

However, Robbie Nelson (Metlakatla) also acknowledged that these indicators are changing "that's where it's real crazy now with…those indicators, the balance is gone…you know, and the salmonberry might be ripe in the first week in June, it's not going to affect salmon coming". He agreed with me when I said, "that's probably because the temperatures are different in the air and the water, so things are growing at different rates". A2 (Old Massett) admits he didn't always check the indicator he commented on (mountain ash), and always seemed to get enough fish "I don't know how true it is, I never did ever look at it that often, and compare it…but I always got a lot of sockeye whenever I went out, except for last year…last year I haven't got any because I missed it all year all, all along…I even had a big yacht to go get it, and I still missed it". Still others don't watch indicators at all, Harvey Williams (Old Massett) said he didn't watch any indicators, and simply went out to fish when the Council of Haida Nations had counted that enough fish went up the rivers and opened it up to harvesting. This shows that indicators might be uncertain, or not "as accurate as they used to be" (Robbie Nelson, Metlakatla). Phenology or "the timing of seasonal activities of animals and plants" (Walther *et al*. 2002) has been shown to be greatly impacted by climate change, often leading to an advancement of stages (e.g., flowering, fruiting), or a disconnection between organisms, such as when flowers open and pollinators are available (Visser and Both 2005; Walther *et al*. 2002). Not only do different traits respond to a changing climate in different ways, but different trophic levels will also respond differently (Visser and Both 2005). The changes in indicators noted in the observations could be linked to: observations that air and water temperatures were changing at different rates and causing organisms to respond differently; people having better technology or less time to harvest and thus not paying as much attention to watching other indicator plants, animals, or traditional harvesting markers; or simply following the governmental rules and regulations about when they can fish, rather than using their own judgement from information gleaned from watching indicators.

As another way of indicating salmon presence, Lionel Bean, Nancy Bean, and Wilbur Brown (all Kake), and Margaret Edgars and Emily Watts (both Old Massett) discussed how the abundance of salmon is connected to that of berries: "the Elders, my mother told me this, and her mother told her, and so did her dad, my grandfather…whenever there's a season when we have lots of fish, we're going to have less berries…but the next season after lots berries…well, it's going to be the opposite…it's always the opposite" (Lionel Bean, Kake) and "they say when there's going to be lots of salmonberries, there's going to be lots of fish" (Emily Watts, Old Massett), and the opposite, certain winter weather would cause fish and berries to both be scarce (Wibur Brown, Kake). Margaret Edgars (Old Massett) thought this high abundance cycle went about every three years: "my grandfather, and my grandparents, and them, used to always say that the weather changes every three years…so everything goes in three-year cycles, berries…every three years, if the berries are thick, the salmon are…thick". This shows how some resources were tied together, and likely the environmental conditions in those years lead to both resources being plentiful together or being plentiful in alternating years.

5.1.5 Pacific salmon as a Cultural Keystone Indicator Species functional group

As Helen Clifton's statement at the start of this chapter emphasizes, salmon are foundational to coastal peoples' happiness and wellbeing, and this includes all five species of salmon. It was seen above that salmon species individually play roles as important cultural and ecological keystone species, and as indicator species, but in this section, I am now bringing all five species together to present them as a cohesive functional group that can be considered a CKIS. The reason all five species of Pacific salmon are considered together as a CKIS in this research is due to the similarities in their life history and importance. It was seen in each species profile that individual species spend various times incubating as alevin in fresh water and in saltwater. However, the common link here is that in general, all five species live in the same environment – even though the timing varies, all five species move from fresh to salt, and back to fresh water during their life history, and widely range throughout the North Pacific including venturing over to the Asian side of the Pacific. In addition, they are all greatly impacted by warmer temperatures, changes in precipitation, density of predators and prey, increased pH and O_2, sea level rise, and storms at all life stages (Martins *et al*. 2012; Okey *et al*. 2014; Zabel *et al*. 2006). Therefore, from the above evidence of all these species of salmon being prime examples of cultural keystones, ecological keystones, indicator species, and playing an important role in the biogeographical and cultural landscape, I argue that this grouping of five species of salmon is an excellent CKIS functional group.

5.2 Methodology

Interviews were conducted with 96 participants in Southeastern Alaska and Northern British Columbia. Participants were identified using a snowball methodology, which builds the data sample through referrals, and interviews were organised in a semi-structured format. The full methodology is described in Chapter 2.

5.3 Results: Ethnoecological data

In this research, all five species of salmon were used and were commented upon in interviews. Overall, salmon were mentioned in about 77% of the interviews and observations were made about *O. nerka* (36) the most frequently, followed by *O. kisutch* (27), *O. keta* (19), *O. tshawytscha* (18), and *O. gorbuscha* (13). People have noticed changes in their timing, individual size, population stability, distribution and behaviour, much of which they link to climatic changes, although these were attributed to other causes as well, or at least these other causes are exacerbating the effects of climate changes.

Data from interviews is presented in depth in the following sections, and the key findings summarised in Table 5.6 at the end of this chapter. In addition to the climatic factors outlined above, the main non-climate factors affecting salmon productivity and harvestability referenced in interviews include: over-fishing from commercial, sports, local/subsistence, and charter fishing, inappropriate legal restrictions, pollution, parasites, and the logging of watershed trees that provide shade cover, erosion protection, and cooler water to salmon. Other non-climatic effects which have been mentioned in the literature, but not specifically indicated in interviews, include: obstructions by hatcheries and weirs; increase in predation; decrease in prey; and overfishing from international fishers off-shore before the salmon return to spawn (Ratner *et al*. 2006). While salmon are a good example of how complex these ecosystems and species are, and how they are affected by climatic and non-climatic factors, it was clearly seen in both the literature and in the interviews that weather changes play a major part in varying salmon distributions and population levels.

5.3.1 Population change

A total to 19 participants mentioned population change, and there was much variation in interviews about how the populations were trending. While the majority of participants acknowledged that there was a decrease in general, there was awareness in the interviews that populations often fluctuate, particularly due to the yearly cyclical pattern of salmon returning to spawn and it was hard to fully understand the variation in population as easily as other species, likely due to some years being intrinsically heavier because of more salmon returning in that year (for example, the 'cyclic dominance' every 4 years for sockeye) and different streams (or the same stream in the case of pinks) having varying abundance every year.

5.3.1.1 No change

Only five people thought that there had been no change in the overall salmon population in the NSE, SSE, and HG geographical areas. Moving southwards, Ken Grant (Hoonah) said that populations depended more on regulations and social change (similar issues to those faced by people that said the population was decreasing) but in contrast, he was the only one that felt that the populations were pretty stable. Myrna Yates (Craig) said that the only change in abundance was simply the yearly cycle, Anthony Christensen (Hydaburg) said that while the odd year was poor, overall, the population was abundant, and Rolly Williams (Old Massett) thought the fish had a 'good, sustained level' of population, apart from anomalous years. Harvey Williams (Skidegate) felt that rather than the abundance changing, it was more the timing that was changing, which made the abundance appear lower: "there's only certain types of salmon…so it's the same ones coming in different parts of the year". Timing and the issues surrounding it are discussed in section 5.3.6.

5.3.1.2 Population decreasing

Fifteen participants[69] described varying levels of population decrease in all four geographic regions, the most from NSE (6) and HG (5), and only a few from SSE (3) and MBC (1) (a general decrease was also seen in the ethnographic literature, although it was thought to be due to overfishing pressures, stricter regulations and logging (in more recent times), e.g., Brock and Coiley-Kenner 2009, Ratner *et al*. 2006). While most participants talked about salmon decrease as a functional group, a few people specified a reduction in a certain species. Adam Greenwald (Hoonah) said that while all the streams were "hurting for parent runs of fish", 2014 was "one of worst for numbers of humpies [pink] and chums, slim on cohos" and A3 (Skidegate) noted that chum salmon abundance was concerning him because they seemed to be 'deteriorating' more than the other species.

Eight participants (only from HG and NSE) did not have a suggestion for why this decreased abundance might be occurring. Sherri Dick (Old Massett) recognised that while there is variation in year-to-year abundance due to yearly cycles, the abundance was still decreasing overall and George and Agnes Davis (Juneau) agreed, saying that while "every 4 years salmon come in heavy", in general they are "headed downhill". A3 (Skidegate) and Charles Jack (Hoonah) also thought the cycles were at play, with Charles Jack further commenting that salmon was "not as plentiful as it used to be". Wanda Culp (Hoonah) noted that in 2013 it had been the largest run she had seen in the last 20 years – the only participant to report any kind of increase in abundance, but in 2014 (the year she was interviewed), it was back to being low numbers: "now this year, not enough fish, they've come through but not enough…and the year before that [2012], no fish, so the bears go hungry". However, this was an anomaly, and she observed that overall salmon abundance is unpredictable, but she

[69] A3 (Skidegate), A11 (Kake), Charles Jack (Hoonah), Michael Jackson (Kake), Charles Jack (Hoonah), Sherri Dick (Old Massett), Harvey Williams (Skidegate), Robbie Nelson (Metlakatla), Ernestine Kato (Klawock), Harold Martin (Juneau), Wanda Culp (Hoonah), George Davis (Juneau), Agnes Davis (Juneau), Captain Gold (Skidegate), Mary Guthrie (Klawock), Fred Hamilton (Craig), Jack Littrell (Old Massett)

could not explain why: “our salmon is so unstable…we don’t know when it’s going to be good and when it’s not, [but] our rivers aren’t doing too good, cause some reason”. Carol Young (Skidegate) also noted that population were not predictable. Ernestine Hanlon Abel (Hoonah) noted that sockeyes used to be so thick it was hard to not catch one, whereas now they hardly get any.

Other participants had explanations for the decreased abundance, including lack of access/availability, logging and land use changes, overfishing (also in Brock and Coiley-Kenner 2009 for chinook and coho), governmental regulations, in addition to climatic changes, although people often recognised that many of these factors are interlinking in the reduction of salmon abundance. For example, logging and commercial fishing (often leading to overfishing) were linked by both Jack Litrell (Old Massett):

> “I know there’s less fish, but there’s a whole lot of factors…it’s people harvesting the fish, and also, I think the major thing is destruction of habitat…from logging, which has been going on for about 60 years”

and Captain Gold (Skidegate):

> “so, commercialization of our foods has really reduced the number, logging has reduced the numbers, the spawning bays are not there, the returning salmon from all the seiners that are becoming more effective at catching fish, etc., you know, it just keeps on going”

In the interviews, it seemed that people’s impressions of abundance were also affected by the amount they could harvest, which is drastically less than they used to due to regulations, and also just a modern way of life - where people used to harvest 100s or 1000s of fish, they now harvest substantially less (Turek *et al*. 2006). For example, when asked if the weather had changed the way he harvested any foods, Charles Jack (Hoonah) responded that “we dried dry fish…you know, 6000, 7000 dry fish a year…the fish and game gave us a permit one time…they decide to put a limit on it, 25 fish for dry fish…my grandfather’s smoke house held 1400 cohos at one time, drying, we’d fill it up two times with cohos, sometimes two and a half times". However, the issues from participants around management and regulations are further discussed in sections 5.4.2 and 5.4.3, access/availability in changed distribution and behaviour in section 5.3.2, logging and land use in section 5.3.3, and overfishing in section 5.3.8.1. The effects of climate change are discussed in the next paragraph.

The variables affecting salmon abundance linked to climate change included warmer temperatures, acidic oceanic conditions, and a lack of oxygen. Ernestine Kato (Klawock) noted that king salmon in particular was less abundant "king salmon was plentiful, now today I got one, 2014, going back to all that, the climate, it's not getting colder, it's getting warmer", and Harold Martin (Juneau) attributed the lack of dog (chum) salmon abundance to acidic oceanic conditions: "they tell me now that all the…dog salmon are gone…they don't come back like they used to, very few, so I don't know what's causing that…maybe…conditions in the ocean, acidic conditions". While both these observations were linked to certain salmon species, all salmon species are affected by temperature (Scannell 1992), and both ocean and fresh-water acidification (Ou *et al*. 2015; Ratner *et al*. 2006). Recent research has even shown that for pink salmon in particular, acidification in fresh water can reduce yolk absorption in alevins, limiting growth capability and influencing survivability (Ou *et al*. 2015). It can also impair their ability to receive olfactory cues, which may limit their ability to sense predators and return to their natal streams (Ou *et al*. 2015), and for sockeye may supress behaviour around spawning, nest digging, and migration (Leduc *et al*. 2013). Ocean acidification also has implications in the salt-water food web and may decrease food sources of other species causing them to prey on pink salmon more (Haigh *et al*. 2015). Rolly Williams (Old Massett) observed that because there was an overabundance of pinks and cohos one year, they seemed to have died off due to a lack of oxygen in warm low water conditions: "it'll drop lower [with no input from snow melt], and it will heat up quicker, and it'll lack oxygen in the water, it'll kill all the fish…the fry and that, that live in there… the tributaries go down, and they dry out, and they lose the coho…like last year, we had close to a million pinks in the system, in the spring, with the coho and everything, they started dying off because there were too many in there, lack of oxygen, the river wouldn't go up…but when it did rain, it went too high". Charles Jack (Hoonah) made the same observation, however he instead attributed it to under harvesting the population due to regulations, and cleaning out the logs in the stream, providing more habitat for fish to utilise, leading to overpopulation:

"that was the main thing, to let some spawn out so we can take, and we took an average of 4000 from that river every year, my grandfather said for centuries they did that, and that river survived and it was really plentiful, and it wasn't a big river, white men came around and changed everything, now that river hardly gets any coho in it, what they did is they cleaned the logs out, and then they allowed over load into the river, and you keep overloading the river, they kill each other off, you know, suffocate, or whatever, you'd find them at the base of the river, just big piles of fish…not even spawned out…so but they can't blame the natives, but they can't blame the fisherman, it's the Fish and Games fault, you know…they let it over, over populate".

Decreasing oxygen levels in the ocean has recently been reported in the literature, and models predict it will decrease between 1-7% in part due to warmer temperatures (Schmidtko *et al*. 2017) and a massive increase in population numbers due to hatchery fish in the system (Ratner *et al*. 2006; Yale Environment 360 2010). In addition to the ocean, lower levels of dissolved oxygen have been reported in streams, again due to higher temperatures and increased fish concentrations, and with the added variable of low flows (Bryant 2009; Ratner *et al*. 2006). The full impacts biologically of a decrease in oxygen are unknown but could have large repercussions on fish stocks (Schmidtko *et al*. 2017). It has also been reported that large amounts of sediment scour the stream beds and create low oxygen levels which suffocate eggs, impacting population levels (Waples *et al*. 2009). Observations by the interview participants of these conditions in both oceans and streams leading to fish die offs are only reported in a limited amount of literature, mostly ethnographic (Bryant 2009; Ratner *et al*. 2006). However, there is enough surrounding evidence to suggest that these are big issues that we are only just starting to realise the impact on fish stocks. Since Indigenous Peoples recognise changes in their day to day lives, this place based, on the ground knowledge can inform policy and management, like in the co-management examples presented below, where Indigenous knowledge helps hone scientific policies regarding harvesting.

Similar to Charles Jack's (Hoonah) impressions of the abundance being influenced by the strict government regulations, Robbie Nelson (Metlakatla) talked about abundance in terms of how much he used to harvest compared to today, rather than the numbers he had seen, but noted that "years ago I would get probably 10 times as much done [processed] than I do now…so now…[I use] dehydrators, because the sun is just not there like it used to be". While in the above quote, Robbie Nelson is talking about the rate of processing being slower because the sun is limiting how much he can process, since many participants noted that the salmon population is decreasing, it could be extrapolated that not only are people not harvesting and eating as much due to a mix of preserving issues, the resource also is not there to be preserved due to the population decrease elucidated above.

5.3.2 Spatial distribution and behaviour change

There were two main factors affecting distribution and behaviour – the level of the water in the rivers, and the temperature of both the ocean and the rivers, although the effects of logging and stormy weather were mentioned very briefly.

5.3.2.1 Water levels

Firstly, water levels were influenced by both uplift resulting from isostatic rebound and from a lack of either rain or snow meltwater. In Chapter 3, it was seen that quite a few participants in the northern part of the study area mentioned the impacts of isostatic rebound on the landscape and their communities, but only one person noted a direct influence of isostatic rebound on salmon populations. Ken Grant (Hoonah) said that he thought the main effect on salmon distribution and behaviour was isostatic rebound, although he suggested it might have to do with an overgrowth of vegetation as well:

> "there's some streams that changed, but I think it's just uplift…there used to be a sockeye stream up bay…and it doesn't produce anymore, I don't know if it's because of uplift, or reveg[etation], or what's happening…so the sockeye doesn't return there anymore…there's some places up the bay where I used to run in and out of, oh I ran through there, it's shallow here! You know, it's getting shallower…yeah…that's uplift…and it is climate change, it's a long one, the glaciers are retreating you know…and it's all part of the picture"

Six participants that noted water levels were a factor in altered distribution and behaviour attributed this to a lack of rain and snow melt, which changes the amount of available habitat by limiting when and how far the fish could migrate. Under one climate scenario used to model a riverine system in Washington State (Gibson *et al*. 2005) it was predicted that there would be more water input into the river systems from winter rains, rather than snow melt, due to reduced water levels from snow into the future. Although in Chapter 3 there is discussion that there is more rain noted overall in this region, there are still issues with there not being enough rain for the salmon, but with even more reduced snow melt, rain might be vital to the ability of salmon to return up their natal streams. Rolly Williams (Old Massett), Harvey Williams (Skidegate) and Captain Gold (Skidegate) all discussed how the salmon had to wait until there was enough rain so that the water was high enough to allow them to enter, as illustrated below, and Rolly Williams (Skidegate) even joked that "it's just no good for us when it rains, because [of bad weather], it's good for the fish but not for us".

> "the salmon before that were sitting outside the creeks, waiting for rain, because there was no rain, and then…towards the end of September all of the sudden we start getting all kinds of rain, and then the salmon was able to get back up the stream" (Captain Gold, Skidegate)

> "this past summer, the water level's been low in the rivers, due to the lack of rain…and even now it's kinda low, you know, the salmon are starting to run, the river has got to be kinda high for the salmon to go into the river…[and] it's not" (Harvey Williams, Skidegate)

Captain Gold (Skidegate) also mentioned that the uncertainty in the rain is a factor as well – not just that there might not be as much rain, but that the timing of the rain is changing, and this is affecting salmon:

> "not as much rain, so to speak, which brings the salmon into the river…like just recently…um...some of the salmon were held outside because the creeks were getting too low…and then the rain started the last two weeks, and, kinda late for them to be going up right now, but they did…just in time…in the past there wasn't a worry about that, they used to be able to set our watch so to speak…and go out and do that…a little bit late this year…I think it has changed in that direction…but close to being the same" (Captain Gold, Skidegate)

One important and widespread observation, which was noted throughout the study region was a reduction in snow (see Chapter 3 for more elaboration of this abiotic factor in general). As directly relates to salmon, one consequence of this is the input into salmon streams from the snow melt, which was noted to affect salmon distribution and behaviour because of the lower water level, and the high temperature (discussed below). In terms of the effects of lack of snow melt, Helen Clifton (Hartley Bay) mentioned that "it's good for the salmon streams to get the snow", but Adam Greenwald (Hoonah) further explained why this is: "there was always snow on the mountains, you know, so consequently, your salmon streams is mostly fed by snow melt, [but they] are drying up [due to a lack of snow]…you know, so that is a dire effect on the salmon".

As we can see from the above, snow and rain inputs into the riverine system are both equally important and this linkage, along with potential impacts if less water enters the system, was illustrated in Anthony Christensen's (Hydaburg) comments:

> "I think there's a lot of species that have a high sensitivity and vulnerability to climate change, especially the smaller sockeye systems, and the smaller pink salmon systems, and the coho systems…because they all have a different habitat need[s], and with less rain fall, critical habitats [are] left dry…and so I think we won't see those impacts on

> those species, for a couple of years, with this low rainfall, I think survivabilities going to go down on salmon species, due to not having, well, good habitat…if you have big snowpack with runoff and good rainfall…those fish get to swim further in to protected zones, and food source areas, and you know get back up into the far reaches of wetlands, and get themselves big and then flush [flesh] out [in the] spring water and then they migrate out…but with…less [of] all of those other things, I think it's going to start to show in the future with the fish stocks"

5.3.2.2 Warmer water temperatures

Secondly, warmer water temperatures both in marine saltwater and freshwater spawning streams were mentioned by ten participants[70] (relatively evenly scattered between the NSE, SSE and HG geographical regions) as having an effect on distribution and behaviour for salmon species as a whole, but also contributing to disruptions in the amounts and times people were able to fish. In the literature, increased temperatures have been shown to affect salmon's physiological processes, such as stress levels, disease susceptibility and progress, and the costs of migration (Reed *et al*. 2011). While in general salmon throughout their entire range are affected by variables relatively similarly, there has been some suggestion that the distributions of northern and southern populations may be responding to temperature changes in different ways. Northern populations have increasing growth and survival rates at higher sea surface temperatures, and southern ones are decreasing in their growth and survival rates (Martins *et al*. 2012). In my research, temperature was primarily described as affecting salmon because they swim deeper to reach the colder water, thus altering people's ability to catch them. Anthony Christensen (Hydaburg) said "we've been having a hard time catching a lot of fish sometimes, because…they are staying deeper then they normally [do], and they aren't showing and jumping and behaving like they usually do, because the fresh water is so warm due to the lack of snowpack up there, melting". A2 (Old

[70] A2 (Old Massett), A3 (Skidegate), A9 (Juneau), Myrna Yates (Craig), Marvin Kadake (Kake), Arnie Bellis (Old Massett), Anthony Christenson (Hydaburg), Reg Davidson (Old Massett), Cora Joseph (Klawock), Ernestine Kato (Klawock)

Massett) thought that this change had been happening in about the last 10 years: "in the last 10 years I guess, we are starting to notice that the spring salmon are starting to go deeper, so the water temperatures are too warm, up above, so the fish were starting to go a lot deeper to where they normally go". However, others did not attribute a timescale to the changes, and it is likely hard to determine exactly when the salmon started swimming deeper due to the variability of their annual cyclical dominance. While in general the salmon are swimming deeper, sometimes they still come closer to the surface, perhaps drawn up by food sources (A3 (Skidegate)), although Cora Joseph (Klawock) said the depth would vary depending on rain: "if it rains, they're going to get a lot of fish…but if it's hot, they are way down [deeper in the water column]".

Sometimes participants described the issue that they might have permission to fish, as the government had counted the fish in the rivers and the run was healthy, but the fishers themselves were finding hardly any fish, which was attributed again to the fish's habit of swimming deeper in warmer water, and thus the impact was that they were avoiding the nets:

> "there's supposed to have been a big run, and we're fishing, and there wasn't that much fish we were catching, but it was supposed to be a big run, but when they were counting the escapement up in the river, there was tonnes of fish up there…when they came in, they went deeper…because the waters too warm…and at the rivers [mouth], because it's getting warm in here, if we don't have the rain when they are running up, they won't go up, cause the waters too warm…so eventually we aren't going to have fish either, if the temperature keeps rising [because there's fewer up there spawning]" (Reg Davidson, Old Massett).

However, one adaptation that people were making to account for the salmon swimming deeper was to use bigger (and thus heavier) leads, as described by A9 (Juneau):

> "down around Kake, we just use small leads when we are trolling…up here [Juneau], you gotta use big lead…cause the fish…the water temperature…they don't like warm water…they go down [deeper] where it's cold"
>
> "salmon, they don't like the warm water…my grandpa used to tell me on sunny day, he said you're not going to catch any king salmon, because they go down deep…I haven't caught a king salmon forever…you gotta troll deep for them".

5.3.2.3 Connection to changing spatial distribution

Most of the above observations did not specify the species of salmon, and thus it was assumed that as a functional group all five species of salmon were affected in similar ways, and only two species were specifically named in interviews as influenced by a changed distribution and behaviour. Perhaps, rather than a certain species being more affected, Anthony Christensen's (Hydaburg) quote at the end of the reduced water level paragraphs above shows that perhaps the size of the stream might be a bigger determining factor in both distribution and abundance than species, which may be why fewer participants listed a species in their observation. For distribution, warmer water was causing the chinook to swim deeper, leading to a reduction in peoples' ability to fish them (Arnie Bellis (Old Massett), A9 (Juneau), A3 (Skidegate), Ernestine Kato (Klawock)), and for behaviour Cora Joseph (Klawock) said that when they had first moved to Klawock she noticed that "the humpies [pink] were just like popcorn…jumping, and I haven't seen it like that since", but she was uncertain if this was caused by lower abundance, a behaviour change, or her observation that there was now a lot of coho in the area, which she thought might be 'blocking' the humpies (pink). Two other people noted a lack of this 'jumping' behaviour as well (Fred Hamilton (Craig) and Anthony Christensen (Hydaburg)), further discussed in other sections.

Third and lastly, while the main effect of logging is on the quality of the habitat, and thus is more fully discussed in that section, it was briefly touched upon by Captain Gold (Old Massett) as affecting distribution and behaviour. He suggested one reason that salmon were being found further away from human development, and sometimes not even returning to the streams, was due to logging impacts: "salmon, we don't get them coming back into the streams as much as we used to, because of the logging, so further away that has less impact on logging, is where we'd find the salmon". Similarly, the main effects of stormy weather can be found in section 5.3.5.1, but A9 (Juneau), was the only one to mention stormy weather affecting the fish's behaviour directly "we like to go out for king salmon, but there's too many [rainy days]…they depend on the weather".

5.3.3 Quality of Habitat

In addition to observations regarding changed distribution and behaviour, including the quantity and accessibility of habitat, another important characteristic was the quality of the habitat. In the interviews, observations about quality of habitat were often linked to two main issues – logging and mining, however some participants also considered the lack of rain to create an unsuitable environment for salmon, thus lowering the quality of the habitat.

As mentioned previously, temperature and stream flow are important habitat characteristics for salmon, and in addition to the amount of rain and the overall air and water temperature changes, they are also affected by riparian vegetation and features. It is important to have trees and shrubs along the bank to provide shade and bank stability, and if this buffer is gone, via logging or windthrow, streams and lakes heat up and rain can wash wood debris or sediment into the streams, both of which affect spawning stocks (Brock and Coiley-Kenner 2009; Bryant *et al*. 2008; Gibson *et al*. 2005; Langdon 2006; Ratner *et al*. 2006). One major landscape change which is an anthropogenic influence, but which exacerbates climate change effects is logging, which was noted in the geographical areas of HG and NSE. Four people (Harvey Williams (Skidegate), Michael Jackson (Kake), A2 (Old Massett), Captain Gold (Skidegate)) mentioned logging in their interviews, and people were divided on how much they felt logging was affecting the habitat quality. One person in Skidegate (Harvey Williams) felt that logging didn't overly affect animals, because of the buffer zone regulations around streams "we can't log near the rivers where the salmon run…they watch us real close on that", however the other three people (in Skidegate, Old Massett and Kake) thought logging had affected salmon negatively, and in three different ways.

Firstly, Michael Jackson (Kake) noted that the history of logging in the 1950's and 1960's had affected salmon runs due to changing the 'chemical make-up' of the streams with chemicals in the drainage from roads and logging: "we knew they were changing the smell of the rivers, the creeks…on the salmon, or they were building roads and shooting [blasting] rock, and all that powder is getting into the stream". He also noted that this impact seemed to be more pronounced on chum, coho, and sockeye, and runs of king seemed to be ok. It has been well-established that salmon return to their natal streams for spawning likely via olfactory cues (Bandoh *et al*. 2011; Dittman and Quinn 1996), although there are other hypotheses, such as the odour being specifically from amino acids (Yamamoto *et al*. 2013) or the result of immunological memory (Zwollo 2012). While it has not been reported in the literature how changing the 'smell' of the stream may affect salmon, higher levels of CO2 have been shown to affect the olfactory sense of salmon (Ou *et al*. 2015; Williams *et al*. 2019). The changing 'smell' as reported by participants may greatly impact the return rates of salmon into certain streams if their ability to detect the signal, or the signal itself, of their natal stream changes.

Secondly, both Michael Jackson (Kake) and A2 (Old Massett) mentioned that because vegetation had been removed from the system via logging, this impacted the temperature and shade value of the stream: "I think logging did…more problems to the island than anything…cause when they logged off the majority of the lakes, they thinned out the sockeye runs quite a bit too…because sockeye need greenery and shade to thrive in the lakes…they wiped out quite a bit of our stocks, and then one river, they wiped out completely, we had no more sockeye" (A2, Old Massett). A2 also added to this, mentioning that in an attempt to correct the issues created by logging, people fertilized, which added to a new set of problems:

"our lake on [the] island, and what they did with that is they logged right out all around the lake, and when they started getting complaints when our sockeye [was] dropping off and dying, they went and fertilized the lake thinking that would help the sockeye that were left there…that fertilizer, all it did was increase the stickleback, and the sticklebacks started doubling and tripling in population, so which pushed out the small fry and whatever was left…and then killed those off, choked out the river, the lake".

Michael Jackson also noted "it's warmer, when they took all the big trees out of it". While A2 (Old Massett) was only commenting on sockeye in their lake phase, this observation, as is Michael Jackson's, is relevant to all species in all the stream systems due to the importance of maintaining the appropriate range of abiotic and biotic variables for salmon development and reproduction. Temperature in particular is tied to rates of development, the impacts of which on salmon has been fully explained above (section 5.3.2.2).

Thirdly, Captain Gold (Skidegate) described how areas with a past history of logging were prone to slides and erosion when there is a large amount of rain, bringing more sediment into the system, which affects the salmon: "it's really a lot of rain, and slides are going to be happening very quickly, which will affect the streams, and the spawners and what not…because all the old logging, over 40, 50, 60 year[s of] logging now, the roots are losing their hold, and the rainfall coming down is overloading all that, and it slides, so if any more slides happen…[it] is going to affect the salmon spawners". In the literature, there was discussion of how sedimentation from increased winter rain flows may both scour and cover the eggs, and landslides and wood debris can block a channel or stream (Bryant 2009; Gibson *et al*. 2005; Ratner *et al*. 2006; Waples *et al*. 2009).

Mining in Alaska was noted as detrimental to salmon stocks in two ways. Evans Kadake (Kake) noted that chemicals "kill the eggs, it kill everything, no mercy", a drastic impact which may result if the proposed Bristol Bay Pebble mine ever goes ahead, and A3 (Skidegate) discussed that the mining that occurred in the Copper River during the early part of the 20th century had caused silt and mud to settle on top of the eggs, starving them of oxygen and thus severely decreasing the sockeye population in the Copper River in the past (see Bryant 2009; Waples *et al*. 2009 for impact of sediment on eggs).

However, on the other extreme, two changes to the quality of the habitat have increased the number of salmon and had a positive impact, both of which are tied to an input of nutrients. The first input was ash from a volcano that Robin Brown (Old Massett) said erupted in 1948, adding nutrients to the ocean off the coast of Old Massett: "I'll tell you a little story – in 1948 when we were fishing Langara, there was that Mount Rainier, you know, up in Alaska, the volcano?...and there were a lot of this little white pebbles [pumice] drifting in the water there, light, floating around, and that year was a huge year for salmon…cause they are eating that stuff out of that [volcano], that iron…". It is uncertain exactly which mountain that Robin is referring to, as Mount Rainier exists in Washington State instead of Alaska and has not erupted since the 1890s. It is thought perhaps he is referring to one of the eight volcanos along the Aleutian Islands which erupted in the mid 1940's[71], at varying distances to Haida Gwaii (Wallace *et al*. 2000). While it is not well studied, there has been some discussion about the short-term positives of volcanic ash contributing iron enrichment, which then improves phytoplankton growth, starting a cascade through the system (Olgun *et al*. 2013). However, some negative impacts on salmon from large amounts of water and sediment entering the riverine system from glaciers and snow fields on the edges of the volcanos have been noted, in particular from an eruption of Alaska's Mount Redoubt in the 1980s-90s (Dorava and Milner 1999). Another more recent description of volcano ash increasing salmon productivity was of the 2008 eruption of Mount Kasatochi on the Aleutian Island, Alaska, which is thought to have caused a record return to the Fraser River watershed of over 34 million salmon, the highest return record since 1913 (Larkin 2010; Olgun *et al*. 2013; Pacific Salmon Commission 2015). This particular episode was also mentioned by an

[71] Mageik, Veniaminof, Pavlof, Shishaldin, Akutan, Okmok, Cleveland, or Great Sitkin

anonymous guest who visited during a portion of Robin Brown and A1's (Old Massett) interview, who specifically discussed this plethora of salmon in the Adams River, a part of the Fraser watershed: "because there are places that hadn't had salmon for decades…like the Adams River, 'what, we got fish this year?!' you know stuff like that, where they haven't had fish for decades, they had fish… so something happened here". Although they did not mention a year for their observation, they were likely referring to this bumper return in 2010.

The second input was an ocean micro-nourishment replenishment scheme implemented in 2013/2014 in the hopes of mitigating climate change, which involved dumping "100 tons of iron sulphate, and 20 tons of iron oxide" into the ocean near Old Massett to increase carbon and phytoplankton production, and ocean productivity, and thus salmon food (Haida Salmon Restoration Corporation 2017). Both Robin Brown and A1 (Old Massett) observed that the year after this happened (the summer before the interview took place) there appeared to not only be larger and increased numbers of all fish, but also fish re-appearing in places they had become scarce:

> "Robin Brown: well, it's, you know it's unbelievable, even when I was halibut fishing last spring, he came in with humongous yelloweye… I've never seen them that big!
> …
> A1: yeah, never seen them that big – some of them are 50 pounds at least, even the black cod…50 pounds, you ought to thank our chief councillors for dumping the iron out there, we've got so much big fish
> …
> Robin: yeah, black cod same thing…they fed all the fish on the coast"

While not directly tied to climate change, warmer water is also less nutrient-rich and thus less productive, which could contribute to decline in salmon, and thus volcanic, iron, or other 'inputs' potentially could reverse or limit this trend. Initially this seems like a positive outcome and may be seen as an extension of applying TEK to new technology. However, there was uncertainty and controversy among interviewees about how actively engaged in such ocean engineering human communities should be, inputs of this type may disguise the true effects of climate change, and we have yet to learn what the long-term effects are of these types of interventions. There has been a great amount of controversy over this particular Old Masset enrichment programme, including its legality (Abate 2016):

> "such a tremendous amount of fish this year! The halibut, and some guys were out there fishing halibut, they were loading 50-foot boats in one night, one day!...You know the reason they are so mad at the Haidas over that? Cause the scientists wanted to do it, but they were chicken…so the Haidas went out there and did it, that's what they're mad over, but they seized their office in Vancouver and took all the documents…so the poor old scientists, now they can look at that…it has proven some people…so there is a possibility that what the Haidas did was, well, Masset, not all the Haidas…the ones down the south end, they don't kinda support us in this, but, um…the thing is, these guys had the guts to go out and do it, and prove something…and I think it proved itself…everybody's very silent about this though, I don't know what's going [on]…" (Robin Brown, Old Massett)

5.3.4 Size

Overall, five participants noted that salmon had decreased in size, with observations based on personal catch and local derby records. These observations were primarily made in the geographical region of NSE, with one from HG, and were also commented on in the ethnographic literature (Brock and Coiley-Kenner 2009). Both Catherine Bolton (Hoonah) and A9 (Juneau) referred to how the size of the winning fish in the local derbies had steadily decreased over the past few decades: "they have an annual derby…one year they had 31 pounds [14.1kg], and then 29 [13.2kg] pounds, last year it was 27 pounds [12.2kg] won it, this year it's 26 [11.8kg]…25 [11.3kg], or 26 [11.8kg]…so the fish are getting smaller" (A9, Juneau). Examining records from the Golden North Salmon Derby (in Juneau, Alaska), the only online record of a fishing derby that was located, it was also found that there was a steady decrease in the size of the winning fish. The winning fish in 1947 was 38 lbs, 4 oz. (17.3kg) and between 1947 and 1977, the winning weight varied between 30 lbs 5 oz. (13.7kg) and 59 lbs 8oz. (27.0kg). Between 1977 and 2008, the winning weight varied between 26.5 lbs (12.0kg) and 38.7 lbs (17.6kg), with only three years having a fish caught that was greater than 40 lbs (18.1kg), and since 2009, the winning weight has not been greater than 30 lbs (13.6kg) (www.goldennorthsalmonderby.com 2019). These derby results from Juneau support the observations made by people that salmon are getting smaller overall.

A9 attributed this smaller size for his personal catch and the derby catch to the higher water temperature: "they are getting smaller…I have…a little boat, and…the propeller tells you how fast you are going…[and] it also tells you the water temperature…it will be, like 48°F [8.9°C]…once in a while, 46°F [7.8°C], then in the afternoon, it will go up to 54°F [12.2°C], 56°F [13.3°C]…that's really warm…too warm". Scannell (1992) also discussed the effect of temperature on various aspects of salmon fecundity and growth patterns, more fully discussed in the temperature section (5.3.2.2). However, relevant to size, Scannell (1992) determined that alevin absorb their yolk faster at higher temperatures, sometimes even starting to re-absorb their body tissue if the food source from the yolk has been used up and the alevin are not able, or ready, to access other food sources, leading them to emerge from the gravel when they are smaller. Higher temperatures also lead to fry migrating to the ocean sooner, when they are smaller, and thus are more vulnerable to predation (Scannell 1992). Harold Martin (Juneau) on the other hand, had another explanation for smaller size, and thought it was due to as much as 80% of the incoming fish population being from a salmon hatchery, which are smaller fish. Sandra Williams (Skidegate), the sole Haida Gwaii participant with this observation, said that the fish were on time, but smaller now.

Only one person commented on variation in the size. A12 (Hoonah) thought that some of the salmon were getting larger and some were getting smaller but did not attribute this size change to a certain feature: "I notice the size of the salmon is getting…larger, the dogs [chums], silvers [cohos], pinks, have increased in size a little bit, maybe by a pound or two…and the king salmon on the other hand has declined…numbers and size…and the catch, so, I don't know how that relates there".

In addition to warmer water temperatures and smaller hatchery fish present in the system, the phenomenon of decreasing salmon size could potentially be linked to the impacts of overfishing (Kendall *et al*. 2009), although this was not specifically mentioned by anyone in the interviews.

5.3.5 Harvesting

People's ability to harvest was affected by several factors, including the weather being too stormy to access resources, the timing of when salmon were returning to spawn changing, different species altering their yearly pattern, governmental fishing regulations, and impacts from overfishing, which are discussed in the following sections. In addition, it is energy intensive to harvest, as stated by Evans Kadake (Kake):

> "and then going out afterwards, on the boat, and going on the river, and buying gas…there's a lot to going out after fish…you have your own boats, your own engine, buy your own gas, lunch, life jackets, oars, stuff like that…a good motor, make sure it runs [well], make sure it has a radio, or telephone, make sure it's operational, have enough food, especially survival gear"

These considerations impact people's ability to harvest. A very similar comment to this one can be seen in section 5.3.7.1 (overfishing), made by Captain Gold (Skidegate), explaining how the pressures to have all this equipment and provide fuel has been listed as a contributor to the need to overfish to compensate for expenditure. The issue of increasing fuel prices was also noted in the literature, causing harvesters to go shorter distances and spend less time harvesting, and if they are wanting to gather adequate fish they must travel further and for longer than before (Brock and Coiley-Kenner 2009).

5.3.5.1 Stormy weather

People primarily felt that stormy weather affected their ability to access the resources, as mentioned by A1 and Rolly Williams (both in Old Massett) who felt that it was harder to harvest if the weather was stormy or not typical, as they "always depend on it [the Indian Summer] when we fish" (Rolly Williams). This was also explained by A1: "with food fish we just wait for a fine day to [fish]… [but] they are there all the time…like right now there's a lot of salmon out there, but you can't get out there and get them". However, if people are dealing with stormy weather and they have to travel further for resources, as Evans Kadake (Kake, cohos and sockeye) and Robbie Nelson (Metlakatla, everything except sockeye) felt they had to, it could make harvesting riskier or impossible (Turek *et al*. 2006), and A9 (Juneau) described a time when they couldn't fish due to stormy weather:

> "I remember one time we went after sockeye in May, the weather was really bad, we were stormed down 5 days I think, the plane had to come and get my son and my father-in-law, and me and another guy we stayed a couple more days, and then it finally calmed down, and we could go across".

A9 also said one elder had told him of an indicator for stormy weather: "so she said it's going to be stormy tomorrow, I said how can you tell? She said, when the raven is flying like this…and then it turns over, like this [makes a little turn]…she said it's predicting the storm, you'll see, next day, wind and rain, wind and rain…and she was right…so even now, watch fall time, watch for raven".

5.3.6 Timing of Salmon

Similar to the abundance observations, there were differences to how people thought the timing of salmon coming back into the nearshore zone after maturing in the ocean had changed. It was split almost equally for the number of people that said there was a change in timing, and the number of people who said there was no change in timing, although the geographic distribution of each type of observation was slightly different. While in this section I am discussing the variation in the specific time of year or month when the salmon are returning, the reasons behind this change are influenced by the biological and ecological factors mentioned above, such as low water levels delaying return, or temperature driving them deeper in the water column. Captain Gold (Skidegate), who thought that the timing was not changed overall, discussed that there were some issues which might prevent the salmon returning in a certain year:

> "[it's] close to being the same and what not, because the only difference is, it's a little bit warmer than when I was in my youth and so on…and therefore not as much rain, so to speak, which brings the salmon into the river… some of the salmon were held outside because the creeks were getting too low…and then the rain started the last two weeks, and, kinda late for them to be going up right now, but they did, get [it]…just in time".

This indicates that the weather (and in response water levels), play vital roles in determining return timing of the salmon species.

5.3.6.1 No Change in Timing

Five participants felt that the timing had not changed, almost exclusively in HG (Sandra Williams (Skidegate), Captain Gold (Skidegate), A1 (Old Massett), Robin Brown (Old Massett)), with only one observation in NSE (Charles Jack (Hoonah)), illustrated by Robin Brown's (Old Massett) statement "they are there all the time...the cycles, they never change". However, A1 (Old Massett) further stated that while he thought there was no change in timing overall, the majority of the differences in salmon being available to harvest was dependant on their yearly cycles, "some years they are kinda late, but not…I mean, there's a difference every year…it seems to be different every year…but they always seem to come, but sometimes they come late, sometimes they come early, it doesn't change".

5.3.6.2 Change in timing

Overall, 23 participants said that there had been a change in the timing of salmon returning to spawn, and thus impacting when they harvested them, primarily in NSE (9), followed by HG (8), SSE (5) and MBC (1). The geographical disparity of these observations shows that a change in harvest time is recognised across the broader study region. However, three participants discussed a change in timing of harvesting without reference to the species in all of their observations, and thus the inter-species variation has not been captured for every observation. Fred Hamilton (Craig) noted that he recalled that he hadn't seen any 'jumping' in the nearshore (a habit often displayed by cohos) by the date of the interview in September, so didn't know if the fish were late coming in or not, but thought the fisherman had had a good fishing season that year, despite him not seeing this trademark behaviour (and thus potentially the fish may not have come into the nearshore yet):

> "that's changed too [the salmon coming in at the same time], like this summer, we have quite a few salmon streams around here, and especially in the fall of the year, when they come in, coming back home to the streams, they are always jumping…I never seen one jump this fall…not one jump…they are either late, or…I can't quite understand what's going on…but they had a good fishing season".

Anthony Christensen (Hydaburg) said that not only are they altering their distribution and behaviour, described above in section 5.3.2, but also their timing: "…they ran late this year, and then they ran sporadic, because of the temperature of the water…and they stayed deep so we couldn't harvest them…stayed deep, and they were erratic, don't want to go in the river…so their whole…normal pattern was totally disrupted…it's been the last couple years". Adam Greenwald (Hoonah) mentioned three species of salmon, but didn't specify at what times they arrived, just that you got fish at different times: "at the head of Tenakee Inlet there's several rivers, and creeks come out there, and one of them is solid cohos, the only thing that goes up there is cohos, and then there's a bigger river that's got dog [chum] salmon and humpies [pink], and everything going up it, and so then, there was a smokehouse, I mean, they get different fish at different times".

The remaining 19 participants did identify the species when talking about timing. These observations were primarily about recognition that the dates of the main harvest had moved, and concerned chinook, coho, sockeye, and chum. Surprisingly, pinks, despite being a very abundant salmon species, were the only species to not be specifically mentioned as having a changed timing. While it would be expected that these observations would have differed in the four geographic sub-regions, observations were more separated along a species division. Chinook was only mentioned by one person, A4 (Hoonah), who commented that they used to know when the run was, but they don't know anymore, but no more specifics were added.

Coho were only mentioned in three communities[72], Kake, Skidegate, and Old Massett, but despite the vast distance between these two communities, almost everyone that mentioned them said that they were coming in later than normal (also noted in Brock and Coiley-Kenner 2009). A11 (Kake) said that cohos had moved from June or the first week of July to September. Pearl Pearson and Lorna Berekoff (Skidegate), interviewed together, said that 'coho time' was late but didn't specify by how much. Harvey Williams (Skidegate) thought that cohos had moved even later than September: "so it's the same ones coming in different parts of the year… right now there's…coho salmon, starting to come into the inlet here [in October]". However, Lionel and Nancy Bean (Kake), noted that the cohos were not only moving later, but also having a longer harvest period in some cases:

> "Lionel Bean: we still hear about, well, cohos we thought we'd get about a month ago, now, they are still showing up, and we're not exactly sure why
> …
> Nancy Bean: right after the 4th of July, we used to be able to go out on that point, Point McCartney".

Wilber Brown (Kake) was the only participant who didn't specify that coho had changed: "After, um…some of his fishing is done, we're done with commercial fishing, in, the last week, second week maybe, the last week in September, we go to Security Bay and get our dog [chum] salmon, and cohos". Reg Davidson (Old Massett) did not specify the particular timings of coho but illustrated its tie to the yearly harvesting cycle: "and our language,

[72] A11 (Kake), Lionel Bean (Kake), Nancy Bean (Kake), Pearl Pearson (Skidegate), Lorna Berekoff (Skidegate), Harvey Williams (Skidegate), Wilber Brown (Kake), Reg Davidson (Old Massett)

is…almost [all] of it is history, because I remember Robert asking this guy what the name of the coho was, he said I don't know what the name of it is, because I don't know when it ran, so that determined when the time of the year that it ran, about the name of it".

Concerning sockeyes, Myrna Yates (Craig) commented that: "Humpy [pink] and dogs [chum] [are] usually in August…[and we are] overwhelmed with them, but still catching sockeye…they say some of it came in early, but even in the last part, of August, they were still catching sockeye, and that['s] unusual…you know, because usually it's overwhelmed with…humpy's [pink] and dog [chum] salmon…yeah, and they were still catching sockeye…even on the last day of fishing they were still catching sockeye". This observation of sockeye arriving later than normal was borne out in the literature (Brock and Coiley-Kenner 2009). In addition, A3 (Skidegate) said the sockeye peak had moved from the week of the 24th of May to about a week later, and A9 (Juneau) said "they used to get sockeye [by the] 1st of May, now we get sockeye June, July". Margaret Edgars and Emily Watts (Old Massett) both observed that the indicators of salmonberries and starlings around sockeye had moved, but not salmon themselves:

> "Margaret: I think it's later in the year now [then] it used to be, when we used to go for sockeye? The salmonberries used to be ripe then
> Emily: oh yeah
> Margaret: now it's later, [they used to ripen in] May…[and now it's closer to]
> Margaret and Emily: June, June
> …
> Margaret: there wasn't as much sockeye going up the rivers like they used to, I don't know why
> Emily: you see all those starlings flying around here
> Margaret: there used to be fish going up by the hundreds
> Margaret: no, we used to, everybody used to get over a 100 fish for their families…not anymore".

Sockeyes were more split in observations than cohos, with participants saying they had come earlier and later. Later runs were observed in both SSE and HG, whereas early runs were only commented upon in SSE. The two people that described earlier runs discussed both overfishing and mis-regulation as factors. Fred Hamilton (Craig) identified that there were two runs, and the early run was being more affected than the late runs, but he attributed this to overfishing: “seems like there were…every year…red salmon is a real popular thing, especially for the local people for food, and Klawock River has an early run of sockeyes and a late run…and it seems like the early run is getting smaller every year, I think that’s because it’s overfished too, because what happens is, a lot of the local people move away, move down state for employment…but when sockeye season comes, they’re all here, putting up sockeyes, now all of them aren’t here, but the family puts it up for them…and I think it’s just being over fished you know”. Cora Joseph (Klawock) noted that salmon had already run up the streams before the season opened, so people were having to fish for them in the stream rather than in the nearshore: “and some of the people, you know, back, oh, say, early July, right after the 4th, they have to go upstream to get the sockeye, because the sockeye already runned up…even before the season opened…and they wait until after the 4th to open it [the fishing season]…they should open before it”. The last two participants to mention were located in NSE and did not note a change in timing, simply noting that they were harvested in June and July (George Davis (Juneau), Wilber Brown (Kake)).

Chum salmon were only reported as having changed their timing by one participant, and most people only noted a variety of dates of their return: August (Myrna Yates, Craig), September (Wilbur Brown, Kake), and October (Harvey Williams, Skidegate). Adam Greenwald (Hoonah) said they were the last salmon to come in in the autumn. Alma Cook (Klawock) thought chum salmon had moved from 21 June to after 24 August: “June 21st we were all done with our salmon pack for the winter, this year it was so bad we got very little, but I had a young boy just come and tell me he got me some salmon eggs, and the fish are just coming in…he said the dog [chum] salmon are just coming into Chalmey, it’s surprising, so late”. In addition to observations about timing, two people noted having ‘super-sized’ chums: “you know, there’s places like Security Bay in Kake where we used to get our dog [chum] salmon in the fall time, because there are big super dog [chum] salmon there…14, 15 pounds (6.7-6.8kg), big fish…we took scale samples, and found out they were 5-year fish…normally they’re 4 years” (Harold Martin, Juneau). A11 (Kake) recalled that her grandparents had a big smokehouse to accommodate these larger chums. Harold Martin (Juneau) also said that he had been told that chum salmon were no longer at Security Bay in current times.

Lastly, there was one observation about the intensity of salmon returning, from Robin Brown (Old Massett): “our salmon, usually our peak is July, that’s another big thing, end of July and first week of August, that’s our season, in Metlakatla, that’s totally changed…there isn’t a peak no more, it’s either a steady run of sockeye for the whole summer, or they come in spurts…you know, and before we were able to just wait for the last week in July and the first week in August, and those two weeks we would make a killing, like, 20, 30 thousand dollars each week”.

5.3.6.3 Overlap with other resources

Because quite a few participants noted that the timing of fishing was changing, sometimes this led to overlap with other resources, making harvest of one harder to do, as seen illustrated by Anthony Christianson (Hydaburg):

> “just like, with the fish, you know, the salmon species, that makes it difficult, because you target windows, you know, traditional times, and when they’re not there then it disrupts the whole harvest pattern…because you have other things that you want to harvest, and when you’re not successful at the time when you’re supposed to be, then it pushes everything off, you know, so, part of the reason we didn’t get all the berries we needed was because there was such a disruption in the fish this year…it put off the other activity of berry harvesting, even though they’re there, you know I’m still trying to get the other needs met”.

He further explained that this overlap was because the fish are not behaving the way they are supposed to and seem to just be going up the river whenever they have a mind to: “the overlap is just because I'm trying to catch this fish, and he's acting funny…so he's not coming and doing his thing when he should be….he's coming whenever…he's comfortable getting up…the river" (Anthony Christianson, Hydaburg). This overlap may potentially lead to harvesters choosing some resources over others, perhaps pushed by ease of harvest, commercial fishing prices set by external forces, resources that provide higher nutritional value, or resources with less strict regulations, and losing out on the full range of their traditional foods.

5.3.7 Diseases

Participants noted several instances of diseases within salmon populations. These included white spots or blisters, flies and worms getting into the meat while processing, and poor quality of meat. These observations were from NSE, HG and MBC, and both 'white spots' and worms in the meat have also been reported in the literature (Langdon 2006; Ratner *et al*. 2006).

Four participants reported the white blisters or spots. Harold and Jacque Martin (Juneau), who had mentioned the possible presence of brucellosis in seals (see discussion of this disease in Chapter 4), also mentioned that salmon might be prone to this disease as well: "we see that in salmon too, you know…I had some salmon and there were white spots all over the meat" (Harold Martin, Juneau). Jacque Martin (Juneau) reported: "I can't think of any other species that have been infested, I'm sure there are…I've seen salmon, but then that's, time immemorial, probably, that they've had…especially for sockeye or king salmon, [they] have…high risk". While brucellosis is quite common in marine mammals and ungulates, incidences in fish have been rarely documented in the literature (Norman *et al*. 2018), but there is a suggestion they may act as a vector of the disease if they become infected from another organism in the Nile (El-Tras *et al*. 2010), and this may be applicable in fish in the North Pacific. A11 (Kake) reported that she had seen, both in person and on facebook "little blisters, little white fluid filled blisters …just full of it…I've only seen it once…but I've seen it on facebook too…and I wouldn't eat it…I wouldn't use it", and Carol Young (Skidegate) said she had seen come sockeye with little clear cysts about six years ago. Catherine Bolton (Hoonah) also noted that warmer water was causing scale loss in coho.

Four observations regarding the quality of the meat were made. Robbie Nelson (Metlakatla) mentioned that because there are more flies around (likely due to the warmer air temperatures), they get into the meat more when people are processing the salmon: "cause we got to dry our salmon…we always try to do it early…maybe from the middle of May, maybe even earlier because there's no flies…but now there's flies…[and they get in] and they lay their eggs in there, and they get all these nasty little worms". Owen James (Hoonah) said that people can catch and eat the salmon as much as they like, but they will never get full, because the hatchery salmon meat "turn[s] to mush" (also mentioned in the literature by Brock and Coiley-Kenner 2009; Ratner and Dizard 2006), with seals having the same problems, and A9 (Juneau) agreed with this assessment "the farmed fish, when you put it in [the] smoke[house]…the meat falls off the [bone]". While the above observations were generalised to salmon as a whole, Arnie Bellis (Old Massett) made remarks on a specific species, that in warmer water sockeyes have more worms in their stomach: "the sockeye, the warmer the water the more worms they get in their stomach".

5.3.8 Non-climatic effects on salmon

While many non-climatic effects such as logging and mining were repeatedly mentioned throughout the interviews, they were interwoven with climate factors, and thus have been primarily discussed above. Two variables that weren't as closely tied to climate but were mentioned repeatedly were overfishing and contamination.

5.3.8.1 Overfishing

One of the factors that greatly influences abundance and distribution that is not climate related is overfishing. As seen in the profiles of each species, salmon are highly utilized by several user groups including commercial, sports, and subsistence fisherman, and there is often conflict between them in the amounts of fish they are extracting from the system (Johnsen 2009; Ratner *et al*. 2006, Turek *et al*. 2006). While there are many reasons for overfishing including high demand for seafood worldwide, more efficient technology, and poor management historically, it is not a simple issue (Finkbeiner *et al*. 2017). Captain Gold (Skidegate), from further south in the Haida Gwaii region, covers most of these issues with his explanation of what, in his view, was the main driver of overfishing in his area: "commercial license people, they're over harvesting because the stocks are getting lower in numbers, so they have to make the amount just to make their payments on new boats, new technology…new nets, so everything costs money, fuel, everything, wages, just a bad picture". These issues were also seen with subsistence fishermen, who have to harvest a certain amount to pay for their boats and equipment. The increase in commercial fishing is also credited with making subsistence harvesting more difficult, coupled with increased costs of fuel (Brock and Coiley-Kenner 2009). With more recent sustainable management initiatives and collaborations between organisations (Alaska Marine Conservation Council 2019; Marine Plan Partnership for the North Pacific Coast 2019; Marine Planning Partnership Initiative 2015; Sustainable Southeast Partnership 2019), and certain types of fishing such as trawlers having been banned in some areas (North Pacific Fishery Management Council 2012; Sitka Conservation Society, 2012; Stiles *et al*. 2010), it is hoped that some fisheries will recover.

Many local people in this region participate in this economy and work seasonally as commercial fishermen. With such a long history of commercial fishing in the area, and in fact world-wide, overfishing is an ongoing concern which is only exacerbated by the presence of sports fishermen, and several participants in both NSE and SSE highlighted the role of sports fisherman and charter boats in overfishing the resource (Turek *et al*. 2006). Harold Martin (Juneau), A9 (Juneau), Ernestine Hanlon Abel (Hoonah), Wanda Culp (Hoonah), and Cora Joseph (Klawock) discussed the large amounts which are shipped out of Alaska, after having been caught by charter boats, and the overfishing done by this sector of fishermen: "a charter boat will go out and they'll get…bass and cod, and they take everything…you can go to the airport even here, and you'll see boxes…boxes and boxes of fish…down there, from charter boats…they are overfishing!" (A9, Juneau). Wanda Culp (Hoonah) expressed frustration that "they're taking boxes and boxes and boxes and boxes of seafood down with them out of here, boxes, every year, boxes, piles of them…and they watch us like a hawk" with regards to the strict regulations around subsistence harvest and set harvest limits. Cora Joseph (Klawock) acknowledged that the people have paid to fish, and can take it away with them, but doesn't like losing all of their traditional food: "the other one that bugs…the heck out of me, is when you are traveling, you see all these fish go out…I can't believe, they are taking all our fish out…sure they pay for it, yeah, you know, but all of our fish…and then they take it down to the lower 48 states and sell it, and we can't [use it]". A2 (Old Massett) also discussed how sports fisherman will fish out one spot, thus amplifying their effect on stocks, as opposed to the commercial fisherman that move around and likely self-regulate, tying back into the section above examining management:

"there's an example…they wiped out a big salmon run that went through there, the spring salmon run…and then when they did that they, that's when you see all these lodges move north, and then they went to Alaska, quite a few of them went to Alaska, it's just you know, steady, [the] same spot, target all the same spots over and over…and that's, it's bound to have an effect, where the commercial fishermen, when they fished, they fished here, they went to there, then back to here, and then they went to there, they didn't just stay in one spot, they moved all the time…so they were, they were more likely regulating themselves instead of fishing in area, they'd move and fish in other areas".

One participant also discussed 'overfishing' by other animals and the imbalance of the ecosystem, primarily sea otters and sea lions. A2 (Old Massett) had noticed an increase in seals and sea lion abundance because it was easier for them to catch the salmon now as they were swimming deeper to reach the colder water: "you know when you see more predators and that…you're seeing more sea lions showing up now…because of the…I think having the fish, salmon, go deeper, it's just easier for the seals to get them, because they got to go way down deeper into the cold, and, the seals can get them from above…the seals from the top, they were up in the shallows, where the salmon could look down and see their predators…and now it's turned around, and vice versa…so that's climate change". While this instance of overfishing is not related to human overfishing, it does relate overfishing to climate change, and opens questions about how climate change will affect commercial and sports fishermen's effects on salmon populations.

5.3.8.2 Contamination

Three participants reported the potential presence of antibiotics and environmental pollution in the meat. Helen Clifton (Hartley Bay) said that "every now and then, of course, the manager of that hatchery, all of a sudden, there, there's some disease happening, and he has to give them antibiotics", which she said felt "un-natural", and that people would prefer not to eat those fish, instead eating the "good salmon" from their fall harvesting sites (non-hatchery fish). She also commented that commercial fisheries are "catching salmon right above the Queen of the North" because the area is open for fishing, and not telling the consumers that they are fishing in polluted waters (both from the ship wreck (in 2006), and from increased summer boating traffic): "we monitored that, and so there's a sheen on the water, and when it's reported, oh, the traffic, the marine traffic up and down the coast is more, during the summer months, and that's why you're seeing more of the sheen on the water, from their bilges". A11 (Kake) and A4 (Hoonah) both expressed a worry about mercury radiation from Japan being in salmon: "[what] we're afraid of is the mercury…from radiation from Japan…we are so close to Japan" (A11, Kake).

5.4 Adaptations

Adaptation was expressed in several ways through the interviews: caring for the environment and habitat of salmon, adapting to habitat change, adapting harvesting and processing strategies to account for differences in weather and modern techniques, and how people expected they would continue to adapt in the future. Local knowledge also suggests that salmon have their own adaptations to climate change. For example, different species of salmon have multi-year cycles for returning to their natal stream, and thus will not all be compromised by a single event such as a dry year, which might otherwise affect a whole spawning population (see Thornton *et al*. 2015). Below I more specifically go into interview information about management of salmon by people, changes in processing, and what people expected would come about in the future.

5.4.1 Respect, Ceremonies and Legends

An important feature of cultural keystone species is having ceremonies based around protocol and use (Turner 1988). Overall, 13 participants[73] described instances of protocol, ceremonies, and cultural importance in their interviews, primarily in NSE (6), followed by HG (4), MBC (2), and then SSE (1). Harold Martin (Juneau) mentioned that "the first king

[73] Charles Jack (Hoonah); Harold Martin (Juneau); Sherri Dick (Old Massett); Reg Davidson (Old Massett); Robbie Nelson (Metlakatla); Robin Brown (Old Massett); Captain Gold (Skidegate); Wilbur Brown (Juneau); Evans Kadake (Kake); Helen Clifton (Hartley Bay); A11 (Kake); Mary Guthrie (Klawock); Owen James (Hoonah)

salmon you get, you have to give it away". The cultural protocol of a 'first food ceremony' is very commonly seen on the Pacific Coast, and first foods ceremonies specifically relating to salmon has been recorded in the literature (Langdon 2006; Johnsen 2009; Ratner *et al*. 2006; Thornton *et al*. 2015). Another protocol commonly seen on the coast concerns leaving the remains of salmon on the beach (Brock and Coiley-Kenner 2009) after you have finished processing or eating (leaving the guts, backbone, head, etc). This was mentioned by Sherri Dick, and Reg Davidson (both Old Massett) added more detail to this observation:

> "when we go fishing, my grandfather would tell us, you know, all animals have spirits, and when we'd catch the fish, and when we'd slice it, he'd make us face the fish up river…so that the spirit would keep going up the river yet…[and] after we are done cutting it and when we are going to start drying it…and when we are putting it in the racks, he'd make us face the head up the river, so that the spirit would continue up" (Reg Davidson).

Another theme oft repeated in these interviews for all resources, but only specifically mentioned for salmon by Charles Jack (Hoonah), Harold Martin (Juneau), Robbie Nelson (Metlakatla) and Robin Brown (Old Massett), concerned only keeping what you needed, or if you were a harvester and provider in the village, catching more then you needed so that you share with elders or other people unable to fish: "for the winter, you know, [for example] salmon we only take what we need for the winter, and we still do that today…just take enough for the winter, and then I leave" (Robbie Nelson, Metlakatla) and "you always share whatever you get" (Harold Martin, Juneau). This ethos is commented upon in local ethnographies (Brock and Coiley-Kenner 2009; Ratner *et al*. 2006).

Three participants discussed how to prepare and eat salmon. As would be expected, salmon are a key food in feasts, and Captain Gold (Skidgate) explained how thin, dry, strips of salmon mixed in with crabapple fruit was an important potlatch dish and Wilbur Brown (Juneau) spoke about his parents teaching him about when to eat boiled fish and seaweed together:

> "usually, the old folks got a fish, boil[ed] fish, they always boil fish with seaweed, I got a king salmon, and I cooked boiled fish, and I brought out the seaweed, and I always had seaweed with boiled fish, I brought out the seaweed, and my father said…no no no, you can't have seaweed…how come? I always have seaweed with boiled fish, "not with king salmon"…and so, put the seaweed away, you know, what reason? I don't know, it was just ah, something that they did, I don't know, I never understood the reason for that…but, we had seaweed with every kind of fish…and how many people know that today? Not many".

Lastly, Wilbur Brown and Evans Kadake (both Kake) talked about how their elders taught them how to prepare a fish for drying, which included not scraping off the blood and slime from the meat, and they said this would make the dry meat less hard. Wilbur Brown (Kake) further added that this processing method would also provide more flavour to the meat:

> "One thing they don't do anymore is after the fish is gutted and cleaned, they would split it in half, and what they have, outside, or sometimes a roof, they would fillet the salmon or halibut, right through the tail, the tail was a little part they would cut in half, and open it up, without smoke, they just put it on those poles, and let it hang there one whole day, it has to be dry, you can't get it wet, just let it hang, and drip dry, the blood and the slime, stuff like that, once it's on there, you don't wash it anymore, clean it with water, water will get it hard…so when it's drip dried, they take that, and they get ready for, they have a little box, like it looks like a little roof, with pegs on it, and they put that salmon over there and start fileting it, it's easier to cut that way" (Evans Kadake, Kake).

One observation which was not necessarily a ceremony or protocol, but which shows how integral salmon were to the coastal people's life was Helen Clifton's (Hartley Bay) discussion about how watching a salmon's lifecycle taught you about the whole cycle of life: "so it's teaching you about the whole cycle of life, he said watch it, and he said there's something else that we're part of, that we can't explain, and he said the salmon know when they're coming home, what they are going to do, and how do they know after 4 years being out, and yet they're coming back, and he said it'll teach you about the lifecycle". There are many other ceremonies that have been described in the literature either for salmon or other resources (Deur and Turner 2005; Johnsen 2009; Langdon 2006; Ratner *et al*. 2006; Thornton *et al*. 2015; Turner 2014), but I am only mentioning the ones referred to by the participants in this research.

5.4.2 Management

People are needing to adapt their harvesting strategies based on abundance and distribution changes in response to anthropogenic (logging, mining) and natural (climate change) influences within a framework of management regulations. Conservation and management of resources by Indigenous Peoples have been done for generations, with respect for the resources and land, and active engagement in this conservation is integral to their worldview (Brock and Coiley-Kenner 2009; Ramos and Mason 2004; Ratner *et al*. 2006,). Management for the salmon CKIS is more complex than the example in Chapter 4 for deer. This is partly because it is comprised of five species, partly because salmon as a group have runs and populations that are threatened or endangered, partly because it is an important economic commercial resource as well, and partly because this resource transcends the international boundaries not only between the US and Canada, but also into countries on the other side of the Pacific Ocean, which makes management a complex issue. Anthony Christianson (Hydaburg) works for both the tribe and city governments, and discussed how it was hard to balance the needs of these different sectors, showing how complex this issue is:

> "I work for both the tribe and the city…and so primarily you know, the city, I believe, our focus is on environmental health within the community, you know, infrastructure that supports our human health, water quality, sewer, garbage, immediate stuff, the tribes' footprint, where we concern ourselves is a little bigger, because the tribal membership and our sovereignty extends out to areas that we traditionally harvest and depend on, which is the rivers and the salmon species, and the seaweed and the halibut banks, the bottom fisheries and we feel like they don't work with us on, access, and a lot in issues, we feel we're entitled to a lot more…as far as…sharing the resource, and who gets their cut, we feel like we got the shitty end of the stick so to speak on that…there's a large scale commercialization of resources happening, and we're not really invested or involved in it…we have more of a reliance on the resource for a food, and subsistence, and sustaining in existence, in this environment, not so much commercial, we still have some of that, but it's what keeps us here, you know…the vast amount of wild resource that's pretty much renewable, you know, so

it's hard to knock them, because they have at least some standard of management that keeps the populations coming back every year".

Participants described adaptive management responses to changes in salmon stocks. For example, Robin Brown (Old Massett) described how people have self-managed to reduce salmon harvests in cases where local people believed the fish populations needed to recover or increase: "here's an example of the conservation of Native People, there is a river across there that catches coho in the fall time, and our people were pounding it quite hard, and people got uptight, and mad about it, cut it out, and they put a stop to it – that's conservation among our own people". Helen Clifton (Hartley Bay) discussed how hatcheries were placed in such a way that they would increase overall salmon stocks without impacting streams with large natural runs: "they wanted to put a hatchery here, to build up the coho stocks that they would get…they go up this little river [right in the village]…for commercial and for our food…but they weren't to touch [fall harvesting camp] where we have a big coho run". However, the opposite was also felt, that local people were not managing stocks effectively: "but other than that, there still are, people are getting it, I think again it's our own people, not managing it properly and leaving it alone when it should be…we are [as] at fault as anything else" (A2, Old Massett). The concept of local and/or Indigenous Peoples also potentially contributing to overharvesting has been mentioned in the literature (Ratner *et al*. 2006).

Only one person mentioned specific management techniques with regards to caring for the salmon resources and monitoring the habitat, improving it anthropogenically to benefit this important resource. Wanda Culp (Hoonah) firstly described a Tlingit management practice of cleaning rocks out of a stream to allow fish to more easily swim up it, an especially adaptive response to conditions of low stream level that may adhere with less summer rain or runoff from winter snowmelt, a practice also described in the literature and referred to as 'stream cultivation' (Thornton *et al*. 2015) or 'streamscaping' (Langdon 2006[74]). She described the process she had done in detail:

> "we know we are stewards of our lands, so we want to take good care of anything that we use, so, for instance, this sockeye river in Excursion Inlet, Tommy started throwing these rocks, smooth rocks from glaciers, you know, round, not smooth, but round rocks, he started throwing them to the side of the stream, because the water was so low, and the salmon need to be able to you know, move, so those rocks were in the way, there were too many of them…so him and I worked on it, just tossing them, just, hundreds of rocks and it worked, so this got back to the stream bed where the fish, the salmon could appreciate it…and what was so cool, is what, what was so cool is when I was standing in it, the water, up to about here, here comes a sockeye and it just gently came and rubbed my leg…and oh, it just made me feel so good…it was like a thank you…so stream maintenance is important… I don't see that occurring, it's not going to occur around here, unless it's somebody's ordered [it], you know, but I don't see the Forest Service even knowing about it".

Secondly, she also described thinning out trout fry, as they will consume salmon eggs:

> "another thing we used to do, is, you know the trout? Sportsman covet the trout…[but] we don't, because they are only there to eat the salmon eggs!...and they come in just like black clouds underneath the salmon…so our people used to get a smaller net, and catch them and thin them out…and they would use them, you know, trout for different things…it wasn't like they just killed them, you know they are good to eat too, but also for fertilizer, other things we use them for, but it was important to thin them out, so that we could maximize the return on the salmon eggs".

Predation on eggs by Dolly Varden trout (*Salvelinus malma*), along with descriptions of thinning, is also reported in Langdon (2006), and Mary Guthrie (Klawock) reported cohos eating sockeye fry in these interviews (further elaborated in 5.4.3). Management in the form of transplanting salmon inland to lakes or to other streams has also been described in the ethnographic literature (Johnsen 2009; Langdon 2006; Thornton *et al*. 2015)[75], but was not mentioned by the interview participants in this study.

[74] Only reported in Hoonah, not Klawock, also includes creating additional pools and other preferred habitats for salmon.
[75] The Alaska Fish and Game website (Alaska Dept of Fish and Game 2019a) also describes several instances of transplantation of pink salmon between 1900-1970, mostly in northern North America and Europe, but also along the coast down to Chile, however very few of these experiments have succeeded. The only introduction that did succeed was an accidental one into Lake Superior in 1956, which has become the first population known to spend its entire life cycle in fresh water, and it is the only population which is known to have a three-year reproductive cycle.

Lastly, some co-management successes that emerged in the interviews was that of sockeye salmon by the Alaskan government and the Hydaburg Cooperative Association, described by Native leader Anthony Christianson (Hydaburg). Through the community's TEK of salmon, they were able to identify the specific timings of different runs and collaborate to fine tune regulations to both enhance the monitoring and protection of fish stocks and ensure that local people are still able to harvest salmon under optimal conditions (Cartwright *et al*. 2005; Conitz *et al*. 2007). Anthony Christianson received a Community-based Conservation Award in 2015 from The Nature Conservancy for his efforts on this project (Stories in the News 2015). A co-management regime combining TEK and science of the dynamics of these CKIS' will hopefully generate adaptive solutions to allow this traditional resource to continue to be sustainably harvested, which can then also be applied in other communities. In Anthony Christenson's own words, describing how they were able to identify the three runs of sockeye via their local knowledge, and manage each separately, rather than as a group, to manage most effectively:

> "so you check the bottom, you look at them, all females go back in…they are the egg producers and we want to continue that species…we try real hard not to catch all the fish…you know I run the management program for the sockeye fishery that we have for subsistence food fish here…and…we've had some real good years, and some bad years; our community gets grants to help facilitate managing a weir, and getting a fish count and tallying our subsistence take, and so we've been basically co-managing that fishery, and we noticed that over the course of the years of that program, the trends in when the genetically different populations came into the rivers, so that there were distinct populations that had you know, they didn't cross breed with each other, they come in June, they come in July, and they come in late August and September, so there are three distinct populations…and that was all sockeye, in a lake system…and so we started to manage them, as three separate stocks, rather than one stock…cause we could overfish the early run, and basically take out the early run…and that's what had happened, we had depleted the early run down through several years of fishing, being excited that that's when they come in, and fished them down to nothing, and so our information gave us the tools to take the pressure off that stock, to ask community members to back off on fishing in June, and without having to go to the regulatory body and say hey, change this…we've already been regulated enough as natives, we don't need to go to that…self-regulation is a lot easier…because then you're taking ownership and you're changing behaviour, and that's going to impact and ensure longevity and sustainability of resources in your fishery, and so that's what we do here you know".

In the literature, there are additional co-management examples located throughout the study area. The Sustainable Southeast Partnership in Alaska is one such example, bringing together seven Indigenous communities (and includes Hoonah, Hydaburg, Kake, and Klawock from this research) and numerous organisations such as Sealaska, The Nature Conservancy, Southeast Alaska Watershed Coalition, Renewable Energy Alaska Project, Southeast Alaska Regional Health Consortium, and Alaska Conservation Foundation, all of whom coordinate with private, state, and federal land managers to manage local fisheries and forests in the best interests of the local communities (Sustainable Southeast Partnership 2019). Another similar example, but in British Columbia, is the Marine Plan Partnership for the North Pacific Coast, bringing together the government of British Columbia and 17 First Nations to design and execute plans for the use of marine resources (Marine Plan Partnership for the North Pacific Coast 2019), divided into four sub-regions. Haida Gwaii is one of these sub-regions, and they have specifically designed the Haida Gwaii Marine Plan to facilitate the Haida Gwaii Indigenous communities and the province to co-manage the local marine resources (Marine Planning Partnership Initiative 2015). Another example is the several organisations incorporated in the management of fish stocks in the United States as a whole, from a governmental viewpoint. Firstly, the Magnuson-Stevens Fishery Conservation and Management Act (MSA), a law implemented in 1976, was developed with the intention of collaborating with stakeholders to protect and manage fishing resources. In practice, this means that the National Marine Fisheries Service (NMFS, under the auspices for National Oceanic and Atmospheric Administration, NOAA) monitors policy throughout the entire nation, while one of the eight councils forges a link between the government and stakeholders, to input and agree on management decisions (Alaska Marine Conservation Council 2019). Local Alaskan fisheries are monitored by the North Pacific

Fishery Management Council (NPFMC), which advises on federal stocks (ground-fish, i.e., cod, pollock, flatfish, mackerel), and jointly monitors salmon, crab, and scallop stocks with the State of Alaska. Additionally, there are several watershed councils which allow community-based collaboration to manage watersheds throughout the study region (Southeast Alaska Watershed Coalition n.d; Skeena Watershed Conservation Coalition n.d.). One example of where the local government organisations, Indigenous community members, local fisherman and scientists have worked together to manage fish stocks sustainably is around the issue of trawling, which has now been banned in parts of Alaska, including in Southeast Alaska, due to its destructiveness to the habitat and high rates of bycatch (North Pacific Fishery Management Council 2012; Sitka Conservation Society 2012; Stiles et al. 2010).

5.4.3 Regulations

This resource is highly regulated by the state, provincial, and federal governments in both the United States and Canada because it is an important resource for a number of user groups – commercial, sports, subsistence, and personal use fisherman, with vital local traditional importance and a world-wide distribution. However, with four user groups, controlled by two countries, in addition to multiple collaborative management schemes, it is a complex situation. Additionally, the impacts of climate change on the oceanic distributions and return timings will be important information in modifying policy and management decisions and implementation into the future (Abdul-Aziz et al. 2011). In this section, I am going to specify the regulations legally imposed by the respective governments, along with people's observations regarding these regulations.

In Canada, a First Nation organisation is issued a 'communal licence' from the Canadian Government that all the members of their band can fish under (Fisheries and Oceans Canada 2019). This communal license may include restrictions around species, quantity, methods, locations, and times, which are community specific (Fisheries and Oceans Canada 2018) but in general a harvester may harvest as much as they want as long as it is for food, social, or ceremonial purposes, the harvesting is located where your First Nation traditionally lived, and you follow any restrictions on the communal licence (Legal Services Society 2017; Fisheries and Oceans Canada 2018). However, in Alaska, the Indigenous fishery is much more controlled, and even as an Indigenous subsistence user, a person has to receive a permit from the state government to fish, which delineates the harvest limits, gear allowed to be used, and the open areas and seasons (Alaska Dept of Fish and Game 2019f). In Juneau in 2018, the annual limits were: sockeye – between 10-50 fish; pink – 150 fish; chum – 50 fish; coho – 20-40 fish, and fishers were only allowed to catch king salmon incidentally (and no more than two), and also had 'possession limits', so often could not catch up to the maximum annual limit on one trip (Juneau Management Area 2018). In Ketchikan in 2018, the annual limits were: no annual limit for king, chum and pink in one small area, but in general king could only be caught in that one small location (Herring Bay), and in the rest of the Ketchikan area annual limits were: sockeyes – between 20 and no annual limit (depending on bay); pink – no annual limit; chum – no annual limit; and coho – 40 fish. Ketchikan again had 'possession limits' and you could not catch up to the maximum annual limit on one trip (Ketchikan Management Area 2018).

The number of participants discussing this topic varied widely between each country; 13 participants[76] discussed regulations and their impact on harvesting, people and stocks in Alaska (with nine in NSE and four in SSE), whereas only one participant[77] discussed regulations in Canada. Because salmon is so integral to the traditional Indigenous way of life in the PNW, the primary observations dealt with participants feeling that regulations around

[76] A4 (Hoonah), A9 (Juneau), Harold Martin (Juneau), Lori Kay Guinard (Hoonah), Alma Cook (Klawock), Michael Jackson (Kake), Mary Guthrie (Klawock), Evans Kadake (Kake), Ernestine Kato (Klawock), Lionel Bean (Kake), Nancy Bean (Kake), Myrna Yates (Craig), Charles Jack (Hoonah),
[77] Carol Young (Skidegate)

salmon were too restrictive, and regulations not taking Indigenous knowledge around climate change and changing lifecycles into account. It should be noted at this point that there are several co-management collaborations happening between Indigenous People and governmental bodies in many locations that I already discussed – see section 5.4.2. I believe the responses recorded in this research shows that while progress is being made to integrate types of knowledge, particularly TEK into scientific planning decision and policy, and the co-management schemes detailed above, from so many years of top-down directives being imposed on Indigenous People from governments, there is an underlying resentment and frustration with not being able to access their traditional resources or provide more input into policy and management.

There was a differentiation noted between the regulations imposed by the state and federal government in Alaska. The state controls the nearshore resources, including salmon as they are entering the freshwater system (Alaska Marine Conservation Council 2019), however tribes are federally recognised meaning they have government-to-government agreements with the federal government (US Dept of the Interior - Indian Affairs n.d) and they have sovereignty over their own lands. Even though they can also share a government-to-government relationship with state governments as well, they don't do so in all cases. However, because the state government is responsible for some resources such as near shore salmon stocks, there has in the past been friction, but most seem to be moving forward into co-management agreements. This is likely why there was the general feeling in several interviews that the federal government is 'better' than the state government:

> "the feds are better than the state…in recognising our way of life…the Alaska federation of natives spent years, and millions of dollars trying to get an amendment to the constitution…putting in that the subsistence, you know, they [the state legislature] always voted it down…in the meantime, we were out there, working hard on this and that, and protecting our subsistence way of life… subsistence take, throughout the whole state, is about 3% of the whole resources… so where do they come off saying we are depleting the natural resources" (Harold Martin, Juneau).

Harold Martin (Juneau) also provided numbers to the limits they were allowed to fish: “they only let us have 25 fish a year…sockeye, a year…they put a lot of restrictions on there”, a number which Charles Jack (Hoonah) agreed with in his interview. While it is possible that these participants may be referring to a year where there were stricter limits due to low return, it is likely that it is not so much an actual number they are recounting, but more the perception of what they are allowed to catch under the regulations, as was seen in Charles Jack's quote[78] in 5.3.1.2, and Ernestine Kato's (Klawock) observations of a decrease in sockeye, because of regulations around fishing:

> “I used to get a lot of fish in the bay here, ok, maybe 200 for the summer, or maybe 300 for the summer…I didn't get one sockeye from this bay…for two years, because you have to have a permit, that's open from a certain time, my fish came from outside…the guys that are seining, my grandson brought to me, maybe about 30, it came from outside…I didn't get nothing from out in the bay”.

Charles Jack (Hoonah) had a story of why incorporating Indigenous knowledge is important:

> “[we have a] limit [of] 6 cohos a day when you are trolling…two up the river [and thus the rest in the salt water]…I told a guy, you know, you got it backwards, what do you mean backwards? You should have two in the salt-water and six in the river…why? The ones out in the salt water hasn't had a chance to even taste fresh water or even lay an egg…but chances are, six in the river, maybe three of them already spawned out…and he looked at me, and he said, oh, he never thought of that either”.

Fish and Game set these limits on the projected return, which is not always accurate. Lori Kay Guinard (Hoonah) suggested that, similar to deer, the government usually counted the fish either from planes or having a computer and tv (likely a video camera for monitoring purposes) in a creek, which were not good techniques to get accurate counts:

“the government, they are going by numbers, and that's all, you know, out of a plane, or now they pick a creek and put a computer in there with a tv on there, and you count so

[78] “we dried dry fish…you know, 6000, 7000 dry fish a year…the fish and game gave us a permit one time…they decide to put a limit on it, 25 fish for dry fish…my grandfather's smoke house held 1400 cohos at one time, drying, we'd fill it up two times with cohos, sometimes two and a half times”

many sockeye a day…well, you can't get the population on that, I mean, one day you had 500 sockeye go through that camera, well you can't times that by 30, because you aren't going to have 500 go through there every day…you might have 2000 one day, you might not have any the next".

Robbie Nelson (Metlakatla) in MBC, expressed a similar worry with government counting techniques:

"And when they're doing the salmon, we know to the date when we could go and get our salmon out at Metlakatla, and I'm sure every one of the other reserves know the same thing, but, when it comes to the fish to go up the river, they're [the government] guessing…how much is going through, so they estimate, right? They can't sit there and count 10 million sockeyes, they estimate there's 10 million…now, when you're guessing on the species, they're depleting the species it's on…for example, two years ago, they said the Fraser River was not going to see a very good fisheries, yet they got 44 million fish"[79].

There are years where unexpected numbers of returns arrive, as scientists and managers have predicted the current return from extrapolating from the last year's harvest, along with how environmental conditions are going to affect the returning salmon in the current harvest year to estimate the return numbers (Larkin 2010; Brenner et al. 2019).

In Klawock exclusively, there were also several stories of fish and game ticketing people (Alma Cook and Mary Guthrie, both Klawock), and people feeling like fish and game was 'out to get them' which I would argue is a by-product of people feeling like they didn't have control over resources integral to their way of life, and perhaps an additional challenge this community might face, as it wasn't mentioned anywhere else.

There was also the perception that sports and commercial fishers are coming in and 'taking out' all the fish[80], described more fully in the overfishing section above (5.3.7.1). As well, it was thought that regulations might favour sports and commercial fisheries with certain season closures (Mary Guthrie, Klawock). Mary Guthrie (Klawock) also felt that even though the sockeye was a more valuable fish to them (due to high oil content) they are

[79] this is likely also referring to the volcanic ash input into the Fraser River, which created an unexpectedly high level of return that had not been predicted, described in 5.3.4, Quality of Habitat.
[80] A9 (Juneau), Wanda Culp (Hoonah), Harold Martin (Juneau), Ernestine Hanlon Abel (Hoonah), Cora Joseph (Klawock), Lori Kay Guinard (Hoonah)

declining while cohos are on the rise, which she attributed to the Alaskan government preferentially raising coho young in hatcheries to cater to the sporting economy, which find cohos more desirable due to their jumping behaviour, size and brilliant silver colour. This is detrimental to the sockeyes, as they can get preyed upon by the coho fry, potentially leading to conflict between Indigenous communities and sport fishermen:

> "the state of Alaska is helping this company to kill the sockeye and raise coho [smolt] because coho are money fish, you get a tourist with no sense, and you say, oh, I got a big one and it's silver! And yet, the sockeye is what we eat [rich in oil], and we've got declining species…because they [the coho smelt] kill them in the lake, and they leave their pen, the coho pens out here, and when the sockeye smolt are going, fry are going out to, then they cut them loose, and coho eat [them], [they] are cannibals…and sockeye are not, they are not flesh eating at all".

While it is a characteristic biologically that cohos are known to eat other salmon eggs as a fry, and fish (including juvenile salmon from other species) as adults, and sockeye are often eaten by larger fish in the lakes (Alaska Dept of Fish and Game 2019c; Fisheries and Oceans Canada 2018; Washington Dept of Fish and Wildlife 2019c), this particular observation was only made by one person, and there has been no evidence found in the ecological or ethnoecological literature of a larger effect than of it occurring.

To help address the worry of sports fishermen taking too many fish, A9 (Juneau) thought that the size limit that had historically been imposed only on commercial fisherman was now being imposed on sports fisherman, due to overfishing concerns, which will hopefully help regulate this sector and allow salmon stocks to recover: "pink salmon is 28…commercial fisherman is 28 inch…but charter boats used to take everything…but they are on limit too now, 28 inch for pink salmon, even us for sport fishing…everythings overfished…between commercial fishing and charter boats".

The last issue the Alaskan participants mentioned was special fishing rules concerning where you could fish for subsistence versus personal use. The personal use fishery is for Alaskan residents that are not Indigenous, or live outside a traditional village, so everyone in

Juneau, Ketchikan, etc. There is also the option of proxy fishing in place where a person can legally become a proxy fisherman for someone else, if the person being fished for is physically or mentally disabled. While eligibility of those needing proxy fishers are relatively loose in British Columbia, they are much stricter in Alaska, where in addition to being disabled a person must also be over 65 (Alaska Dept of Fish and Game n.d.; BC Ministry of Forests, Lands and Natural Resource Operations n.d.; Turek *et al*. 2006). Lori Kay Guinard (Hoonah) suggested that it was a good system to help take care of everyone in the community. If for example someone couldn't get out, other people would give them some of their harvest. As a testimonial to its effectiveness Harold Martin (Juneau) reported that his nephews in Angoon take care of him, which likely happens with many of the elders that have moved to larger cities, perhaps for medical needs. Michael Jackson (Kake) mentioned some of the restrictions on these fishing types, for example someone has to live in a subsistence village (with subsistence permits) to be able to harvest certain sockeye from special lakes. Evans Kadake (Kake) however, mentioned problems with this system, because sometimes the proxy fisher said they gave you your fish, but they didn't, which could lead to bad feelings.

It is easy to see people's frustrations with the governmental regulations. Though in 2018 the limits were quite high, they can change year to year. Even the idea of getting a permit might seem alien to some people and make them feel like their food is being taken away by the regulations, as seen in Lionel Bean's (Kake) statement: "they'll make the laws whether you like it or not…we're losing everything". Five other people felt similarly, that the government wasn't listening to their knowledge[81]. Harold Martin (Kake) summarised what I think many people were feeling:

> "When they have gillnetters, and set netters, and purse seiners, all at the mouths of these big rivers…they got charter boats coming in, and they are bringing people in from all over the United States…when you go to the airport, you see piles and piles of

[81] A4 (Hoonah), Harold Martin (Juneau), Myrna Yates (Craig), Michael Jackson (Kake), and Nancy Bean (Kake).

> boxes of our fish going, out, and out [from the sports fisherman]…and they deny us our way of life, you know… even though the state and federal government has taken over our lands conceptually, in our minds, and our hearts, it still belongs to us…and we treat it like it belongs to us, with great respect, we don't pollute, we don't kill things for nothing".

Similar frustrations of regulatory limits not acknowledging people's needs, that food was more than just subsistence but a 'way of life', the need to 'bend the [regulation] rules' to allow Indigenous users to harvest as needed (as otherwise they may be pushed to harvest illegally), and that possibly that the government shouldn't be involved in subsistence fishing, were expressed in the ethnographic literature from the study region (Ratner *et al*. 2006).

In Canada, only one participant mentioned regulations. Carol Young (Skidegate) suggested that now they are limited to five fish a family. However Canadian Indigenous People are allowed to fish as much as they want on traditional lands, so perhaps there was one year of low returns, and thus a limit was placed, or again this might be a perception of a limit due to there being restrictions in general.

5.4.4 Processing

Similar to deer, many of the processing adaptations that people employed were due to improvements in preserving technology, such as having dehydrators, freezers, or novel canning techniques. Overall, 15 participants discussed processing techniques or timings in their interviews, with the majority (eight) being from communities in NSE, three participants from SSE and HG each, and one from MBC.

Ten participants focused on how people have changed the way they process salmon, but there was disagreement if these changes had occurred because of pressures from weather or technology changes, and how many people still dry or smoke. When asked how the weather has affected food processing, A13 (Juneau) responded by saying "for one thing, we can't dry our salmon, or our seaweed…outside", Helen Clifton (Hartley Bay) noted that they can't dry coho in the sun because they don't have as much anymore, and Robbie Nelson (Metlakatla) said that he now used "dehydrators, because the sun is just not there like it used to be", but Charles Natkong (Hydaburg) didn't think that the weather had made many of these processing changes, but rather improvements in technology: "we used to smoke the salmon too…everything we used to put up before, now, we just put it in the freezer". Evans Kadake (Kake) reported that people in Kake favoured hemlock for smoking, and in Klukwan they favoured cottonwood.

For prevalence of drying and smoking techniques, Ester Greenwald (Hoonah) commented that even canning is not as common as it used to be: "there aren't very many natives that have smokehouses anymore, and they don't dry their fish, there's just a few that dry fish…[and] not a lot [of jarring either]…but there are some, definitely". Charles Jack (Hoonah) also noted that smoking fish had changed now but disagreed with Ester Greenwald (Hoonah) about jarring, saying it was the same now. Vickie Le Cornu (Hydaburg) discussed the difficulty of smoking fish in rainy weather, saying that was often why people were using freezers now. Evans Kadake (Kake) said that another driver for freezing was the advancing age of people and not being able to help as much with the time intensive processing techniques of the past, although people would sometimes prepare the fish before it was frozen so that it was easier to defrost and go straight into jars later. However, in contrast, Jack Litrell (Old Massett) reported that he still saw lots of people with drying racks, hanging their fish up outside, and Alma Cook (Klawock) agreed that people were still drying and smoking: "[we] put up our salmon the way we do all the time, it's just less of it". And lastly, Michael Jackson (Kake) and Harold Martin (Juneau) discussed the shift from using salting and/or grease to preserve to using freezing and jars to preserve: "when cans came around, then jars…they adapted to that really quickly" (Michael Jackson, Kake). However, while freezing is more recent (20th century), the adaptation to first cans and then jars is not a recent adaptation (mid-19th century), and people have been jarring for many decades.

Three of the participants qualified when in the year certain processes used to take place but didn't specify that timings had moved in response to any changes. Harvey Williams (Skidegate) said that May to July were good months for drying fish as you didn't get as much rain then, and you needed the sun as you couldn't dry indoors without "smell[ing] up the house", and Harold Martin (Juneau) said that September was the month for smoking (which he preferred to air drying, because of the better taste). While neither participant specified the species used, based on the disparity of preserving times, it is possible that different species were used by each participant, as it is unlikely that processing times for a single species would have spanned June to September. A9 (Juneau) noted that the preserving process was about the same, but the main issues with time of processing depended on the weather.

One of the drivers to jarring and freezing more is likely that either the weather conditions in the months described as ideal for preserving (Harvey Williams (Skidegate), Harold Martin (Juneau), Robbie Nelson (Metlakatla), Michael Jackson (Kake)) no longer exist, or due to advancing age or lack of time or people power in a modern world, people need to be quicker at processing their harvests (Evans Kadake, Kake)). However, Joel Jackson (Kake) explained that "if you smoke it first, and then freeze it…it'll keep longer", and reduce freezer burn, in opposition to the idea of lack of time being a driver in freezing techniques. Evans Kadake (Kake) provided another possible explanation for a reduction in smoking are health reasons: "we can't eat smoked anymore because it gets in the blood stream, sooner or later, it's going to bother your health, but I like to taste smoked products once in a while, not too much smoke on it, just enough to taste". There was quite a diversity of opinions on the prevalence of processing techniques and reasons behind the changes, which could be driven by participants living in different geographical areas, or age or gender of participants, but it seems to be a mix of weather conditions and lifestyle changes.

5.5 Answers to Research Questions

The results of CKIS data gathering on salmon in this chapter specifically answers sub-questions 2, 3, 4 and 5, and further contributes to addressing the main overarching research question.

Sub-question 2 (Are observed weather changes affecting how people access, harvest and prepare resources in their territory?): This question is answered because it was seen that the weather observations regarding less snow resulted in warmer temperatures being seen in both the air and water, which primarily impact where in the water column the salmon swim, their smaller size, a decreasing population, and the timings of when they return. Another weather observation said to have impacts on salmon is that an increased frequency of storms makes it harder to harvest this resource. Weather impacts at access, harvesting and processing stages affected how much people were able to harvest and how they harvested and preserved this resource.

Sub-question 3 (Which species (culturally and ecologically important and otherwise) were observed by people throughout this region to be experiencing change?): This question is answered because through interviews all five species of salmon were identified as species which were culturally important, and were experiencing change in several biometric parameters, such as population change, spatial distribution and behaviour change, quality of habitat, size, harvest conditions and timing, overfishing, pollution, and diseases. Throughout further background investigation into this species, it was found that in addition to being cultural keystone species, and weather indicator species, they are also ecological keystone species, making them good CKIS examples.

Sub-question 4 (How do observed changes indicate broader shifts in biodiversity?): Salmon are a key resource connecting marine, freshwater and terrestrial environments because of where they live and what eats them. Thus, at one end of their lifecycle, if salmon eggs and fry are not surviving, and at the other end populations are decreasing, they are getting smaller, and they change their timing of return, due to increased water temperatures, a lack of oxygen and acidification, this will impact the animals that depend on them, such as bears and eagles, and even the plants that make use of the nitrogen from the rotting carcasses, and lead to major shifts in the biodiversity make up in the region.

Sub-question 5 (How can Traditional Ecological Knowledge and climate data be used in conjunction to present a comprehensive picture of local climate change effects and inform adaptive responses, including knowledge transmission between generations, and capability for resilience into the future?): This question is answered because TEK observations regarding shifts in population change, spatial distribution and behaviour change, quality of habitat, size, harvest conditions and timing, overfishing, pollution, and diseases, along with longer term climate predictions in the region, can be vital information for management policy makers to manage future harvesting of salmon populations. As well, the adaptations from local self-management schemes that people described in this research can be important for increasing their capacity for resilience into the future and respond to the influence of climatic change on it, sustaining harvesting so that future generations understand how to use this resource.

5.6 Geographical trends

In this section, I analyse the CKIS results according to geographical trends, to explore if people were making the same type of observation in different sub-regions, or whether certain regions were experiencing different stressors, or observing different changes. In table

5.4 below, I have grouped the ethnographic data into main observations and sub-observations, along with the number of people that made that observation, in each region of my study. Three observations were mentioned in all four regions: population decreasing, salmon swimming deeper because of a lack of water input (lower water levels), and timing of return changing. Even though all four regions mentioned that salmon were swimming deeper due to a lack of water input, more people overall mentioned the cause for salmon swimming deeper to be warmer water temperatures (10, versus 6). The observation mentioned the most often was that of timings of returns changing (23). Overall, ~41% of observations were noted in two or more communities, and the region with the most observations was NSE with ~40%. For this CKIS example, there were many more observations made in only one region (~57%) than the other two CKIS (deer 42% and berries 29%), perhaps showing there was more variety in how people observed this species. Also, the number of observations in NSE was closer to the number in HG than in the other CKIS examples (NSE ~40% and HG 36%), a spread that was more expected, since ~35% of the total participants in each region were interviewed.

Table 5.4. Number of people making each observation of changes influencing salmon populations, divided into sub-region.

Main Observation	Sub Observation	NSE	SSE	HG	MBC	Total
5.3.1 Population change	No change	1	2	2	0	5
	Population decreasing	6	3	5	1	15
5.3.2 Spatial distribution and behaviour change – swimming deeper	Swimming deeper - water levels affected by isostatic rebound	1	0	0	0	1
	Swimming deeper - water levels affected by lack of water input	1	1	3	1	6
	Swimming deeper - warmer water temperatures	2	4	4	0	10
	Not displaying ‘jumping’ behaviour	0	3	0	0	3

	Moving further away from human developments due to logging	0	0	1	0	1
	Kings behave differently in stormy weather	1	0	0	0	1
5.3.3 Quality of habitat	Logging effects chemical makeup of stream	1	0	0	0	1
	Logging doesn't affect salmon or habitat	0	0	1	0	1
	Logging has reduced shade making temperature warmer	1	0	1	0	2
	Logging creates erosion	0	0	1	0	1
	Mining chemicals kill eggs	1	0	0	0	1
	Mining creates more mud and silt, settles on top of eggs	0	0	1	0	1
	Input of nutrients from volcanos/micro-nourishment scheme improves habitat	0	0	2	0	2
5.3.4 Size	Decreased in size	4	0	1	0	5
	Variation in size, smaller and larger	1	0	0	0	1
5.3.5 Harvesting	Too stormy to access fish	2	0	2	1	5
5.3.6 Timing	Timing of return not changing (just yearly fluctuations)	1	0	4	0	5
	Timing changing	9	5	8	1	23
	Overlap with other resources	0	1	0	0	1
5.3.7 Diseases	White spots/cysts	3	0	1	0	4
	Scale loss	1	0	0	0	1
	More flies, lay eggs in meat	0	0	0	1	1
	Hatchery salmon turn to mush	2	0	0	0	2
	Worms in stomach	0	0	1	0	1
5.3.8 Non-climatic effects	Overfishing	4	1	2	0	7
	Pollution (ships fuel, mercury)	2	0	0	1	3
	Antibiotics (from hatcheries)	0	0	0	1	1
Total observations		44	20	40	7	111
Percentages		39.6%	18.0%	36.0%	6.3%	

I have also summarised the observations people made about how they had adapted to climatic and biodiversity changes, and other topics such as reciprocity, management, regulations, and harvesting and processing techniques (Table 5.5). Only two observations were noted in all four regions, that processing techniques had changed due to weather, and that there were a variety of protocols and ceremonies regarding salmon. This last observation was also the most frequently noted (13 observations). Overall, ~44% of observations were noted in two or more regions, and the region with the most observations was again NSE, with ~59%. For this CKIS example, there were many more observations made in only one region (~56%) than the other two CKIS (deer ~30% and berries ~39%), perhaps showing there was more variety in how people observed this species. There were very few observations of management, regulation, or harvesting and processing changes and adaptations from MBC, mostly observations of respect, ceremonies, and legends.

14 participants talked about the adaptations that they had implemented. As management techniques, observations were made about people cultivating streams (or 'stream-scaping' – making stream habitats more favourable) and thinning out trout fry, that prey on salmon fry. Both of these adaptations were noted in NSE. Also, in NSE, one observation was made that bigger (and thus heavier) leads are being used to sink fish lines down in were the fish are deeper in the water column to escape warmer surface water. The last adaptation that people mentioned, in all four regions, was that processing techniques have changed. While some participants thought this was due to increasing age in harvesters and advancements in technology, eight participants specifically thought that people used more dehydrators and freezers as adaptations to preserve food in the face of less sunny and more rainy days. Not as many people discussed how they managed themselves, likely because salmon have strict governmental regulations on harvesting amounts and times, but in NSE

there was one observation discussing the co-management success between an Indigenous community (Hydaburg) and the government, and how they have self manged some of their catch to reduce harvests locally when needed.

Table 5.5. Number of people making each observation of adaptation, reciprocity, management, and regulations and harvesting and processing techniques divided into sub-region.

Main Observation	Sub Observation	NSE	SSE	HG	MBC	Total
5.4.1 Respect, ceremonies and legends	Protocols and ceremonies	6	1	4	2	13
	Only keeping what you need	2	0	1	1	4
	Salmon as a key food	1	0	1	0	2
	Preparing for drying	2	0	0	0	2
5.4.2 Management	Self-managed to reduce harvests	1	0	0	0	1
	Strategic hatchery placement	0	0	0	1	1
	Stream cultivation	1	0	0	0	1
	Thinning out trout fry	1	0	0	0	1
	Co-management successes	1	0	0	0	1
5.4.3 Regulations	Perception of not being allowed to harvest very much	2	1	0	0	3
	Counting techniques may not reflect accurate populations	1	0	0	1	2
	People getting tickets from fish and game	0	2	0	0	2
	Government not taking TEK into account	5	1	0	0	6
5.3.2.2 Warmer water	Bigger leads to sink down to deeper swimming salmon	1	0	0	0	1
5.4.4 Processing	Processing changed due to weather	5	1	1	1	8
	Processing changed due to technology advancement	0	1	0	0	1
Total Observations		29	7	7	6	49
Percentages		59.2%	14.3%	14.3%	12.2%	

5.7 Conclusion

It was shown over and over in this chapter how important a species salmon is, each individual species and the functional group as a whole, as an ecological and cultural keystone species, and as an indicator species. In this study, as in the literature, there is a lot of interplay between climate variables (temperature regimes, increasing acidification, and amounts of snowfall and rain) which has an important impact on the behaviour, distribution, abundance, and size of all five species, with temperature being the most widely monitored variable (Martins *et al*. 2012). While it was seen that non-climate variables also affected salmon, it was recognised that climate is one of the most encompassing changes to affect them and affect their relationship with humans. Summed up by Ratner et al. (2006): "It all depends on weather more than anything else…whether you have a good return or no". Due to the close connection to salmon described in this interview data and throughout the literature it has even been hypothesised by Johnsen (2009) that potentially Indigenous cultures could have selected for certain traits (such as earlier arrival to spawning grounds, or larger sizes) and that is the basis behind some of cultural protocol (such as first salmon rites). Letting the early arrivals through to spawn may have played an active role in managing different streams, runs, and species of salmon. This vital resource, which many Indigenous People rely on for sustenance or economic benefit (Ratner *et al*. 2006) will likely be drastically impacted by weather changes, as evidenced by the observations of large numbers of salmon dying off due to differences in these variables:

> "so, if the climate continues to warm up, and less rainfall becomes reality, we'll see a lot of smaller fish systems probably die off…we've already seen mass die offs in the last couple of years due to low oxygen levels, due to lack of rainfall…last year in particular was a really bad season" (Anthony Christenson, Hydaburg).

Anthony Christensen's observation of the extent of the impact of changing variables on salmon, particularly rainfall and high temperatures, hints at the enormity of what people may face into the future. Reed *et al*. (2011) have also discussed models looking at the genetic variation in migration which may cause some runs to select for earlier migrations in response to water levels and temperatures. Between drawing on traditional knowledge, and the natural resiliency of humans and salmon, it is likely that this resource will continue to be harvested into the future, although there may be challenges.

In the last two chapters I examined two sets of animal species, one terrestrial and one marine, for how they illustrated my CKIS example. In the next chapter, I use a terrestrial plant species to demonstrate the CKIS concept.

Table 5.6. Table of observations relating to salmon.

Type of Observation	Changes seen	Impacts	Responses	Example participant perspective
Size of fish	➢ smaller ➢ more fish are < 3 kgs (Catherine Bolton, Hoonah)	➢ still have the same limit for numbers, so getting less fish in weight	➢ lessening amount of fish able to get	"they have an annual derby…one year they had 31 pounds [14.1kg], and then 29 [13.2kg] pounds, last year it was 27 pounds [12.2kg] won it, this year it's 26 [11.8kg]…25 [11.3kg], or 26 [11.8kg]…so the fish are getting smaller" (A9, Juneau)
Contamination	➢ mercury and radiation from Fukashima	➢ Can't eat when pregnant	➢ lessening amount of fish able to get	"the ladies in Alaska, especially on the coast, have been warned, not to eat halibut, or any fish, during a certain time in pregnancy" (Lionel Bean, Kake)
Changed distribution and behaviour	➢ swim deeper in warm water (heavily reported) ➢ used to come in a precise schedule but now don't (Anthony Christianson, Hydaburg)	➢ hard to catch ➢ not available ➢ swim deeper, under net	➢ reduction in fishing to assist in conservation (Robin Brown) ➢ fishing closer to river	"we've been having a hard time catching a lot of fish sometimes, because…they are staying deeper than they normally, and they aren't showing and jumping and behaving like they usually do, because the fresh water is so warm due to the lack of snowpack up there, melting" (Anthony Christianson, Hydaburg) "if we don't have the rain when they are running up, they won't go up, cause the waters too warm…so eventually we aren't going to have fish either, if the temperature keeps rising" (Reg Davidson, Old Massett)
Timing of Harvest	➢ sometimes later than expected ➢ indicators don't match anymore	➢ not available or smaller/more scattered runs	➢ can't get as many fish	"I think it's later in the year now, it used to be, when we used to go for sockeye? The salmonberries used to be ripe then…now it's later" (Margaret Edgars, Old Massett)
Stormy weather	➢ unsafe to go out on boat	➢ can't go fishing	➢ not getting fish, risk injury if try and go out and get caught in a storm	"like right now there's a lot of salmon out there, but you can't get out there" (A1, Old Massett)

Increased nutrients	➢ ash from a volcano, 1948 (Robin Brown, Old Massett) ➢ iron filings dumped off coast recently (Robin Brown, Old Massett)	➢ fish were increasing ➢ boom in numbers of fish	➢ more fish to catch ➢ re-invigorated stock ➢ refreshed nutrients available	"and there were a lot of this little white pebbles in the, drifting in the water there, light, floating around, and that year was a huge year for salmon …because they are eating that stuff out of that, from that iron…" (Robin Brown, Old Massett)

Chapter 6 Berries - Blueberries (Vaccinium spp.) and Salmonberry (Rubus spectabilis)

"In fall time, the seasons from when we gather different things…one of the main staples of our culture is the berries…we are all dependent upon it for the fruits, and that's where we're finding, there are more droughts in the spring time, and then there are really rainy seasons, and then they extend it…where the berries will start blooming because of the warm spring, and then it will get cold…whereas, before, when I was growing up…it was a constant warming up from winter, and the berries went through that development, they started budding, and then they started growing their flowers, and the real sensitive part, the heat, or sun, warmed them up and they grew, but now we are getting these warmer spring times, and then, whether it's a cold freeze, and it freezes the buds and the stems sometimes rots and the whole plant dies…or, it'll be a nice warm up and then it just gets warmer and warmer, and it goes into a drought…two months, or a month and a half drought, we've never seen that…length…and then with that gone [the snow melt disappearing quickly], the berries just kinda shrivel up…and that's very disturbing, like this year, we had a…a warm end of the winter, and then it got very warm, the plants came out and then we had…a cold snap…and then from that cold snap it went into a drought, a warm drought…and the berries never did recover." (Michael Jackson, Kake)

6.1 Introduction

Like salmon as a CKIS category, berries include a suite of culturally and ecologically significant species. Thus, for this CKIS example, I am including salmonberry (*Rubus spectabilis*) and the blueberry species (*Vaccinium* spp.) that commonly occur in the study region: *V. alaskaense* (Alaskan blueberry), *V. ovalifolium* (ovalleaf blueberry), *V. caespitosum* (dwarf bilberry) and *V. uliginosum* (bog blueberry). The reason all five species of berries are considered together as a CKIS in this research is due to the similarities in characteristics of their life history and importance, and overlaps in their geographical, ecological, cultural, and indicatory characteristics. I will firstly address the biological characteristics of each species individually, as described in regional floras, address their EKS, CKS, and indicator status from the literature and interviews, and then elucidate their keystone and indicator importance as an entire functional group, including why they were picked as a focus functional group, before moving into all the observations from the interview data.

6.1.1 Biological Profile

6.1.1.1 Salmonberry (Rubus spectabilis)

Salmonberries grow along the entire Pacific Coast, from California to Alaska, and eastward to Idaho. The shrubs are known for forming dense thickets, approximately 1-4m tall. Stems are covered with a papery bark, especially older ones, and scattered prickles. Leaves are grouped with three leaflets and have toothed margins. Flowers bloom from February or March through to July and are characterised by single blooms about 1-3cm across, with large vibrantly coloured pink to magenta petals. Berries are aggregate fruits, 1-2cm, with 20-80 drupelets, and with a wide variety of colours, from yellow to red to orange (eFloras.org 2008; Lyons and Merilees 1995).

6.1.1.2 Alaskan blueberry (Vaccinium alaskaense)

Alaskan blueberries only grow west of the Cascades, from northern Oregon to Alaska. Shrubs are approximately 1.2m tall. Leaves are oval-shaped, and while they are similar in shape to the ovalleaf blueberry, they differ in that the midrib of the leaf of Alaskan blueberries may have infrequent glandular hairs. Flowers are pinkish coloured bells, and berries are a blueish-black and lack a whiteish 'bloom' (Lyons and Merilees 1995).

6.1.1.3 Dwarf bilberry (Vaccinium caespitosum)

Dwarf bilberries grow throughout the west coast, from California to Alaska, and also grow across North America to the east coast, although primarily in the northern half of the continent. They can be very short plants, varying from 2.5 cm to 60 cm, but they tend to be about 10-20 cm tall. Leaves are finely toothed along margins, and flowers are pinkish coloured bells, about 4-7 x 3-5mm. Berries are blue with a grey 'bloom' and are 5-9mm long (eFloras.org 2008; Lyons and Merilees 1995).

6.1.1.4 Ovalleaf blueberry (Vaccinium ovalifolium)

Ovalleaf blueberry grows west of the Cascades, particularly into interior British Columbia, and from Oregon to Alaska, and also grows in forests on the East Coast of North America. They can often be found in the shade and are about 1-4m tall with a straggly form. Leaves are oval-shaped, very similar to the Alaskan blueberry, and flowers are also pinkish coloured bells, but bigger at about 5-7 x 4-5mm. Berries are blueish black, about 8-10mm long, but in contrast to the Alaskan blueberry, they often have a whitish 'bloom' (eFloras.org 2008; Lyons and Merilees 1995).

6.1.1.5 Bog blueberry (Vaccinium uliginosum)

Bog blueberries grow across North America, from California to Alaska on the west coast, from New Hampshire north on the east coast, and across the interior in the northern part of the continent. The plants form dense mats which can get up to 60cm tall, although it is often shorter than this in alpine habitats. Leaves are leathery with rolled, entire edges and prominent veins underneath. Flowers are on long stems with a pinkish coloured bell, about 3-4mm long. The tips of the petals at the mouth of the bell are reflexed, creating a wider more jagged opening than other blueberry species. The fruit are blue, with a waxy bloom, and are about 6-8mm in diameter (eFloras.org 2008; Lyons and Merilees 1995).

6.1.2 Ecological Keystone Species (EKS)

Salmonberry are a keystone species for the role they play as forage and habitat for various animals, including humans. Salmonberry provide cover and nesting sites for many local birds and mammals, such as red squirrels, mice, black bears, and beavers (USDA Forest Service 2018a). Many parts of the plant are eaten and are a vital food source for a large number of animals. Leaves and twigs are an important food source for local PNW ungulates such as deer, mountain goats, elk, and moose, as well as smaller mammals (i.e. rabbits, porcupine, beaver) and fruits are eaten by a wide range of local species from birds (i.e. grouse, songbirds, American robins) to small and large mammals (i.e. squirrels, foxes, mice and other rodents (primarily the seeds), and black and brown bears) (USDA Forest Service 2018a; USDA-NRCS 2012). Finally, the nectar is an important food source for bees, butterflies, other insects, and hummingbirds (USDA Forest Service 2018a; USDA-NRCS 2012). In addition to their food value, a salmonberries' rapid growth and dense belowground root and stem systems bind soil well, making them important species for stabilizing eroded or disturbed sites (British Columbia Nature 2002; USDA Forest Service 2018a; USDA-NRCS 2012), an observation also noted in interviews by Michael Jackson (Kake): "they took [a] cutting, and they know that it would self-propagate, or clone itself, and they put them in gardens" and Charles Jack (Hoonah) – "salmonberry, you take a branch and you poke it in the ground, it'll grow…a lot of times my mom…when the first branches are [out]…[she would] break a limb, peel off the skin and put it in the ground".

As a keystone species, blueberries play a role as a forage and habitat for various animals, including humans. They are thought to provide cover to mainly bigger animals due to the height of the plants (USDA Forest Service 2018b), and in terms of food availability, leaves, flowers, and fruits are utilized. In this region, leaves are an important food source for both local ungulates such as deer, mountain goats, and elk (USDA Forest Service 2018b, 2018c) and for the larval stages of Lepidoptera, several species of which feed solely on *Vaccinium spp*. (particularly *V. uliginosum* from this study area, Natural History Museum 2019). It is especially a favourite food of black-tailed deer (*Odocoileus hermionus*) in

Western Washington (USDA Forest Service 2018b). As well, fruit are eaten by a wide range of local species from birds (i.e., grouse, ptarmigan, pheasants, songbirds) to small and large mammals (i.e., squirrels, foxes, and black and brown bears) (USDA Forest Service 2018b, 2018c). Finally, the nectar has been documented as an important food source for several species of both long and short tongued bees (Hilty 2015). In addition to its food value to animals and humans, blueberries are very economically relevant to local people, both commercially and with wild harvesting (Alaska Dept of Fish and Game Division of Subsistence 2019). Blueberries can grow from seed, cuttings, or damaged parent plants quickly, and thus can spread (or be planted) to cover cleared areas rapidly, providing stabilization and a food source in disturbed sites (USDA Forest Service 2018b, 2018c).

One important ecological change affecting this CKIS, as suggested both in the literature and by Indigenous observers, is that earlier and warmer springs are causing plants to bud earlier than normal. This pattern of earlier flowering often leads to a disconnection with pollinators which either have not arrived (e.g., hummingbirds), or have not become active (e.g., bees), in turn decreasing the amount of fruit able to form (Visser and Both 2005; Walther *et al*. 2002). Further damaging to fruit formation is the increasingly common pattern of a warm start to the spring that encourages early bud growth that is subsequently killed by a later frost, as described by participants in this research. Even if fruits do set under these variable conditions, the quality and quantity can vary greatly depending on the summer and autumn weather conditions. If the conditions are too wet, the berries either become saturated with water and don't produce the necessary sugars to fully ripen, or they rot before ripening. In addition, increased rainfall can cause immature forms of insects and worms (species not specifically identified by the interviewees) to occur more frequently in the berries, which renders them less favourable for consumption. Alternatively, if the conditions are too dry, as evident with hotter, drier weather spells in early summer, the berries will desiccate and dry out before they ripen. From these observations, it can be seen that changing late winter, spring, and summer weather conditions can be tracked by the quality of these CKIS fruits. Furthermore, observing the phenology of salmonberries and blueberries can indicate critical changes in climatic conditions during the growing season. Observations were also made throughout the interview data[82] about how they were food to various animal species such as deer, wolves, bears, and birds, and even including invasive bird species such as starlings and pigeons, and that their absence would affect the animals that eat them (Michael Jackson, Kake).

6.1.3 Cultural Keystone Species (CKS)

Using harvest data from CSIS (Table 6.1), it can be seen how many berries have been harvested in Alaska. As stated in Chapter 2, the Methods chapter, every government has a different way of reporting catch records, and unfortunately it is hard to access data from British Columbia. However, in Alaska, berry harvest is recorded by the Community Subsistence Information System (CSIS) by the Alaska Department of Fish and Game (Alaska Dept of Fish and Game Division of Subsistence 2019). Harvest data for berries had been recorded every year since 1982, but not every community was recorded every year, and before the 2000's the unidentified berry harvest was reported in quarts rather than pounds, and harvest was not broken down into species, which makes comparison tricky. The percentage of the total harvest that is composed of either unidentified berry harvest, or specifically blueberry and salmonberry is also included in this table, because it shows that despite a large percentage of households in each community harvesting relatively large numbers of berries, it doesn't actually translate into the largest percentage of resources used.

[82] A11 (Kake), Sherri Dick (Old Massett), Margaret Edgars (Old Massett), Captain Gold (Skidegate), Adam Greenwald (Hoonah), Mary Guthrie (Klawock), Michael Jackson (Kake), Marlene Johnson (Juneau), Cora Joseph (Klawock), Jack Litrell (Old Massett), Emily Watts (Old Massett)

Table 6.1. Berry harvest patterns.

Community	Year	Blueberry (Gal)	% household harvesting	% of total harvest	Salmon berry (Gal)	%HH	% of total harvest	Unidentified berries	%HH	% of total harvest	Other species harvested
Craig	1997	---	---	---	---	---	---	13,972 (Qts)	58.4%	0.05%	---
	1987	---	---	---	---	---	---	2,178 (Qts)	40.0%	0.01%	---
Hoonah	2016	2293	64.6%	5.2%	1044	66.2%	2.4%	24,822 (Lbs)	75.4%	14.2%	A
	2012	2741	71.3%	4.4%	795	49.2%	1.3%	24,048 (Lbs)	77.0%	9.6%	B
	1996	---	---	---	---	---	---	14,955 (Qts)	71.4%	0.07%	---
	1987	---	---	---	---	---	---	4,148 (Qts)	69.7%	0.02%	---
	1985	---	---	---	---	---	---	7,245 (Qts)	66.2%	0.04%	---
Hydaburg	2012	534	72.9%	1.2%	364	64.6%	0.8%	5,159 (Lbs)	77.1%	2.9%	C
	1997	---	---	---	---	---	---	3,095 (Qts)	60.8%	0.03%	---
	1987	---	---	---	---	---	---	1,533 (Qts)	52.2%	0.02%	---
Kake	1996	---	---	---	---	---	---	2,920 (Qts)	65.8%	0.03%	---
	1987	---	---	---	---	---	---	4,537 (Qts)	69.7%	0.07%	---
	1985	---	---	---	---	---	---	3,501 (Qts)	65.7%	0.03%	---
Klawock	1997	---	---	---	---	---	---	7,742 (Qts)	59.4%	0.04%	---
	1987	---	---	---	---	---	---	1,942 (Qts)	49.2%	0.01%	---
	1984	---	---	---	---	---	---	1,794 (Qts)	69.4%	0.02%	---

Notes: These data are records from CSIS, including the gallons harvested for each species, and either pounds or quarts reported for unidentified berry harvest.
A – Low bush cranberry, high bush cranberry, crowberry, elderberry, currant, huckleberry, cloud berry, nagoonberry, raspberry, strawberry, thimbleberry, twisted stalk berry, wild rose hips
B - Low bush cranberry, high bush cranberry, elderberry, gooseberry, currant, huckleberry, nagoonberry, raspberry, soapberry, strawberry, thimbleberry
C – huckleberry, thimbleberry, other wild berry

The importance of this resource was also seen in the interview data. Participants interviewed reported that both salmonberries and blueberries were very important to them for food and, particularly with regards to blueberry, were an economically viable wild harvest, especially noted in Hoonah and Kake.

Another way of recognising the cultural importance of a species to an Indigenous group is to examine its role in the language, and the number of terms that appear relating to anatomy, life stages, and other resource characteristics (Turner 1988). The three Indigenous groups in this study, the Tlingit, Haida, and Tsimshian, all have their own languages, and it is this data which has been explored here to examine linguistic importance. To link this CKIS example to the linguistics literature I reviewed dictionaries for names for salmonberries and blueberries in each language (Table 6.2).

The language references (Anderson 2018; DeVries 2014a; DeVries 2014b; Edwards 2009; Lachler 2010; Roberts 2009) were also searched for additional terms relating to the CKIS examples (such as anatomy, harvesting techniques, processing, etc). For all this case study, there were a large number of terms found relating to these species and their use, indicating a high cultural significance, not just for harvesting, but in the social fabric more generally (Turner 1988).

Generic terms for berries were found in Tlingit and Haida, relating to flowering, size and stage of ripeness of berry, and food use. Specific terms for blueberries were only found in the three Haida dialects, covering anatomy, location, and the action of gathering. Specific terms for salmonberries were found in all three languages, relating to season and location, anatomy, colour and size of berry, medicinal usage, and mythology.

Table 6.2. CKIS names from the three languages throughout study area.

English name	Scientific name	Tlingit name	Tsimshian name	Alaskan Haida name	Old Massett Haida name	Skidegate Haida name
Blueberry (generic and oval-leaved)	*V. ovalifolium*	kanat'á[1]; kakatlaax[2]	smmaay[3,4]; smmay[3]	Hldáan[5]; hldáan Gadg[5]	hldaan[6]	hldaan[7]
Blueberry, Alaskan	*V. alaskaense*	naanyaa kanat'aayí[1]; naanaa kanat'aayí[2]	--------------	hldáan kidg[5]	--------------	hldaan[7, 8]
Blueberry, bog	*V. uliginosum*	ts'éekáxk'w[1]; láx'loowú[2] (swamp); ts'éekáxk'w[2] (mountain)	--------------	Gáan xáwlaa[5, 9]; hlGu Gáanaa[5]	HlGu Gáanaa[6]; Gáan xáw'laa[6, 9]	tllga GaanGa[7]; Gaanxaaw 'laa[7]
Blueberry, dwarf	*V. caespitosum*	kakatlaax[1]	mihaał[3,4]	--------------	--------------	--------------
Salmon berry	*R. spectabilis*	Was'x'aan tléigu[1] Ch'a aanáx tleikw[2]	makooxs[4]; magooxs[3]; mak'oxs[3]; mak'ooxs[3]	sk'áwaan[5]	--------------	sk'aawGan[7]

[1] - Thornton 2008; [2] - Newton and Moss 2009; [3] - Anderson 2018; [4] - Thompson 2003; [5] - Lachler 2010; [6] - DeVries 2014b; [7] - DeVries 2014a; [8] - *Vaccinium alaskaense Howell* (seems to be ovalifolium); [9] - Also a name for saskatoon berry; Note: hldaan radaga; hldáan radga, hldáan radg = berry of Vaccinium ovalifolium (S, M H); hldaan qidga; hldáan qidga, hldáan qidg = berry of Vaccinium alaskaense

6.1.4 Indicator Species

Salmonberry require locations that have wet and moist conditions and are rich in nitrogen (Halverson *et al*. 1986; Klinka *et al*. 1989), and thus their presence often indicates a close source of water (Halverson *et al*. 1986), in addition to the obvious indicator of the local soil and moisture regimes (Halverson *et al*. 1986; Klinka *et al*. 1989).

Blueberries require habitats that are acidic, poor in nitrogen and wet, such as bogs (Hilty 2015; Klinka *et al*. 1989; USDA Forest Service 2018b), and thus their presence indicates this local soil and moisture regime (Halverson *et al*. 1986; Klinka *et al*. 1989). Additionally, blueberries indicate two ecological scenarios. They frequently appear shortly after a disturbance occurs, such as clearcutting, producing a more open forest floor, as they can take hold easily with more light and a lack of competition and can thus indicate land-use changes. However, they are also a common species in old growth ecosystems (due the open forest structure), and thus indicates the presence of mature forest (USDA Forest Service 2018b). Because of this disparity in indicating habitat types, blueberries are a better indicator of soil type in various scenarios than forest successional stage.

6.1.5 Salmonberry and Blueberries as a Cultural Keystone Indicator Species functional group

As Kake elder Michael Jackson's statement at the start of this chapter emphasizes, berries are a main staple of people's diets, and in contrast to the highly regulated salmon and deer examples used in previous chapters, people are freely able to harvest berries, even in more urban environments. In addition to being a daily staple they are an important food for communal feasts and ceremonies, providing an integral connection to heritage and culture, a connection that is being damaged by ecological and climatic changes. Several participants (Adam Greenwald (Hoonah), Fred Hamilton (Craig), Michael Jackson (Kake)) used words like 'mainstay', 'main berry' and 'depend upon a lot' when referring to both salmonberries and blueberries, a recognition of their importance to people, and Lori Kay Guinard (Hoonah) thought that of all the species changing around them, blueberries and salmonberries had changed the most. Therefore, from the above evidence of all these species of berries: being prime examples of cultural keystones, ecological keystones, indicator species, playing an important role in the biogeographical and cultural landscape, being closely monitored by harvesters, common enough to be seen in many places, and significantly influenced by changes in weather at critical growth stages, I argue that this group of berry species are an excellent CKIS functional group to understand how TEK can be bridged constructively to western scientific knowledge.

6.2 Methodology

Interviews were conducted with 96 participants in Southeastern Alaska and Northern British Columbia. Participants were identified using a snowball methodology, which builds the data sample through referrals, and interviews were organised in a semi-structured format. The full methodology is described in Chapter 2.

6.3 Results: Ethnoecological data

Many species of berries were noted in interviews as being harvested, including huckleberries, nagoonberries, high bush cranberries, strawberries, greyberries, low bush/bog cranberries, grey currants, crow berries, soap berries, and some of these species were highly valued by a few people. However, partially due to people's individual preferences, and partially due to the geographic range of each species, these were more isolated cases. Therefore, in this research, both genera of salmonberries and blueberries, which were used and were commented upon by a vast number of people with a wide geographic spread, have been chosen to represent the third CKIS example in this study. While only one species in the

Rubus genera, or any plant genera, goes by the common name salmonberry, and is thus easy to identify in the interviews, blueberries were not divided into the individual species in the interview data, because all blueberry species that occur in the study area were referred to throughout all the interviews as 'blueberries'. It should also be noted that many times people simply referred to 'berries' when discussing an observation, so being able to match every observation to a specific species of either blueberries or salmonberries has not always been possible, but if the person did specify, then this has been noted.

Overall, salmonberries and blueberries were mentioned in about 94% of the interviews. People have noticed changes in their timing, population spread, the effects of weather on berry quality and quantity, and adaptation to a lack of berries, much of which they link to climatic changes, although these were attributed to other causes as well, in particular logging. Data from interviews is presented in depth in the following sections, and the key findings summarised in Table 6.5 below.

6.3.1 Population change

A large number of participants mentioned that the amounts of berries were changing. Vegetatively, berry bush abundance varies primarily on logging and forest openings occurring, creating a space with more light and thus higher capacity for photosynthesis. Since this change is prompted by a non-climate variable, it is fully discussed in section 6.3.6.1 Logging. In the current section, I am discussing the changes in the amount of reproductive output, which is more closely tied to climate variables, although still influenced by logging and land use changes. While many people attributed this mainly to climate change, Merle Hawkins (Ketchikan) and Marlene Johnson (Juneau) thought that man-made development was the biggest cause of change. Only two participants, Mary Guthrie (Klawock) and Myrna Yates (Craig), were quite adamant that the berries had not changed, and felt that if you went out to harvest, you could find berries, you just had to work at it: “you can’t just go stand on the side of the road and say, well, there’s no berries, you gotta get in there, and you gotta work your…behind off to find where the berries are growing” (Mary Guthrie, Klawock). Since, overall, 13 people in all four sub-regions commented on berries decreasing, and only two mentioned about being able to find berries if you tried, I think either they are possibly more persistent harvesters, and spend more time looking, since more effort is being required to harvest at customary levels, or feel they have to push young harvesters to go out by saying you have to keep working at it to find berries.

6.3.1.2 Amount of Reproductive Output

Observations around the amount of fruit produced by the berry bushes was highly variable, perhaps pointing to the fact that climate, logging, and development can all impact the vegetative growth, presence or absence of bushes, and the reproductive capacity of the species on a yearly basis. Firstly, the least common observation – from only one person, (A9, Juneau), said that there were more berries now, due to logging practices: “when I was a little boy, my mom used to take us berry picking, we never used to get anything close to what they are getting now…but there was no logging then”. However, he went on in the next sentence to say “around here, it’s hard to find blueberries”, indicating that while there might be bursts of growth, he likely does agree with the majority of the participants that berry productivity is increasingly variable.

Secondly, eight participants[83] noted that they thought fruit output was about the same as it had always been. Half of these observations were from the HG subregion and may potentially be influenced by the impact of browsing deer. Potentially people may feel that the

[83] A3 (Skidegate), Lionel Bean (Kake), Sherri Dick (Old Massett), Mary Guthrie (Klawock), Cora Joseph (Klawock), Jack Litrell (Old Massett), Harvey Williams (Skidegate), Myrna Yates (Craig)

berry output is about the same because the decrease of berries caused by climate changes has been obscured by years of over browsing, as deer have been present for many years: “I think they’ve been producing” (Sherri Dick, Old Massett). One of these people, Lionel Bean (Kake), when asked if the growth or amounts of berries had changed, observed “not much has changed here”, but then also noted later in the interview: “this year we didn’t have as many salmonberries as last year”. Cora Joseph (Klawock) overall noted that berries were the same, but also recorded a one off low year (and thus a one-year anomaly, and not a broader pattern): “there was none, the berries weren’t even there…I don’t know if they got picked or what, when we went down, we thought we’d find some berries, but there were none at all…we were looking for blueberries and huckleberries…just this year [there’s been nothing], it’s like that, but see, for instance, same with, our salmonberries, didn’t ripen, and we didn’t have no rain”.

Thirdly, thirteen participants[84] discussed how they are getting less berries than normal: “two years ago I could pick maybe 12, 19 cases of salmonberries, just from here you know, there’s so much, the last two years maybe 3 quarts is all I got, hardly any, you can see them blooming and all that, but they weren’t producing fruit…so that’s changed the last couple of years, you know” (Marvin Kadake, Kake). Two of these, Lionel Bean (Kake) and Cora Joseph (Klawock), also thought that berries were the same, mentioned above, and perhaps this comment of less was a more recent effect of landscape: “we were looking for blueberries and huckleberries…just this year [there’s been nothing there]” (Cora Joseph, Klawock), and five of them[85] said both that the berries were up and down, and unpredictable,

[84] A2 (Old Massett), A10 (Hoonah), A11 (Kake), Lionel Bean (Kake), Nancy Bean (Kake), Margaret Edgars (Old Massett), Fred Hamilton (Craig), Cora Joseph (Klawock), Marvin Kadake (Kake), Ernestine Kato (Klawock), Harold Martin (Juneau), Robbie Nelson (Metlakatla), Emily Watts (Old Massett)
[85] A10 (Hoonah), Margaret Edgars (Old Massett), Fred Hamilton (Craig), Harold Martin (Juneau), Emily Watts (Old Massett)

and less overall, observations that validate that fruiting abundance may have high interannual variability.

Lastly, while a few people above either said berries were increasing or decreasing, the majority of participants, 19 in total[86] agreed that the amounts of berries were variable and unpredictable, with lots of between year variability: "as far as gathering, you know, that's a year to year thing, it just depends on the weather is doing, last year there were no blueberries, none, zero, zip…we went out and fortunately, the year before was a really good blueberry season, I mean just off the charts… so we put up literally a whole freezer I think, we'd picked a hundred quarts of blueberries" (Anthony Christianson, Hydaburg) and Wilbur Brown's (Kake) observation that "some years people pick berries, other years, can't even find them, some years everywhere, this year [2014] not too bad". These observations were made primarily in NSE (10), but participants in all four regions did note this unpredictability.

6.3.2 Flowering and fruiting patterns

The quote at the beginning of this chapter illustrates how complex the interactions between berries and weather changes are believed to be. Throughout the interviews, several themes emerged about how berries respond to weather changes. Overall, the most observations of weather were made in NSE, followed by SSE, HG, and MBC, however the majority of the HG observations with weather were concerning early flowering and frosts, rather than the amount of rain and sun.

[86] A6 (Old Massett), A10 (Hoonah), Wilbur Brown (Kake), Anthony Christianson (Hydaburg), Helen Clifton (Hartley Bay), Alma Cook (Klawock), Margaret Edgars (Old Massett), Ken Grant (Hoonah), Ester Greenwald (Hoonah), Lori Kay Guinard (Hoonah), Fred Hamilton (Craig), Charles Jack (Hoonah), Joel Jackson (Kake), Evans Kadake (Kake), Harold Martin (Juneau), Jacque Martin (Juneau), Fanny Nelson (Metlakatla), Emily Watts (Old Massett), Harriet Williams (Kake)

6.3.2.1 Early Flowers

Firstly, 16 participants[87] discussed the intricacies between weather and flowers in all four sub regions, although NSE had the most participants (8). Participants discussed that flowers are coming out very early in the year, primarily referring to salmonberries. In fact, when I visited Haida Gwaii in February 2015 for field work, I observed that the salmonberries were already blossoming (February-March is the very beginning of their season recorded in the botanical literature for their entire range). Participants noted buds and flowers anywhere between January and March: "now, we see blossoms out and we're in January" (Reg Davidson, Old Massett), "in January you see the little buds start to come out" (Ken Grant, Hoonah) and "this spring in March, and that was early, our salmon berry bushes were budding…and that's a little early…it wasn't cold…March is the month of North wind, when it's our coldest, but every now and then, someone walking the streets or something, will look at the salmon[berry]… wow, budding already, you know…and that don't happen until April" (Wilbur Brown, Kake). This pattern of early flowering due to unseasonably warm weather had two main ramifications: there is a disjunction between flowers and bees, and late frosts kill the buds or flowers, both of which lead to a lower fruit yield.

It was been well evidenced that the phenology of many organisms is shifting in response to climate change, and not only are individual organisms changing, but also the gaps between organisms that depend on each other, such as bees and flowers. These gaps are creating a disjunction (Visser and Both 2005; Walther *et al*. 2002), and because this particular partnership results in a massive advantage for the plant, that of producing fruit, and thus seeds and sexual reproduction, it is vital for the survival of the species. Moreover, the production of berries is of high cultural importance: "that means we won't have berries again,

[87] A9 (Juneau), A13 (Juneau), Wilbur Brown (Kake), Anthony Christianson (Hydaburg), Helen Clifton (Hartley Bay), Reg Davidson (Old Massett), Margaret Edgars (Old Massett), Ken Grant (Hoonah), Merle Hawkins (Ketchikan), Charles Jack (Hoonah), Michael Jackson (Kake), Linda Kruger (Juneau), Harold Martin (Juneau), Emily Watts (Old Massett), Rolly Williams (Old Massett), Myrna Yates (Craig)

because there's no bees around" (Reg Davidson, Old Massett). In addition to temperature change shifting phenology, rain may also affect bee behaviour, as noted by one participant: "you don't see too many bees out when it's raining" (Helen Clifton, Hartley Bay). While it is not fully understood yet, a recent review shows that flowers are often affected by pollen degradation and nectar dilution in rain, and the effects on pollinators are not fully elucidated, but a decrease in activity has been documented (Lawson and Rands 2019).

Not only are bees and flowers not aligning for pollination because of the different phenological responses to warming temperatures, but a lack of pollination is further exacerbated by a decrease in the bee population, a phenomenon also documented worldwide, and in the PNW, in the literature (Bromenshenk *et al*. 2010; Cameron *et al*. 2011; Hatten and Strange 2015; Pampell *et al*. 2015):

> Emily: because some years you don't see the bees pollinating…and some years you can hear the bees all over…and I notice sometimes when I'm walking you don't hear them
> Margaret: there hasn't been pollinating bees around for a long time (Emily Watts and Margaret Edgars, Old Massett)

Similarly, earlier (winter) warming may stimulate new (spring) buds and fruit development; but if this warming is followed by renewed freezing temperatures towards the end of winter, and especially by freezing precipitation, the fruits will often die, with potential devastating effects on the harvest, as seen in the following comments: "whereas, before, when I was growing up, it was the main, it was a constant warming up from winter, and the berries went through that development, they started budding, and then they started growing their flowers, and the real sensitive part, the heat, or sun, warmed them up and they grew, but now we are getting these warmer spring times, and then it's a cold freeze, and it freezes the buds" (Michael Jackson, Kake) and "if the blossoms are already out and the cold snap comes it will ruin the berries for the year" (Margaret Edgars, Old Massett). This is greatly detrimental to people's use of this resource, and they are pleased when either the flowers are later in the spring, or there isn't a late cold snap: "we had a late spring and we were happy with that because when you get a late spring, we get a lot of blueberries and salmonberries because the frosts don't kill their blossoms, see, their blossoms come out too early because it frosts up until May, late May you know, and if they blossom by then we know we aren't going to get many berries, but this year that didn't happen, they blossomed real good and there was a lot of them that got it" (Charles Jack, Hoonah).

6.3.2.2 Size of berries

The size of the berries was almost exclusively commented upon in Kake, Hoonah, and Juneau. The most common observation, by seven participants[88] in these communities, was that berries had decreased in size, although one person said that you could find larger berries, but only way back in the forest (A11, Kake), and the only person that commented on size outside of the NSE region, in HG, said they were about the same size as always (Sherri Dick, Old Massett).

6.3.2.3 Lack of rain in growing season

10 participants[89], primarily in NSE and SSE (four in each), and two in MBC, discussed how a lack of rain at various stages in the growing cycle affects berry production. While Lionel Bean (Kake) felt that plants were able to compensate for lower rainfall, with adaptations: "we could go two to three weeks without rainfall, in some places and it won't affect it that much…maybe like 3-4 inches on top, you could really easy just get in the muskeg and go like that and you'd have water…the roots travel a long ways", or berries were

[88] A13 (Juneau), Lionel Bean (Kake), Nancy Bean (Kake), Catherine Bolton (Hoonah), Donald Bolton (Hoonah), Wilbur Brown (Kake), Lori Kay Guinard (Hoonah)
[89] A11 (Kake), A13 (Juneau), Lionel Bean (Kake), Anthony Christianson (Hydaburg), Helen Clifton (Hartley Bay), Mary Guthrie (Klawock), Fred Hamilton (Craig), Michael Jackson (Kake), Vickie Le Cornu (Hydaburg), Fanny Nelson (Metlakatla)

now being found under canopies instead of on top: "let's just say you're looking at the brush out here…and there's no berries on it, but if you lift up the brush underneath, under the canopy, that's where you'd find them…so the moisture was coming from somewhere, and it's probably coming from the muskeg" (Lionel Bean, Kake). However, most participants discussed how lower rainfall amounts are leading to berries not ripening and becoming desiccated, because they need a certain amount of rainfall: "it was so hot and dry for such a long period of time, that a lot of berries and stuff didn't ripen…like blueberries and things like that" (Anthony Christianson, Hydaburg) and "they were all withered…[there was] no rain at the right time" (Vickie Le Cornu, Hydaburg). Another key is that the rainfall needs to be at a certain time, and it is being found that the rainfall patterns are changing: "this summer, we got days of sunshine, when the berries were just starting…we didn't get enough rain…they need rain [to finish getting big enough before fully ripening]" (A11, Kake).

6.3.2.4 Too much rain in growing season

12 participants[90], primarily in NSE (6), but also in the other three regions, discussed how too much rain at various stages in the growing cycle affecting berry production. The main issues that arose were that the berries were flavourless and not sweet because of too much rain: "our berries are not tasty this year" (Wanda Culp, Hoonah), and that the berries had mildew or were rotting: "because of the rain, it rots the berries really fast" (Emily Watts, Old Massett) and "it did rain a lot this year, so I think that's made a difference in our berries, it's rotted a lot of them…mildew got to them" (Wanda Culp, Hoonah). Harder rains are also causing the berries to fall off the bushes: "because of the heavy rain here in the summer now, it rains so hard, and the berries fall to the ground" (A13, Juneau). Thus, it was shown in the

[90] A13 (Juneau), Catherine Bolton (Hoonah), Donald Bolton (Hoonah), Wanda Culp (Hoonah), George Davis (Juneau), Agnes Davis (Juneau), Margaret Edgars (Old Massett), Mary Guthrie (Klawock), Merle Hawkins (Ketchikan), Ernestine Kato (Klawock), Emily Watts (Old Massett), Fanny Nelson (Metlakatla)

last two sections that there needs to be a balance in the amount of rain for optimum berry growth (particularly size and abundance).

6.3.2.5 Influence of sun in growing season

In addition to the amount of rain during the growing season, the amount of sun is equally important. Seven participants[91] primarily in NSE (5), especially Hoonah, noted the effect of a lack of sun. The observations of 'less sun' were mostly thought to be either from the temperatures not warming up enough: "they never ripened, because the weather wasn't warm, although it didn't rain all that much, but it wasn't warm (Charles Jack, Hoonah) or from there being too much rain throughout the summer: "because [there's] rain, they didn't get enough sun" (Helen Clifton, Hartley Bay). Linking in with the above observations of rain making the berries tasteless, participants also noted that certain amounts of sun are needed to ripen the berries fully: "we were worried about the blueberries getting sweet enough…because we hardly got any sun this whole summer, and then just the last few weeks there was this intense sun and guess what?...the berries got sweet" (Ernestine Hanlon Abel, Hoonah).

Only three people[92], widely spaced in the regions of NSE and HG noted a negative effect of too much sun, burning blueberry flowers (particularly noted in April by A13, Juneau) and berries: "you can just tell they are slowly but surely, they are dying off on their own, and a lot of that's because, well, we get the sun, and when we get it you just like get it full force, it's like sitting under a heat lamp, you know, 40, you get sun out here, 40 degrees feels like a 100 degrees down south" (Lori Kay Guinard, Hoonah). One of these participants, Lori Kay Guinard, made observations addressing both situations of too much sun and not

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[91] A11 (Kake), Helen Clifton (Hartley Bay), Wanda Culp (Hoonah); Lori Kay Guinard (Hoonah), Ernestine Hanlon Abel (Hoonah), Charles Jack (Hoonah), Vickie Le Cornu (Hydaburg)
[92] A6 (Old Massett), A13 (Juneau), Lori Kay Guinard (Hoonah)

enough sun, recognising the impacts of increased variability in weather patterns: "and then you turn right back around and the next day 40 degrees can feel like 20 degrees down south [laughs], it's a strange climate up here in the last few years…you could usually tell you know, what it was going to be like…[but] you can't anymore". These observations echo comments described in Chapter 3 referring to there being some days that were really hot and burning people.

Three participants[93] also discussed the temperature, regardless of the amount of sun, equally spaced between the subregions of NSE, SSE, and HG, saying that cold temperatures also affect berry production when it is too cold later in the summer: "it doesn't turn out the way it should, not thick, just goes dormant…sometimes, like it doesn't produce too [many] berries" (Margaret Edgars, Old Massett). Thus, it was shown through the interview data that it is also important to have balance between too much sun and not enough so that the berries gain optimum flavour and abundance.

6.3.2.6 Interaction between amounts of rain and sun

Many of the participants had observations regarding rain and sun not as individual components affecting berries, but rather the interaction between them will provide a good berry harvest in a given year, showing that people understood the complexity of the abiotic factors influencing berries, and the need for a balance between sun and rain:

> "good weather for a long time produces berries quick, so that's what you watch for…poor weather, slow growth and slow ripening…cause sometimes the slow growth on berries produce a sweeter fruit…then the ones that come real quick…but the ones that come real quick with a little bit of rain, gets so big and fat!...they fall off by themselves…[and the] ones that get slow…I mean good ripening, without that much rain, is a little tighter, and lasts longer on the stem…so both are good" (Captain Gold, Skidegate)

[93] Margaret Edgars (Old Massett); Merle Hawkins (Ketchikan); Charles Jack (Hoonah)

> "when they ripen, [with] a little bit of sunshine, and then when it started raining…especially when it rained for, oh, say three to four days…then it stopped, it made the salmonberries sweet, made the huckleberries and blueberries bigger" (Cora Joseph, Klawock)

Throughout all the rain and sun observations, there was an underlying thread of concern that the correct conditions for berries might not be happening every year, and the acknowledgement of the importance of the weather:

> "this year they are smaller, and they are not tasty…salmonberries, raspberries, blueberries, they are not up to par…because of the weather, it's been unbalanced, we've had too much rain, and not enough sunshine…and that has taken its toll, literally, on the berries…you know, it just does, there's nothing you can do about it…the weather dictates everything, EVERYthing" (Wanda Culp, Hoonah).

With this observation, Wanda Culp is not only expressing the importance of weather in shaping berry quality but seems to be conveying people's feelings of helplessness not being able to influence the quality of the berries because they can't control the weather. Additionally, it's not just the influence of different amounts of sun and rain but also the uncertainty by having 'unbalanced' and varied weather.

6.3.3 Quality of resource

Throughout the above sections, it can be seen that even though many participants are still able to harvest this resource, even if there are challenges with the weather and the quantity of resources, sometimes the quality of the berries are compromised, making them harvestable but less desirable. Some participants did not feel that the quality was lower, but for those that did, references were made to tasteless, smaller, not sweet, and dried out berries. Jack Litrell (Old Massett) further discussed how the quality is not always linked to colour, although he surmised that water content was key in the taste: "every year is different, some years they are big and sour, and other years they're sweeter, it's hard to say…it doesn't have to do with the colour either…the bright red ones can be really sour…I think it might have something to do with the water content, or something, I'm not sure". While he was referring to red huckleberry (*Vaccinium parvifolium*) for this example, this type of response by the berries to weather was also alluded to by others when talking about the "balance" of sun and rain needed in ripening (Section 6.3.2.6).

6.3.4 Timing of resource

Salmonberries tend to ripen first in the summer, from May onwards, followed by blueberries from July onwards (Lyons and Merilees, 1995), an order echoed by three participants[94] in the NSE and HG subregion. However, in both HG and NSE again, four other participants[95] said that berries had almost switched their timings, because some were later than normal, and some were earlier, often making salmonberries and blueberries ripe at the same time, or that everything was mixed up. For example, A11 (Kake) mentioned that they have a harvest calendar for describing when resources were harvested, which was no longer accurate: "our months were known by what was happening in that month…it's probably changed quite a bit now, it's changing with the times, you know, everything is changing…it's changing so much…[so] not really, we've just started to teach the kids a long time ago how they learned about the animals [and plants]". In addition to her above comments, Sherri Dick (Old Massett) and one more interviewee, Fanny Nelson (Metlakatla), further explained that berries are both early and late, observations that are again likely tied into the unpredictability of the weather between each growing season.

In addition to the five people that described a mixed-up timing above, a further 13 participants felt that timings had moved either earlier or later in the year. Four participants[96] equally divided between NSE and SSE, but only in the communities of Kake and Hydaburg,

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[94] Captain. Gold (Skidegate), Marlene Johnson (Juneau), Emily Watts (Old Massett)
[95] A4 (Hoonah), A11 (Kake), Sherri Dick (Old Massett), Carol Young (Skidegate)
[96] Lionel Bean (Kake), Anthony Christianson (Hydaburg), Joel Jackson (Kake), Vickie Le Cornu (Hydaburg)

presented observations that the timings of berries fruiting were moving earlier in the season: "I see most of the berry species are coming in a little earlier" (Anthony Christianson, Hydaburg) and "the blueberries started ripening early this year, because it was so warm in our early spring" (Joel Jackson, Kake). In contrast, nine participants[97], primarily in NSE (mostly Hoonah), but with a few in the HG subregion (only Old Massett), observed that the timings of berries fruiting were moving later in the season: "an example is salmonberries, we never got any later than June…because they were gone, they were the first berries that we found…well, three weeks ago Wanda and I went picking and I got 20 quarts of salmonberries…it was about the first part of August we were picking…that's highly unusual" (Ernestine Hanlon Abel, Hoonah).

However, six participants[98] equally split between NSE, SSE, and HG all thought that the timing of berries had stayed practically the same, only altering on atypical years: "it was early this year [the first year she's noticed it]…and the berries, the salmonberries were already ready, you know…cause that's not right" (Myrna Yates, Craig), or in certain conditions: "sometimes, you know, you get an area where they'll be ripe early, where the sun is directly hitting them…but it's pretty much the same" (Marlene Johnson, Juneau).

6.3.4.1 Indicators

Participants varied in their responses of how they would know when to go out harvesting for berries. The majority of participants (7)[99] that commented on this observation said that they would monitor all the time to find the right time to harvest: "Like blueberries,

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[97] Nancy Bean (Kake), Catherine Bolton (Hoonah), Donald Bolton (Hoonah), Agnes Davis (Juneau), Gwaii Edenshaw (Old Massett), Margaret Edgars (Old Massett), Lori Kay Guinard (Hoonah), Ernestine Hanlon Abel (Hoonah), Emily Watts (Old Massett)

[98] A3 (Skidegate), A7 (Old Massett), A10 (Hoonah); Marlene Johnson (Juneau), Vickie Le Cornu (Hydaburg), Myrna Yates (Craig)

[99] A7 (Old Massett), A9 (Juneau), Sherri Dick (Old Massett), Margaret Edgars (Old Massett), Joel Jackson (Kake); Cora Joseph (Klawock); Emily Watts (Old Massett)

we just go out and check" (A9, Juneau). However, this is very time and energy intensive, and not feasible for all harvesters: "over the years we've learned to look for how the weather is and making sure we keep track of berries…and if we aren't watching, then it just comes and goes" (Joel Jackson, Kake). One participant (Cora Joseph, Klawock) further specified what they are looking for when they are monitoring the berries: "you can always tell by looking at berries, when they are soft, you know…they are ripe" (Cora Joseph, Klawock). While Charles Jack (Hoonah) was the only person to specify what they watched to indicate when to pick berries: "when the thimbleberries are ripe, the animals [worms and bugs] have moved out of the blueberries, so the blueberries are [bug free and so]…it's time to pick [them] when the thimble berries are ripe", salmonberries are an important indicator for salmon, which has been discussed fully in Chapter 5. Myrna Yates (Craig), who also felt there was not a significant difference in abundance (6.3.1.2), said that berries were always picked at the same time: "it would always come at the same time".

Another common observation, by nine participants[100], referred to how berries fit into the general harvesting cycle. While some of these observations varied between people thinking there had been no change (A3, Skidegate), unsure of timings because plants are not on a timetable (Captain Gold, Skidegate) and how salmon and berries cycle together (discussed in Chap 5), other people discussed the impacts on getting other resources because the berries had shifted timing. While Anthony Christianson (Hydaburg) presented this conflict in harvesting from a salmon viewpoint (quote in Chapter 5), a negative consequence of resource overlap from a berry viewpoint was explained by Cora Joseph (Klawock) for one harvest year: "[the berries were] ripe too fast…because I was busy working the fish and I didn't have time to pick berries and work on fish at the same time".

[100] A3 (Skidegate), Anthony Christianson (Hydaburg), Margaret Edgars (Old Massett), Captain Gold (Skidegate), Cora Joseph (Klawock), Fanny Nelson (Metlakatla); Emily Watts (Old Massett), Myrna Yates (Craig)

6.3.5 Degradation

Four participants[101] in both HG and NSE, discussed degradation in berries in the form of worms in the berries, either from waiting too long to harvest: “you wait too long sometimes, they get wormy” (Captain Gold, Skidegate) or from growing under trees: “some years you’ll find berries real thick by [the] trees, and we never pick by trees…because of worms” (Ernestine Hanlon Abel, Hoonah). Getting the worms out of the berries was solved in several ways – either waiting to pick: “[when] the thimbleberries are ripe, they [the worms] are gone [from the blueberries]” (Charles Jack, Hoonah) or soaking the berries: “just soak them in water” (Ernestine Hanlon Abel, Hoonah). While Marlene Johnson (Juneau) didn’t note an overall effect of weather on berries, instead attributing more non-climatic influences to her observations, she did observe that when the weather is wet, there aren’t as many worms: “the only thing I notice on the blueberries is that they are nice and big [from the rain], there’s no worms…because of the rain, [when] they are dried, the worms get in when there’s not much [rain]…[and] they get drier…they’re just not many, they’re just not there [when it’s wet]”.

6.3.6 Non-Climatic effects on vegetative and reproductive growth

“It’s not just the weather that affects the plants” – as succinctly put by Margaret Edgars (Old Massett), she points out that there are other factors affecting berries in addition to climatic effects. In the following section, I discuss the non-climatic effects that were commented upon in the interviews as affecting berries. One example is that while the quantity of fruit is affected by both climatic and non-climatic factors, vegetative growth was

[101] Captain Gold (Skidegate), Ernestine Hanlon Abel (Hoonah), Charles Jack (Hoonah), Marlene Johnson (Juneau)

almost solely dependent on non-climatic factors, with more logging leading to an increase in growth, and human development leading to a decrease in growth, each of which are fully explained below.

6.3.6.1 Logging

Logging affected berries in two different ways, depending on what stage of harvesting or growth the forest is at. When logging first occurs, it opens up the forest, either on the edges, or in the middle of a large tract, which allows more light in and thus more berries to grow. Eleven participants[102], primarily in NSE and HG, talked about how abundance of the berry bushes is increasing due to these openings in the canopy, saying things like: "the clearcutting, the trees and everything that they dropped and hauled out, sometimes I think that they did good for the small berries, because they came back like a rash, the salmonberries, the huckleberries (Lionel Bean, Kake); "when they log…it's good habitat for the berries…the open, they do well in the open" (Jake Litrell, Old Massett) and "they get a lot of berries in Kake, but I think it's a result of, when they log…it's called clearcutting, it cuts everything down and gives the berry bushes more rain, more sun" (A9, Juneau). Wanda Culp (Hoonah) viewed it as their payment for having their forests cut down: "only because we have suffered with clear-cuts…so that's our payback, is berries". Captain Gold (Skidegate) commented that this landscape pattern, of openings being created through logging, simulated the land management systems people used to use via burning practices, indicating the plants might be used to this growth pattern, just in a different context: "the berries, the berry plants could come back quite often because…we used to have a long practice of clearing land and then burning it and making way for berry plants". Participants also mentioned that they see

[102] A2 (Old Massett), A7 (Old Massett), A9 (Juneau), Lionel Bean (Kake); Wanda Culp (Hoonah); Captain Gold (Skidegate), Ester Greenwald (Hoonah), Merle Hawkins (Ketchikan), Michael Jackson (Kake), Evans Kadake (Kake), Jack Litrell (Old Massett)

this same pattern of berry bushes increasing along new roads, particularly as road systems expand out from communities: “the blueberries and stuff may come [i.e., proliferate] for a couple of years after the road is built” (Marlene Johnson, Juneau).

A further eleven participants[103], some of which were the same as in the above set, but being exclusively from NSE and HG this time, discussed forest succession after logging, and how alders (*Alnus spp.*), spruce (*Picea spp*.), false azalea (*Rhododendron menziesii*), and hemlock (*Tsuga spp*.) start to move into the open areas, including along roadsides, eventually shading out the berry bushes, saying things like: “it don’t take them [alder] long to cover up a gravel road, it’s growing everywhere, like grass…it just smothers the growth of berries” (Evans Kadake, Kake); “everything is grown over, everywhere…a lot of the blueberry spots where we picked…alders [grew]…into it…and did away with the blueberries, the blueberry branches they have to have sunlight, and alders cut off the sunlight” (Charles Jack, Hoonah) and “in the shade they are disappearing, they need a certain amount of light” (Jack Litrell, Old Massett). A11 (Kake) also commented that along the roadsides, dust may be an issue with not finding berries, but she was unsure of this, and likely it can be attributed to young alders and other trees coming up.

Six participants[104] noted an additional consideration to logging practices – the hazards logging slash presents to harvesters, creating the higher risks of tripping over logs or falling into holes, and had several personal stories to share of them, family members, or friends hurting themselves: “it’s dangerous, I broke my foot two years ago, getting berries…because of the logging that was done, they left all the slash and everything, so it was just harsh to even get out there, I wasn’t even in the woods yet, and I slipped and broke my damn foot”

[103] A2 (Old Massett), A11 (Kake), A13 (Juneau), Nancy Bean (Kake), Charles Jack (Hoonah); Marlene Johnson (Juneau), Cliff Johnson (Juneau), Captain Gold (Skidegate), Evans Kadake (Kake), Jack Litrell (Old Massett), Jacque Martin (Juneau)

[104] Nancy Bean (Kake), Wanda Culp (Hoonah), Margaret Edgars (Old Massett), Ernestine Hanlon Abel (Hoonah), Merle Hawkins (Ketchikan), Emily Watts (Old Massett)

(Wanda Culp, Hoonah), "it's like clear-cut areas…its real rough terrain…the last time I went, I think both my friend and I, we both fell" (Merle Hawkins, Ketchikan), and "you can't even walk in the woods where it's been logged…it's so ugly, and they didn't clean it up…I used to worry about my mum, I'm glad she's not picking anymore, because you'd be walking along, and all of a sudden you could go through a hole, real big hole, your whole body sometimes, or just your whole leg, you know, it's dangerous…when did picking berries become such a high hazard" (Ernestine Hanlon Abel, Hoonah).

While clearcutting has occurred for many years in this entire region, Marvin Kadake (Kake) pinpointed that much of the clearcutting in Kake had occurred in the 1970's, and Fred Hamilton mentioned that logging affects berries, but neither addressed it further. The impacts of logging was also detailed in Chapter 4, as it relates to deer populations.

6.3.6.2 Pollution

Only one participant, Harold Martin (Juneau), mentioned the possibility of pollution with berries, that of finding toilet paper in the woods, and not wanting to harvest berries there anymore: "I used to get salmonberries [at a harvesting spot], but one day I went out there, and in this one bush where was a pile of toilet paper…I never went back again".

6.3.6.3 Invasive species

Invasive species were described as affecting both the physical ability of people to harvest berries, and the availability of berries. Wanda Culp (Hoonah) noted that there is a tall species of grass, which she stated was introduced by road builders, likely to provide stabilization to the roadsides, that hinders their ability to pick: "what about this tall grass that we have that gets, just literally pollinates our berries, and slaps us in the face, makes picking berries harder and harder…that's invasive, THAT'S invasive…this real tall grass, that's

Forest Service…the road builders, that what they sprayed the sides of the road with when they built them, totally invaded us". While she also expressed worry that this pollen may confuse the berries, it is unlikely to affect the berry flowers due to incompatibility and a difference in pollination vectors.

Unidentified invasive plants were also noted as competing for space with natives: "if we're getting invasive plants, um…good luck to ours, you know what I mean?" (Mary Guthrie, Klawock), and invasive birds (including starlings, pigeons, and some unidentified birds), particularly noted in the HG subregion, were eating the berries: "the other thing that we have a lot of, that we never had before are those starlings…that are flying everywhere, we never used to have those birds here, and they are just big, huge flocks of them everywhere, and they are affecting the [amount of] berries" (Sherri Dick, Old Massett).

One special case of an invasive species is deer on Haida Gwaii. Whereas deer are native to most of the study region, they are not native to Haida Gwaii, a discussion point that was fully elucidated in Chapter 4, from the perspective of the deer's effect on the landscape. It is re-mentioned here because while deer affect all plants on Haida Gwaii, they in particular affect the abundance of vegetative growth of berry bushes, which also greatly affects the availability of berries for people: "two places out there…where they fenced it in, it's just full of berry bushes, and medicinal plants…and the poor deer was walking around, made a big thing…around the fence-in area…wanting to get in that really bad…so that's when we realised how much the deer affected the plants" (Margaret Edgars, Old Massett).

6.3.6.4 Pests

The presence of pests, which was not related specifically to climate changes was mentioned solely by Helen Clifton (Hartley Bay), who was worried that the tent caterpillars (*Malacosoma californicum*) that had recently shown up in the village on their domesticated apple trees might jump species to the native crabapple, and may even go to other fruits: "it's just that type of caterpillar that would jump to other fruit trees, and so people were out checking…you know we have the high bush crabapples [*Malus fusca*], up in Old Town…could it be something that we would have to…look at where they [were] attacked by this same foreign caterpillar, and nobody…thought of checking it out, and do they attack other forms of fruits, so that would be something to know". While tent caterpillars have been known to infest other species besides apple (Cranshaw 2004), there was only one mention of them as potentially having blueberries as a host (Blueberry Field Guide 2020). However, there is another species, fall webworm (*Hyphantria cunea*), which has been noted in domesticated blueberries (Blueberry Field Guide 2020; Cranshaw 2004), and if either species becomes a widespread pest in gardens, it could potentially jump to wild species, although no research has been found on that in the literature to date.

6.3.6.5 Erosion

The effects of erosion were only mentioned by one participant, Lori Kay Guinard (Hoonah), with a connection to logging-caused erosion affecting berries: "well they clear-cut it so much that the erosion..the whole mountain side is just mudslide after mudslide after mudslide…and there goes all your berries". However, erosion as a whole is a landscape issue and was more fully addressed in Chapter 3.

6.3.6.6 Development

Lastly, a non-climatic factor that affected both the number of bushes and access to remaining bushes has been development of buildings and infrastructure, which was noted by six participants[105]. Marlene Johnson (Juneau) felt that rather than weather, development was the biggest factor affecting berries, because they build on the flat areas where berries grow, and others noted that these buildings were replacing berries' habitat in villages: "we used to get them around town, but the houses came up and took our bushes away" (Ernestine Kato, Klawock) or the development was spreading out around the villages: "there was a ravine where the water comes of the mountains, and that whole area was just loaded with berries…and now it's all filled in and developed" (Merle Hawkins, Ketchikan). While four of these participants lived in more urban areas (i.e., Juneau, Ketchikan), which might influence their observations, similar observations were noted in the more remote villages as well. Another issue regarding development, was that through this, more private property was being claimed, limiting people's access to resources: "now it's all posted, private property" (Harold Martin, Juneau) and "somebody was picking out towards the circle out there, they got all these signs that say no trespassing" (Emily Watts, Old Massett).

6.4 Adaptation

Despite there being a plethora of climatic and non-climatic changes affecting berry quality, abundance, and accessibility, people are adapting in several ways, as detailed below. One adaptation that was unique to only two participants in the study area, widely spaced between NSE (A4, Hoonah) and HG (Margaret Edgars, Old Massett), and has not been reported in the literature, was that of people feeling they might start to have to pollinate the berries by hand if the bees disappear: "we got to go out and pollinate the berries ourselves" (Margaret Edgars, Old Massett), with a tool like a cotton bud.

[105] A4 (Hoonah), Merle Hawkins (Ketchikan), Ernestine Kato (Klawock), Marlene Johnson (Juneau), Harold Martin (Juneau), Fanny Nelson (Metlakatla)

6.4.1 Store bought fruit

One way that people had adapted to uncertain amounts of berries and lack of access was to buy berries at the store to supply feasts and other cultural events, and for every day preserving. This was documented by seven participants[106], exclusively in NSE: "a lot of them that don't go out berry picking are buying blueberries, cases of it and other berries there, and [preserving them and] use[ing] them for the potlatches" (Ken Grant, Hoonah) and "I think our people using berries of any kind, wild, has declined…we still have those that go pick the berries for the parties…but I have seen, I hate to even say that, I have seen times where some of our people have gone to Costco and bought the blueberries for the parties…it's a lot easier to just go buy them from Costco" (Marlene Johnson, Juneau).

6.4.2 Respect

Respect for the plants was observed in several ways, all of which are also observed in the literature amongst various Indigenous groups and for various resources. Firstly, five participants[107] noted that when they were harvesting, they wouldn't take too much: "you never picked out a spot" (Mary Guthrie, Klawock), "we don't pick a bush clean, we always leave it and go to the next bush, and go to the next bush, so that we don't clean it out (Ernestine Hanlon Abel, Klawock), and "one of the main ones [protocols] is only take what they need" (Captain Gold, Skidegate). Sherri Dick (Old Massett) and A13 (Juneau) additionally commented that you would share with everyone: "you share with the ones that can't go out anymore, especially the elders" (A13, Juneau).

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[106] A13 (Juneau), Catherine Bolton (Hoonah), Don Bolton (Hoonah), Ken Grant (Hoonah), Marlene Johnson (Juneau), Evans Kadake (Kake), Jacque Martin (Juneau)
[107] Wilbur Brown (Kake), Captain Gold (Skidegate), Lori Kay Guinard (Hoonah), Mary Guthrie (Klawock), Ernestine Hanlon Abel (Hoonah)

Secondly, four participants[108] talked about how they would pray or say thank you to the plants when they harvested: "our grandmothers used to tell us we got to respect the plants, whatever plants we're harvesting from, used to say a little prayer and respect the areas where we were picking…but nowadays we just go out and pick, but we do say our own little prayer, and just thanking mother nature for all the berries that they produce" (Margaret Edgars, Old Massett).

Lastly, Jacque Martin (Juneau) mentioned that her mother was strict on how they treated the land: "my mother was very strict on how we treated the land, when we were out…when she took my daughter out berry picking, and was afraid of a snail…[and she told my daughter to] apologize to the snail…[when] my mother took me out berry picking to a creek we were walking up the middle of the creek, and I was learning to whistle, I was a young girl, and I was whistling, and she stopped me, because she said I would call up a land otter".

6.4.3 Management

In the interviews, I asked participants about how they 'took care' of berry bushes. Indigenous People have long cultivated plants on the Northwest Coast (Deur and Turner 2005; Thornton 1999; Turner 2014), although these practices are not as common today, as seen with Sherri Dick's (Old Massett) response to this question that taking care of berry bushes was more of "an old-time thing…way back, even before my mum's generation…and she's 94". However, several people did describe the different techniques they employed to manage this resource in more recent times. These techniques included pruning and respect while harvesting, which are further described in the sections below, because they were

[108] Margaret Edgars (Old Massett), Joel Jackson (Kake), Ernestine Hanlon Abel (Hoonah), Emily Watts (Old Massett)

mentioned by numerous people. However, there were a few management techniques that were only mentioned by only a few people, which I will address first.

Firstly, several techniques were mentioned by people which have also been well documented in the ethnographic literature. This includes evidence of human habitation, trading, ownership of resources, fertilizing, and encouraging growth via leaving seeds behind.

1) Two participants, Delores Churchill (Ketchikan) and Michael Jackson (Kake) noted that berry bushes were often evidence of human habitation: "when she [an anthropologist DC knows] sees salmonberries in this spot, in the middle of nowhere, she digs, and usually there's evidence that people had camped there" (Delores Churchill, Ketchikan). The observation of culturally important species occurring near habitation sites has been well documented in the literature (Deur and Turner 2005; Fisher *et al*. 2019; Turner 2014).

2) Three participants, Robin Brown (Old Massett), Captain Gold (Skidegate), and Merle Hawkins (Ketchikan) discussed how berries are used in a trade context. They were traded for other resources, another well-established routine between groups of Indigenous People and the Department of Indian Affairs was mentioned as having given out fruit trees and berry bushes to Indigenous People, although it was unclear if these berry bushes included salmonberry or blueberry bushes. Robin Brown (Old Massett) also described a protocol of giving a family a salmonberry bush if wronged: "the early days, they even used to, when something went wrong, they…[gave] a family a salmonberry bush".

3) Sherri Dick (Old Massett) commented that people 'owned' sites: "they'd go over there and camp over there, look after it, go back, harvest it, you know…people would own a certain area, and berry patches, or places to fish, that belong to the local villages". This phenomenon is also well documented in the literature (Deur and Turner 2005; Turner 2014).

4) While fertilizing important resources is well known in the literature (Deur and Turner 2005; Thornton 1999; Turner 2014), only Captain Gold (Skidegate) noted this technique, which he said was used for all the plants, and anything you had in the garden, including berries: "when you are active in gathering food, and you get a carcass of salmon or halibut, or different animals…you can use that for fertilizer…[and] some of those plants and what not, in the past, I imagine were feed a lot because of the people's active lifestyle…you're gathering food, you're gathering a lot of salmon, sea lions, seals, all those, and the by-product of all that is the waste, so you feed the plants, it makes sense".

5) Ernestine Hanlon Abel (Hoonah) noted that when she is out harvesting, "a lot of the berries drop…we just let it drop…it's meant to be on the [ground]…it wanted to be there…so we just leave it there and that will be the new berries", a technique referred to in Deur (2014), but not something I had seen recorded in other

literature. Mary Guthrie (Klawock) made a similar observation, but more in terms of leaving bushes to provide seeds for the next generation: "if you trample it all under foot it's not going to be here next year…if you don't leave some for seeding, it won't be here next year".

There was also one technique that I have yet to find evidence in the literature for, so perhaps it is a newer adaptation to land use changes. Lori Kay Guinard (Hoonah) described a technique of protecting berry patches from eroding away: "if you see some areas where you know, it looks like it's going to erode away, and you really want that patch to stay, well you can start putting rocks up, you know…kinda walls and stuff".

6.4.3.1 Pruning

Eleven participants[109] in all four subregions described how they pruned berry bushes. Participants were divided for which berry they managed for – Alma Cook (Klawock) was the only one to mention both berries: "when we go berry picking for the last time [of the season], our parents used to tell us to break the branches off, pick the berries and then break the branches off, so they knew they had to be pruned…so that's how they kept it going…[we did it for] blueberries, huckleberries, salmon berries, grey currants, crabapple", while an additional two people each said blueberry (Marlene Johnson (Juneau), Fanny Nelson (Metlakatla)) and salmonberry (Myrna Yates (Craig), Captain Gold (Skidegate)), and six people[110] didn't identify the berry specifically. There were differences identified on the need for pruning, for example, Fanny Nelson (Metlakatla) said that she pruned blueberries, although Myrna Yates (Craig) recorded the opposite, saying blueberries didn't need to be pruned because they were "so plentiful", and she only pruned salmonberries. All the berries were said to be pruned for two main reasons.

[109] Lionel Bean (Kake), Nancy Bean (Kake), Alma Cook (Klawock), Margaret Edgars (Old Massett), Captain Gold (Skidegate), Lori Kay Guinard (Hoonah), Joel Jackson (Kake), Marlene Johnson (Juneau), Fanny Nelson (Metlakatla), Emily Watts (Old Massett), Myrna Yates (Craig)
[110] Lionel Bean (Kake), Nancy Bean (Kake), Margaret Edgars (Old Massett), Lori Kay Guinard (Hoonah), Joel Jackson (Kake), Emily Watts (Old Massett)

Firstly, it was to increase their productivity: "you know, cut them back, and then they grew more next year…that'll be good that you're pruning them, they'll come back double the size" (Lionel Bean, Kake). Secondly, bushes were pruned to make them more manageable to pick from, as the berries would be lower:

> "when I pick salmonberries at the end of the year, and I do on the outside…mom always told me to break off the top of the branch, you know, so that way they will grow [and bush out more]…and there'll be more berries…when they get too tall you don't have many salmonberries…but if you break off the top, the next year is plentiful" (Myrna Yates, Craig).

The act of pruning to take care of the berries was engrained as a natural part of how you were taught to harvest – Joel Jackson (Kake) said that at first, he didn't realise why they were taking the branches to their elders, and that by doing so they were pruning at the same time as taking care of their elders:

> "well, I basically, you know, like when you're out picking berries and stuff, oh, we were taught, and I thought it was just because, you know, we'd bring branches out to the older people that couldn't get in the woods and stuff, but come to find out later on, when I start learning more about berries, you…broke it, packed it out, and especially when it was real nice and thick, you know, and you come to find out later on it was to keep the berries bushes from growing too high, and they would spread out more…so, you [are]…increasing the crop…I thought it was just, you know, take it out to the older people so that they can eat it"

Similar to the above observation, Marlene Johnson (Juneau) did not elucidate why people pruned, but simply recalled a memory of taking branches to some of her elders when she was younger: "we had a couple elderly ladies, I remember, used to go berry picking with us, they couldn't get around in the woods very good, you know, they would sit down on the stump, and then we would go…and break off blueberry branches that were heavy with berries, and take it to them, and they would pick them off of the branches…as they just sat there, in the woods" – very likely this is another example of how management was engrained in people's practices, which has also been noted in the literature (Turner 2014).

On the other hand, four participants[111] stressed that they didn't break the branches at all, their elders had never taught them that, and to do so would be wrong: " [I] remember when we used to break the branches, my grandma would say just pick it where it's at…don't break the branch" (A11, Kake) and "they respect the berry bushes by not breaking the branches, they just took the berries off…I see a lot of people, a lot of berries on the branch, and they'll break it off and take it, and they'll eat the berries, you know…just leave them where they are, and they'll come back". Pruning has been well documented on the coast as a management technique to improve berry production with larger fruit that were a higher quality, and to encourage new growth (with many species of berries, but also specifically mentioned for blueberries and salmonberries, Turner 2014). However, to link these differing sets of observations, perhaps pruning vs. not pruning would depend on the time of year, the size of the bush, the amount you were pruning, how people were 'pruning' (clean cut, vs ripping branch off), or how stressed the plant was from the weather/climate conditions of that particular year – all conditions may not have been passed on in the interviews by the participants when they were remembering their traditional knowledge.

6.4.4 Regulations

There are as yet no state or provincial regulations in place controlling the harvest and use of berries. However, concern was expressed that regulations such as harvest limits would be implemented: "pretty soon they are going to start measuring the berries!" (Lionel Bean, Kake) and "I think berries are…open season, there's no regulation on that, but as people move in and others begin to use the same resource[s] we are, of course they'll enforce limits, and then you got to get permits, and you can only get so much" (Ken Grant, Hoonah). As

[111] A4 (Hoonah), A11 (Kake), Cora Joseph (Klawock), Harold Martin (Juneau)

well, private property limits ability to pick, as described above by Harold Martin (Juneau) and Emily Watts (Old Massett).

6.4.5 Commercialization of berries

In addition to using berries themselves, and within the community, ten participants[112] also describing the commercialization of berries, primarily blueberries:

> Ester: they are selling them [blueberries] now, pretty good price
> …
> Adam: they ship them up to Anchorage…and they reduce down into this kinda vitamin, good for the eyes
> …
> Ester: and the funny part of it is, the tips of the branches also retain that, so they aren't that particularly about how clean they have to be
> …
> Adam: you don't have to take the stems off of them, because there's just as much vitamin in the stems as there is in the berry, so they just as soon you leave them alone
> …
> Ester: not all blueberries are good, and domestic blueberries are just…way, way less (Adam and Ester Greenwald, Hoonah)

And:

> "salmonberries have been really difficult to find the last couple of years, we've been picking [blue] berries for Denali Biotech [a company which is making supplements out of wild berries harvested by local people], out of Homer, they like to buy salmonberries [too], but salmonberries are hard to come by…blueberries are consistently there" (A12, Hoonah)

While I did not find evidence for the presence of a commercial blueberry buyer in Anchorage, or a brand called "Denali Blue", mentioned by Michael Jackson (Kake) as being made from blueberry flakes, vitamin C and fish to make supplements, there is a company called "Denali Biotechnologies", based in Homer, AK, which was specifically mentioned in the quote from A12 above, and by Joel Jackson (Kake, Michael Jackson's brother), who said

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[112] A9 (Juneau), A12 (Hoonah), George Davis (Juneau), Agnes Davis (Juneau), Captain Gold (Skidegate), Ken Grant (Hoonah), Adam Greenwald (Hoonah), Ester Greenwald (Hoonah), Lori Kay Guinard (Hoonah), Mike Jackson (Kake)

he was a broker for them. They make a supplement out of blueberries called "AuroraBlue" (Denali Biotechnologies 2013). Even though Michael Jackson has given an alternative name to the company website, all evidence points to this company being the one the residents in Kake and Hoonah are referring to. While they also have a product called "DenaliRed" from the fruits of *Rosa* spp., and "DenaliGreen" from *Taraxacum* spp., there is no evidence on their website of a product made from salmonberries, like A12 (Hoonah) noted.

6.5 Answers to Research Questions

The results of CKIS data gathering on berries in this chapter specifically answers sub-questions 2, 3, 4 and 5, and further contributes to addressing the main overarching research question.

Sub-question 2 (Are observed weather changes affecting how people access, harvest and prepare resources in their territory?): This question is answered because it was seen that the weather observations regarding the amounts of rain and sun impacted the harvesting of berries, particularly the interactions between the amounts of rain and sun. When there is not enough rain, the berries are dry and desiccated, and if there is too much rain, the berries rot, and are unsweet. If there is not enough sun, the berries do not ripen quickly enough, and if there is too much sun, the berries can dry out and 'burn'. As well, early springs, caused by temperatures rising earlier than normal, can lead to issues with flowering and bee pollination, affecting how many berries set. This affected how much people were able to harvest and how they harvested.

Sub-question 3 (Which species (culturally and ecologically important and otherwise) were observed by people throughout this region to be experiencing change?): This question is answered because through interviews, both salmonberries and several species of blueberries were identified as species which were culturally important, and were experiencing change in several biometric parameters, such as reproductive output, flowering and fruiting patterns, harvest timing, distribution, and pests. Throughout further background investigation into these species, it was found that in addition to being cultural keystone species, and weather indicator species, they are also ecological keystone species, making them good CKIS examples.

Sub-question 4 (How do observed changes indicate broader shifts in biodiversity?): This question is answered in two ways. Firstly, the earlier springs causing earlier flowerings is leading to a disjunction in the presence of pollinators being able to pollinate, and flowers being killed by late frosts. This affects pollination events, meaning less flowers and fruit to be food for humans and other animals (i.e., bees, bears), with a potential to influence biodiversity of berry bushes and the animals that depend on them for nectar and fruit.

Sub-question 5 (How can Traditional Ecological Knowledge and climate data be used in conjunction to present a comprehensive picture of local climate change effects and inform adaptive responses, including knowledge transmission between generations, and capability for resilience into the future?): This question is answered because TEK observations regarding shifts in the amount of reproductive output, timing of resource, and flowering and fruiting patterns, along with longer term climate predictions in the region, can be vital information for management policy makers to manage future harvesting of berry populations. As well, the adaptations from local self-management schemes that people described in this research can be important for increasing their capacity for resilience into the future and respond to the influence of climatic change on it, sustaining harvesting so that future generations understand how to use this resource.

6.6 Geographical trends

In this section, I analyse the CKIS results according to geographical trends, to explore if people were making the same type of observation in different sub-regions, or whether certain regions were experiencing different stressors, or observing different changes. In table 6.3 below, I have grouped the ethnographic data into main observations and sub-observations, along with the number of people that made that observation, in each region of my study. Four observations were mentioned in all four regions: Decreased reproductive output, variable and unpredictable amounts of reproductive outputs, early flowers, and berries rotting and unsweet due to too much rain. The observation mentioned the most often was that reproductive outputs were variable and unpredictable (19), closely followed by the number of observations regarding early flowering (16). Overall, ~71% of observations were noted in two or more communities, and the region with the most observations was NSE with ~53%. Since more participants in both NSE and HG were interviewed (~35% of the total participants in each region), it was expected that one or both of those would be a higher percentage of observations, but NSE having almost 53% of observations is significantly more than expected.

Table 6.3. Number of people making each observation of changes influencing berry populations, divided into sub-region.

<table>
<tr><th>Main Observation</th><th>Sub Observation</th><th>NSE</th><th>SSE</th><th>HG</th><th>MBC</th><th>Total</th></tr>
<tr><td rowspan="4">6.3.1.2 Reproductive output</td><td>No Change</td><td>1</td><td>3</td><td>4</td><td>0</td><td>8</td></tr>
<tr><td>Increased output</td><td>1</td><td>0</td><td>0</td><td>0</td><td>1</td></tr>
<tr><td>Decrease output</td><td>6</td><td>3</td><td>3</td><td>1</td><td>13</td></tr>
<tr><td>Amounts variable and unpredictable</td><td>11</td><td>3</td><td>3</td><td>2</td><td>19</td></tr>
<tr><td rowspan="4">6.3.1 Flowering and fruiting patterns</td><td>Early flowers</td><td>8</td><td>3</td><td>4</td><td>1</td><td>16</td></tr>
<tr><td>Smaller berries</td><td>7</td><td>0</td><td>0</td><td>0</td><td>7</td></tr>
<tr><td>Larger berries deep in forest</td><td>1</td><td>0</td><td>0</td><td>0</td><td>1</td></tr>
<tr><td>Berries same size</td><td>0</td><td>0</td><td>1</td><td>0</td><td>1</td></tr>
</table>

	Unripe and desiccated berries (lack of rain)	3	4	0	2	9
	Rotting and unsweet berries (too much rain)	6	3	2	1	12
	Berries falling off bushes (hard rain)	1	0	0	0	1
	Not enough sun to ripen berries	5	1	0	1	7
	Too much sun burning flowers and berries	2	0	1	0	3
	Few berries from cold temperature	1	1	1	0	3
6.3.4 Timing of resource	Mixed up timings	2	0	2	0	4
	Ripening earlier	2	2	0	0	4
	Ripening later	6	0	3	0	9
	Timing stayed the same	2	2	2	0	6
	Knowing when to harvest	2	1	4	0	7
6.3.5 Degradation	Worms in berries	3	0	1	0	4
6.3.6 Non-Climatic factors	Logging increasing berry bushes	6	1	4	0	11
	Forest succession shading out bushes	8	0	3	0	11
	Hazards from logging practices	3	1	2	0	6
	Pollution	1	0	0	0	1
	Invasive species	1	1	2	0	4
	Pests - caterpillars	0	0	0	1	1
	Erosion	1	0	0	0	1
	Development	3	2	0	1	6
Total Observations		93	31	42	10	176
Percentages		52.8%	17.6%	23.9%	5.7%	

I have also summarised the observations people made about how they had adapted to climatic and biodiversity changes, and other topics such as reciprocity, management, and commercialisation (Table 6.4). Only one observation was noted in all four regions, that of pruning as a management technique, and this observation was also the most frequently noted (11 observations). Overall, 61.5% of observations were noted in two or more regions, and the region with the most observations was again NSE, with ~65%. There were very few observations from MBC, only one, that of pruning for management. Nine participants talked about two adaptations that they had implemented; in the widely separated regions of NSE and HG, participants had mentioned people pollinating flowers themselves to assist with fruit production. Another adaptation is that people were starting to use more store-bought fruit than in the past, an adaptation only mentioned in NSE, but by quite a few participants (7). Scattered throughout all four regions, there were also quite a few observations made regarding how berry resources and bushes were managed, and in both NSE and HG there was discussion of how some people harvest to sell to companies that make dietary supplements, particularly out of blueberries, providing an income source.

Table 6.4. Number of people making each observation of adaptation, reciprocity and management, divided into sub-region.

Main Observation	Sub Observation	NSE	SSE	HG	MBC	Total
4.4 Adaptations	People pollinating flowers	1	0	1	0	2
	Store bought fruit	7	0	0	0	7
4.4.1 Respect and Ceremonies	Not taking too much	3	1	1	0	5
	Thanking the plant	2	0	2	0	4
	Respect for entire landscape	1	0	0	0	1
4.4.2 Management	Traded to other people	1	1	1	0	3
	'Ownership' of sites	0	0	1	0	1
	Fertilising	0	0	1	0	1
	Leaving some berries when harvesting	1	1	0	0	2
	Rocks placed to stop erosion of bushes	1	0	0	0	1
	Pruning	5	2	3	1	11
	Never breaking branches	3	1	0	0	4
6.4.5 Commercialisation		9	0	1	0	10
Total Observations		34	6	11	1	52
Percentages		65.3%	11.5%	21.2%	1.9%	

6.7 Conclusion

Throughout this chapter, it can be seen that both blueberries and salmonberries are key species ecologically, culturally, and as indicators, and thus make a prime example of a CKIS, and also demonstrate a good example of a CKIS complex, or functional group. The main weather changes that were influencing berries was the interaction between amounts of sun and rain, and warmer temperatures that can lead to early flowering and changes in fruit quality. Despite people facing many challenges to berry harvesting from logging and development, and weather changes greatly affecting the berries throughout their lifecycle, berries are still important to people in the PNW. Jack Litrell (Old Massett), Margaret Edgars (Old Massett), Emily Watts (Old Massett), Harold Martin (Juneau) and Jacque Martin (Juneau) all felt that the younger generation in the community were showing a special interest in learning about berries, and that overall, a lot of people were still active in harvesting and assessing berries as a CKIS.

Table 6.5. Table of observations relating to salmonberries and blueberries.

Type of Observation	Changes seen	Impacts	Responses	Example participant perspective
Timing of flowering	➢ warmer, early springs, earlier flowers ➢ no bees out (Margaret Edgars, Old Massett)	➢ less fruit available	➢ can't harvest because no berries	"well, right now, it's kind of extreme, like, right now, we see [salmonberry] blossoms out and we're in January…and that means we won't have berries again…because there's no bees around" (Reg Davidson, Old Massett)
Quality of fruit	➢ too much rain and not enough sun – berries rot ➢ not enough rain - desiccated	➢ no flavour	➢ don't like eating	"salmonberries, raspberries, blueberries, they are not up to par… because of the weather, it's been unbalanced, we've had too much rain, and not enough sunshine" (Wanda Culp, Hoonah)

Chapter 7 CKIS and Resilience and Adaptation into the Future

> "You know, your culture goes with you wherever you go, when I was going to aquaculture and fisheries school…in Bellingham, we had our big school on Lummi Island, and we had a boat, a school boat, you know, and I borrowed that boat on weekends, and I went out, and the Lummi People, they don't eat the same foods we do…so I went down, I found out where the cockles were at…and I found out where the gumboots were at, [and] I found a lot of seagull eggs out there, but I never bothered them, I found out where the herring spawned…I got some seaweed…see? Your culture goes with you…wherever you go, you're going to survive" (Harold Martin, Juneau)

7.1 Introduction

The opening quote in this chapter is a powerful one, that speaks to how culture itself, especially among NWC Peoples long familiar with adjusting to changing and dynamic climates, is a primary adaptive tool that can be taken with you wherever you go. Harold Martin seeks to apply his deep placed relational knowledge of subsistence fishing and gathering in a novel situation and location, namely harvesting conditions in Southern Northwest Coast Lummi territory in Washington State. Just like the quote, the data within this thesis showed over and over how the application of deep knowledge of CKIS by local people demonstrated how they are adapting to changes in resources in the short term, ultimately building to overall resilience to be able to endure in a landscape heavily impacted by climatic changes and still ensuring their cultural survival, a topic that is touched upon again in the bottom of this chapter regarding dependence on the land into the future.

While Harold Martin's quote particularly emphasizes the applicability of his individual resilience in a novel location, it also highlights that not only have individual people developed resilience to withstand climate variability within their personal and household repertoire, but also at a larger-scale within their social-ecological system, through long term inter- and intra-community connections. This resilience comes from knowledge developed via individual and collective experience of adaptations in communities over generations.

A recent IPCC report (Oppenheimer *et al*. 2019) on the implications of sea level rise in coastal communities discussed how anthropogenic drivers can cause people to be more aware of change, and thus able to consciously develop adaptations and resilience. The report discusses how the social structures and capabilities of coastal communities greatly increase resilience and adaptive capacity due to their close relationship with the natural world and their ability to recognise change, highlighting four main anthropogenic drivers, including gender inequality, the loss of Indigenous and Local Knowledge, social capital, and perception of risk. Both coastal communities and Indigenous communities, and even more so communities that are both coastal and Indigenous, share common traits of a close connection to their environment, depending heavily on the use of natural resources, and importing many resources (such as groceries). This makes them at high risk for natural hazards, but they also have knowledge to identify risks and hazards to better enable their adaptation. Coastal communities and Indigenous Peoples can have increased adaption because they may recognise that coastal processes can change, accelerate, or be subject extremes which threaten their very existence. Additionally, there are often trade and relational networks in place to facilitate the movement of people, resources, stories, and knowledge (Le Dressay *et al*. 2010; Thornton 1999; Turner 2014), including knowledge of how to recognise and adapt to risks and hazards. This sharing of knowledge, which along with trust of sources of information and access to resources, constitutes social capital as described by Aldrich (2017), has been shown to assist people in adapting to specific novel situations based on them relying on their past knowledge and connections to build community resilience to future challenges (Aldrich 2017; Oppenheimer *et al*. 2019; Petzold 2018).

Indigenous communities are also on the forefront of climatic changes, as discussed in the Introduction chapter, making it doubly important they draw on their strong deep environmental and societal connections and knowledge to inform adaptation and resilience. In this chapter, I will be presenting an overview of how resilience and adaptation are expressed throughout the entire study region for all species, and how people are moving into the future. Additionally, I continue to assess and explore my proposed concept, formed from the analysis of interview data and conceptual background data, of a 'Cultural Keystone Indicator Species' (CKIS), which I define as a '*critical species of both cultural importance and perceptual salience in relation to environmental change*', in a broader socio-ecological and regional context

7.2 Adaptation and Resilience

As described in the introductory chapter, The Stockholm Research Centre has developed seven principles of resilience to enhance society's capacity to respond to stress and disruption. These seven principles include:

1) **maintain diversity and redundancy**
2) **manage connectivity**
3) **manage slow variables and feedbacks**
4) **foster complex adaptive systems thinking**
5) **encourage learning**
6) **broaden participation**
7) **promote polycentric governance systems**

A theme across all seven resilience principles is collaborating between knowledge systems. Sharing diverse knowledge through deliberative learning widens understanding of the problem and how to approach it in a more comprehensive and integrated way. However, as principle 7 touches upon, there may be issues with what priorities to choose when managing an ecosystem. Resilience can't be built equally for every ecosystem and for every species, due to differing needs, just like the management challenges in ecosystem-based management presented in the introduction chapter. For example, logging might be beneficial for expanding berry distribution and quantity and may even have short term benefits for deer in low snow-fall years by providing a mixed habitat, while at the same time being very negative for salmon populations in lakes and streams, due to sedimentation from increased erosion. This means that sometimes choices must be made about what to manage for over what timescales. This is where the CKIS concept comes in handy, because while each CKIS species will have different management needs, their continued presence, facilitated by people's knowledge, allows local people to retain the knowledge of HOW to harvest, even if the species and its local importance might end up fluctuating as the environment changes more, be it through natural or human influences. Accordingly, this research shows, through the CKIS examples elucidated, that Indigenous Peoples of Southeast Alaska and Haida Gwaii have been resilient to changes in key species, such as using a less preferred salmon or berry species or harvesting moose instead of deer. As salmon resiliently adjust the timing and configurations of their returns to avoid warmer temperatures and lower water flows, and deer resiliently move further up mountains in low snow years to take advantage of the vegetation for feed – so too there are some impacts that the species are not able to adjust to, leading to increased die offs as a result, making Indigenous Peoples' knowledge of resiliency of species usage even more important.

In this research, resiliency can be seen on several different levels. On one hand, species are being resilient in adapting, as just shown, while on the other hand Indigenous societies are resilient by applying their knowledge to harvest the same species under different environmental and behavioural circumstances in novel and unique ways, or by using their knowledge to expand their portfolio to track different species to fulfil their subsistence needs. Such portfolio diversification is an important resilience technique that enables people to adapt to changes in abundance and distribution of food species.

In summary, resilience in both social and ecological systems is about "the ability to live with change and develop with it…[through] improving and innovating on that path" (Biggs *et al*. 2015). TEK can offer particular insight into understanding resilience and is vital for incorporating into appropriate management schemes alongside western science knowledge due to its being able to: 1) contribute long-term observations of critical species' population and behaviour trends, 2) incorporate insights of a range of local stakeholders, and 3) provide a 'nuanced understanding' (Herman-Mercer *et al*. 2011) of small scale, regional trends, some of which may be in areas that are little studied or absent from scientific datasets (Herman-Mercer *et al*. 2011; Murray *et al*. 2011; Raymond-Yakoubian *et al*. 2017; Thornton 2001; Thornton and Manasfi 2010).

While in the past there has been an emphasis on vulnerability-based approaches (Cameron 2012; Ford 2009; Ford and Smit 2004; Ford *et al*. 2006; Ford *et al*. 2018), even going so far as to observing that researchers have taken the vulnerability of IP for 'granted' and trying to increase their resilience externally, such as through incorporating them into global markets. Now, however, there is a gradual, but growing, movement towards strength based, resilience centred approaches (Biggs *et al*. 2015; GRAID 2020; Resilience Alliance 2019; Stockholm Resilience Centre 2019; Wyllie de Echeverria and Thornton 2019), as researchers have realised that Indigenous Peoples have internal ways of being resilient which have been developed through their deep connection to place, and generations of TEK as a building process for learning about and responding to change (Ford *et al*. 2020). Vulnerability is sometimes viewed as the absence of coping ability (Ford *et al*. 2020), and throughout this study I have shown that people have coped, and thus are resilient instead of vulnerable. One reason that moving towards resilience is important is because, not only Indigenous people, but all people around the world, face more extreme and less predictable conditions and challenges, we can't just 'substitute' anymore, such as planting a different crop. Instead, networks of connections that allow for redundancy in the system must be developed, as described above. A change of paradigm is needed by using the collaboration of knowledge systems in a framework of resiliency, a framework which is already been seen in Indigenous knowledge and responses to climate change.

Emblematic of this adaptive capacity and resilience, as it developed in the past among Northwest Coast Indigenous groups, are the many stories of the Flood in oral history, in which clans or communities survived inundation from massive sea level rise by seeking refuge on the tops of high (2000+ foot) mountains, and then re-establishing themselves on the altered land in the aftermath (Emmons and de Laguna 1991; de Laguna 1960, 1972; Hunt *et al*. 2016; Turek *et al*. 2006). These and other "epitomizing events" (Fogelson 1989, cf. Thornton 2016), markers of Peoples' resilient and adaptive histories and identities, were often referenced in my interviews. Building on the definitions of adaptation and resilience above, in the interview data, adaptation can be more seen in how people might alter a specific harvesting technique, such as fishing deeper for salmon with larger weights, or travelling further for deer but overall, with each of these adapting techniques they are building resilience in their ecosystem and into their lifestyles, such as their adaptation of buying blueberries at Costco.

7.3 Social Climate Change

Another implication of adapting resource use is that research participants recognised themselves as a component of climate change. Current lifestyles in remote communities are heavily dependent on high CO_2-emitting fossil fuels (Hobson 2019; Sikka *et al*. 2013). Several hundred years ago, Indigenous Peoples interacted with their landscapes in a more self-sufficient and less carbon intensive way. Now, however, power in communities is typically provided by diesel-powered electrical stations brought in through energy intensive pathways, due to their isolated geographical position, leading to larger amounts of high carbon fuels being consumed in remote communities for livelihood activities, food and other imports, transport, storage, heating, lighting, and so on (Hobson 2019; Sikka *et al*. 2013). As a result, people in these remote areas also are contributing to greenhouse gas emissions, albeit in a relatively small (compared to urban areas) but often increasing (Powell 2015) way. It is significant, too, that regardless of their emission being infinitesimal in the aggregate, some communities have not only acknowledged their place in contributing to climate change, but are implementing schemes to reduce their footprint, such as switching to alternative energy sources (especially small hydropower instalments) to create more sustainable futures (BC Hydro 2019; Brewer II *et al*. 2017; Council of the Haida Nation 2019; Haida Gwaii Observer 2018; Hobson 2019; Old Massett Village Council 2019b; Sikka *et al*. 2013; Stefanelli *et al*. 2019).

Ken Grant (Hoonah) emphasized the idea of local people both being affected by and affecting "Social Climate Change". He states that it is not just the climate that is changing, or the government, or pollution, or the ability to afford fuel, but rather their entire way of life, and the combination of all these factors, and how they approach the landscape: "the thing that's changing is the social change…our people used to depend on gathering, processing fish, smoking fish, smoking deer meat, seal meat, and that, but now it's not [the same], the smokehouses have changed too, there used to be big smokehouses with lots of racks and we did the old style, what we called newspaper style" (Ken Grant, Hoonah). He also talked about how this “social climate change” was affecting regulations as more people are using the resources:

> I think that [with] social change, [you have] new regulations, you can only…harvest so much, I think berries are, you know, open season, there’s no regulation on that, but as people move in and others begin to use the same resource we are, of course they’ll enforce limits, and then you got to get permits, and you can only get so much, it’s changed quite a bit, like, even just building my new smokehouse, I had to go down and buy a building permit” (Ken Grant, Hoonah).

This sentiment, that climate change is not the only or even the most important impact on local peoples’ present lives, but rather one driver in a concatenation of forces reshaping Indigenous lives, is widely echoed in the literature on climate change and Indigenous Peoples (see, e.g., Crate and Nuttall 2009), and was seen over and over in these interviews.

Another issue which must be addressed here is the way the food harvesting is viewed. In Berkes (1988), he notes that numerous terms are used to describe the connection between Indigenous People and their harvest of traditional resources in Canada, mostly based on regional variation in laws, and the disciplines that are discussing these issues. He suggests that, due to the OED definition, the term ‘subsistence’ fits most closely to the relationship between the resources and the people and should also be used because this is the term that is used in Alaska. However, Newton and Moss (2009) argue that, while Indigenous lifeways are termed ‘subsistence living’ in a legal sense for separating out commercial and recreational uses from traditional uses of wild renewable resources, this term is problematic because some dictionary definitions often defines it as the “minimum food or shelter to support life”, and ignores the wealth of deep connections between people and landscapes that subsistence relations engender (further discussed in Thornton 1998). The term was referred to by participants in Alaska and is used by the Alaskan government to refer to resources harvested by rural Indigenous People. However, people have taken exception to this term, rightly saying that this is their way of life, and using the term ‘subsistence’ seems to indicate that their lifestyle is ‘under’ other lifestyles, and not as highly valued: “Subsistence doesn’t talk about our way of life, we have a rich way of life, a rich one [emphasis on RICH], and they call it SUB-sistence… we don't use it, [we say] customary and traditional use, or you know, I've heard people call it other things, you know, our way of life…but subsistence is an insult" (Wanda Culp, Hoonah). This reaction was echoed by A9 (Juneau) as well: "that was our lifestyle, but fish and game, the state, they put subsistence…the state is the one that…put the name subsistence [on our activities]…for us there was no subsistence, it was a lifestyle…like…one guy was asking me, are you going to have fish head soup, and he laughed about it, and I said nothing to laugh about, I said I've eaten fish head ever since I was a little boy, I said it's our lifestyle" (A9, Juneau). Because of this problematic framing, it was used in this thesis, as it is in widespread use, and its issues have been recognised, however this term was only used to refer to resources in a regulatory context, but not when talking about people's perceptions of their environment (Thornton 1998).

7.4 Management

Another outcome of social capital mentioned at the beginning of this chapter is that the networks and knowledge sharing that arises from it leads to community trust in observations, particularly where a group might have little support from the formal state, provincial, or national government (Aldrich 2017). Most government planning and decision-making processes do not at present focus on TEK or CKIS, at least not directly. For example, the Indigenous Peoples in this study region have found that the US and Canadian governments don't always address issues that are important to the community, such as modifying hunting and fishing seasons to account for fluctuations in the populations. Many of my participants felt that government officials only make token community visits to ask opinions at local meetings, and do not take TEK into consideration in decision-making, or that official harvest rules and regulations are too rigid and standardized to take local knowledge about climate variation and its local impacts into account. However, within their own governmental systems, they can incorporate local adaptations to some extent as seen throughout some of management decisions discussed in the individual CKIS chapters. This is why collaboration between knowledge systems and the co-management schemes discussed throughout this thesis is so important to implementing regional resilience. The three policy practitioners interviewed in this study felt that the government was improving its communication with communities, but there are still conceptual and implementation gaps, leading to local knowledge being at best "unevenly incorporated" into climate and resource management policy (Linda Kruger, Juneau). This uneven or lack of incorporation of local knowledge, in turn, can lead to "scepticism…fear, [and] insecurity… on the part of the Native community to share knowledge" (Linda Kruger, Juneau). To gain a higher level of conceptual and practical integration of TEK into management, keystone and indicator species and ecosystem change need to be taken into account in the management of the ecosystem from a federal and state/provincial viewpoint.

However, some co-management successes were noted. Previous research, explicitly mentioned in interviews, documented the importance of TEK in sustainable harvesting of seagull eggs (a CKIS in some island communities) in Glacier Bay (Hunn *et al*. 2003; Catherine Bolton and Ken Grant, both from Hoonah). Additionally, a relevant co-management example is one of the Sustainable Southeast Partnership's programmes, the Hoonah Native Forest Partnership, which is looking at how to manage the watershed as a whole to create resiliently harvestable populations of salmon, deer, and berries, all three of my CKIS examples, along with their companion flora and fauna (Hoonah Native Forest Partnership 2020). Although the species, CKIS or otherwise, that was most highly documented in interviews and the literature for co-management was salmon (see chapter 5), this example shows how a clear focus and prioritization of a suite of CKIS species has led to an adaptive management solution using both TEK and scientific knowledge to manage stocks. While these may not address climate change management specifically, the same process could be implemented to create a partnership between different knowledge sources and sectors to develop climate change resilience strategies through a CKIS focus.

7.5 Transmission of knowledge to future generations

The dependence of people's survival in the past being based on knowing how to manage, harvest, and prepare resources was demonstrated by Adam Greenwald (Hoonah) showing how resource use was woven into the fabric of peoples' traditional lifeways: "my education was in this box, they taught me how to dry fish, and when I got my fish all dried, I put it in a bentwood box, I know how to dry…fish eggs…and when [the] fish eggs are dry I put them in a bentwood box, so if I had a good education, we ate good…we had [a] bentwood box, [it] was all filled with smoked deer ribs, smoked seal meat, dried fish eggs, dried sockeyes, smoked humpies, the more education I had, the better we ate…so my education is in this bentwood box". These traditional foods are not physically stored in this bentwood box, but Adam Greenwald is demonstrating how his personal knowledge of the resources adds to his cultural knowledge. In Tlingit culture, and for other Northwest coast peoples, bentwood boxes were important both physically and metaphorically. Physically, they were used over cooking fires to boil water and other liquids (by dropping hot rocks in), and as one of several types of food storage containers. Metaphorically, people describe them as holding their culture, songs, dances, oral history, and traditional knowledge passed down generationally, and often linked to clans and/or hereditary chieftainships. Recalling these types of connections to help with future challenges will be important.

Many respondents lamented that members of their community do not gather as much as they used to, particularly the younger generation, and that, in addition to access issues tied to weather and sea-level changes, access to resources was further limited by working hours (jobs), permit applications, harvesting regulations, and costs of fuel and boat maintenance. There were mixed feelings by interviewees about how knowledge will continue to pass down through generations given the rapid social and ecological changes. Every community in the study region either had a culture camp or was very close to another community that had a culture camp, as of 2017, and culture camps in five communities were specifically mentioned in the interviews[113], Hydaburg, Kake, Juneau, Klawock, and Old Massett. Wanda Culp (Hoonah) had mentioned in her interview in 2014 that there were no culture camps in Hoonah, and children might go to Juneau to attend one, but as of 2017, there is now a culture camp in Hoonah (Nu 2018). Kake has one of the longest running culture camps, at over 30 years. These culture camps, and other programmes being run in the local schools, provide the younger generations the opportunity to learn and practice their traditions, and make connections between harvesting and traditional activities, with the guidance of Elders: "they help them how to put up food, this year they jarred a bunch of salmon, and did a bunch of picking berries, and putting up jam for the elders…and…they taught them how to clean the fish" (Myrna Yates, Klawock) and "it [the camp] goes through all the processes, and everything, how to hunt and all that you know…you even learn [to] call on your own voice you know, [noise of calling, a keening noise]…calling the deer [grunting noises], whatever animal you want to call, you know…so we go through all the motions you know, it's fun, it's really fun doing it" (Marvin Kadake, Kake). And not only the young people are learning, but they are teaching their parents as well, who might have missed learning about the lifestyle when they were young: "some of the kids will go home and teach their parents how to do it

[113] **Juneau Culture Camp**: Ken Grant (Hoonah); Wanda Culp (Hoonah); Harold Martin (Juneau)/ **Kake Culture Camp**: Harriet Williams (Kake); Michael Jackson (Kake); A9 (Juneau); Wilbur Brown (Kake); Lionel Bean (Kake); A11 (Kake); Owen James (Hoonah); Marvin Kadake (Kake); Harold Martin (Juneau); Jacque Martin (Juneau)/ **Hydaburg Culture Camp**: Myrna Yates (Klawock)/ **Klawock Culture Camp**: Myrna Yates/ **Old Massett (Rediscovery) Culture Camp (Lepas Bay)**: Margaret Edgars (Old Massett); Emily Watts (Old Massett); Sherri Dick (Old Massett)

again…not only that, but we teach them respect for the land, and the food" (A11, Kake). The importance of cultural harvest camps is also seen in the literature with Turek *et al*. (2006) stating that "sockeye harvesting is to Tlingits what textbooks are to schools".

But not all of the younger generation is interested in taking part in this, and it is not clear how older traditional knowledge and new climate change would be reconciled in such forums. However, it is likely that there will be a merging of technology and knowledge, partially to aid in rapid knowledge transfer to counteract loss, similar to that which is being done in participatory mapping studies in the arctic (Bennett 2012; Gill 2013). The younger generations are often proficient at technology and letting them engage with their Elders through the medium of pictures, videos, recordings, internet media, and interactive maps will facilitate knowledge transfer in new ways. However, Robert Nelson (Metlakatla) thought that if there were enough people engaging in these cultural enterprises, that it would catch on: "I think if there's enough of us that are, that take the time to actually go and show our kids, how to harvest and dry, and jar and say, like we could jar salmon, and I've got jarred salmon that are probably 7 years old, the older the better, I know how to dry all the fish and everything, but yeah, I would like to try and save that [the knowledge of how to harvest and process their resources]…and I know there's a way, it's just working with…everybody's busy schedule".

7.6 Resilience into the future

The results from this research shows some prioritising of resilient responses to climate, landscape, and resource change, through the sustainability of subsistence and renewable CKIS resource industries, however, more investigations are needed to fully understand the ramifications of how people can prioritise within modern governmental and lifestyle constraints. PNW Coast Indigenous Peoples are currently facing rapidly changing landscape and biodiversity conditions, and this is greatly impacting their traditional lifestyles.

However, as mentioned previously with the "epitomizing events" that people have experienced in the past, this is not the first time people have had to draw on their knowledge to be resilient to change. Campbell and Butler (2010) have examined the archaeological record of salmon for the past 7500 years and have found that over that time salmon have experienced variation in seasons, temperatures, stream flows, sedimentation, atmospheric circulation, sea level rise, and other disturbances, similar to what they are facing today. Past Indigenous Peoples were able to adapt and be resilient to the fluctuations in salmon due to rules and ceremonies to provide accountability, the flexibility to utilise other resources, and management of the landscape (Campbell and Butler 2010). And just like people have adapted and been resilient to landscape and resources changes over the past 15,000+ years, or longer, to time immemorial, people will continue to draw on their broad resource base and their beliefs and rituals to keep their resources producing well. This again emphasises how the 7 principles of resilience discussed in the Introductory chapter (Biggs *et al*. 2015; GRAID 2020) are expressed in an Indigenous world view, and the importance of collaboration between knowledge systems in responding to climate change – Indigenous knowledge systems have already survived one, or more than one, crises, and their knowledge will be invaluable in making management decisions into the future, resulting from people's long-term perspectives on resource use and flexibility, protocols, and sharing (Herman-Mercer *et al*. 2011; Murray *et al*. 2011; Thornton 2001; Thornton and Manasfi 2010). Research such as that from this thesis and similar studies show how within a broader ecological and social context of dwelling, the collaboration of TEK and Western Science knowledge can assist communities in responding to future environmental changes using a range of place-based adaptation modes, as evidenced throughout this thesis. Examples of these adaptation modes include co-management of important resources, modifying harvesting and processing patterns, or using alternative resources, such as store-bought berries or moose.

Even though store-bought food is common in communities today for daily consumption, the high cost of even basic commodities, and the cultural imperative of maintaining traditions and knowledge through food gathering, mean that local people are still committed to wild food production, and it is one way that they express resilience and adaptation, as they are still dedicated to harvesting despite challenges. Not only do traditional livelihoods immerse and emplace people in their traditional cultural habitats, they are also considered healthier. In many communities, traditional foods are even featured in state-supported social service and health settings, such as senior centres and hospitals. Some of the interviewees even commented that, with the 'drying up' of oil, gas, and other non-renewable resources, and the rising costs of living in their communities, they would need to depend on the land *more* in the future:

> "I don't know, but if it comes down to it, well, then we [will] have to start learning how to survive off of deer meat, you know, if it comes to that point, then we are going to have to go back into the old days, where we used to cook by wood stove, fire, campfire" (Cora Joseph, Klawock)

To do this, they will have to understand how their ecosystems and habitats are changing and adapt accordingly. Peoples on the Northwest Coast are, and have been, experiencing and adapting to climatic changes through continued interactions with their changing ecosystems and biodiversity over many thousands of years.

In addition, in some locations, participants felt they had a buffer to climate change, based on their micro-climate, because many villages are located tucked behind inlet heads, and being surrounded by natural areas with little impact, compared to more built-up areas further south:

> "if there is climate change, I feel we got a buffer on either side of us here…being in Southeast Alaska, because we still got several hundred miles of emerald edge south of us and several hundred miles of emerald edge north of us…and we are on the ocean, so our climates only going to be as moderate as the ocean is going to permit it, you know, as extreme as it's going to allow it to be…so we're pretty fortunate for as far as where we sit in the geographical area…the impacts are going to be a little more mild here" (Anthony Christianson, Hydaburg)

While research participants recognise that significant weather changes are occurring, such changes are not necessarily regarded as unprecedented. Many Northwest Coast communities have experienced major environmental changes, such as glacial movements, tsunamis, and drastic sea level rise in the past, yet still survived and recovered, resiliently. Despite being wary about the future, most respondents possess a positive outlook regarding their ability to cope and adapt. They view themselves and their culture as always having adapted to environmental change, and thus continuing to adapt to future change.

Between the culture camps helping to transmit knowledge between generations, a trend towards co-management schemes, and greater inclusion of traditional knowledge into scientific and governmental knowledge, progress is being made, however much more work must be done.

7.7 Conclusion

In conclusion this chapter summarises the place of the CKIS concept in the regional socio-ecological system, and its use as a framework to integrate TEK firmly into the dialogue of resource management, adaptation, and resilience in the face of a changing environment. If CKIS species are as important to the 'dominant' society as they are to local people's livelihoods and sense of identity, they may gain attention, as in the case of salmon, but this is not true of all species that are considered to be CKIS, and attention itself does not guarantee appropriate management of any CKIS species in the face of climate change. Instead, CKIS can be an important lens through which to improve understanding of ecosystem structure and functioning in relation to climate change and a focal point for guiding appropriate adaptation strategies to deal with impacts to these species and broader questions of social-ecological resilience, security, and wellbeing.

Chapter 8 Conclusion

8.1 Introduction

In this conclusion chapter, I would first like to recap my aims and objectives from the introductory chapter. The main overarching aim of this research was to investigate how the effect of climate change can be seen on the landscape and biodiversity through understanding local and Indigenous knowledge of culturally and ecologically important species, that also indicate climatic changes. The specific objectives delineated to meet this aim were to record the local and traditional knowledge of the following: observed changes in weather, landscape and biodiversity; how important species are monitored and assessed as indicators of climatic changes; and the adoption of resilient and adaptative responses to these changes.

I chose to use key species as a lens to monitor change because cultural keystone species have been widely used in Indigenous and ecological knowledge studies to advance our understanding of historical ecology as well as contemporary conservation and restoration efforts (Branton and Richardson 2014; Estes and Palmisano 1974; Garibaldi 2009; Garibaldi and Turner 2004; Hilty and Merenlender 2000; Mills *et al*. 1993; Peacock *et al*. 2011; Simberloff 1998; USDA Forest Service 1997). These species function as a proxy to understand the impacts of climate change, providing windows into what is happening more broadly in an integrated social-ecological system, rather than a simple reductionist lens. Accounting for all variables in a complex system is impossible, but necessary for understanding climate change effects to people and ecosystems and using a whole systems conservation view is similar to the kincentric worldviews held by Indigenous people. Additionally, I chose to examine the advantages provided by focusing on culturally and ecologically key species because these species serve to bring together different threads to support a continued restoration and conservation informed from both Indigenous and ecological knowledge, and I formed my research questions to address this topic.

One problem that can be seen repeatedly in research involving TEK and Western Scientific knowledge is importance of incorporating forms of knowledge equally. I already discussed in section 2.7 how many Indigenous people are demanding more input as to how their knowledge is being used, and how TEK should be considered independently and alongside Western Science and not through it. It is important to acknowledge their ownership of their knowledge, the unique understanding that can be achieved through a TEK lens, Indigenous Peoples' rights to be involved with decisions, and thus to firmly place Indigenous People at the centre of knowledge in their communities and research that will affect them. Climate change is a large and complex topic, and even more so when understanding it from both Indigenous and Scientific knowledges, and along cultural and geographical gradients, and it is experienced in different ways by different communities. While there in much interest in understanding climate change over timescales and how to respond to it, our tool kit is limited. This is why my concept of a CKIS can be a versatile and necessary tool when examining bridging climate change knowledge from Indigenous Peoples and Scientific sources. If a species is either mentioned by numerous participants, or mentioned often, it indicates that this species has a high cultural significance not just for harvesting and processing, but also in the social fabric of certain groups of people (Turner 1988), and if a species is ecologically important as well, then they are prime examples to bridge between these two knowledge systems and better understand the impact of climatic changes.

The incorporation of knowledges from both Indigenous people and Western Science has been discussed in many ways in the literature, using terms like bridging, braiding, and weaving, to illustrate how these knowledges are linked together. Throughout this thesis I used the term ‘bridging’, as I viewed my research to be creating a bridge to facilitate connection between the strengths and advantages of each knowledge system in understanding and responding to climate change. However, a related concept which has recently been gaining traction, and which is worth mentioning here, is a theoretical concept that was delineated in 2005 by Mi’kmaq elders called ‘two-eyed seeing’ (Bartlett et al. 2012). ‘Two-eyed seeing’ has been explained as seeing the strengths of TEK with one eye, and the strengths of Western Science with the other eye (Bartlett et al. 2012) to provide multiple perspectives to the same problem. Two-eyed seeing doesn’t simply ‘paste’ the two views together, but rather integrates them in a holistic manner by using the strengths of each knowledge system to achieve a joint overall aim (Wright *et al*. 2019), while at the same time recognising that they are discrete and complete systems in their own right (Bartlett *et al*. 2007), and that Indigenous People are equal partners with scientists in research, not simply passive participants (Peltier 2018). Wright *et al*. (2019) conducted a literature review on the application of two-eyed seeing in research, and found only 37 studies that apply this idea, primarily in the fields of healthcare and education, with only 2 studies applying the concept to ecological and geographical research. It is important to consider how knowledges interact in the research I, and others, conduct, because it helps to address the power imbalances which often occur between science and policy, and Indigenous knowledge, and which should be considered more in policy decisions (Mantyka-Pringle *et al*. 2017; Martin et al. 2017), and also highlights how TEK is sometimes made to ‘fit’ inside science’s paradigm, rather than being valued independently (Mantyka-Pringle *et al*. 2017).

In this thesis I have used methods that allow me to investigate a Western Science viewpoint of resource use and climatic changes in the region from harvest data, weather station data, climatic models, and scientific literature, and investigate Indigenous knowledge of resource use and change, and weather changes in the region from interview data, along with references to past ethnographic literature. The importance of culturally important species that are key to people and indicate changes ecologically have been well documented in past ethnographical literature, and in this research, as seen throughout this thesis, and those species identified through a close collaboration with communities are a prime example to illustrate the two-eyed seeing concept.

8.2 Main research question

My main research question sought to examine to what extent can species which hold critical relevance in people's lives due to their cultural and ecological significance be used as proxy measures to understand and monitor the impact of climate change on a regional landscape scale, and serve as an indicator of the impacts on the landscape and socio-ecological systems in the face of climatic changes?

I termed these critical species 'Cultural Keystone Indicator Species' (CKIS) and examined CKIS examples through multi-sited case studies using both TEK and the scientific and ethnographic literature. I argued that these species form an exceptionally salient lens for viewing the processes and impacts of climatic change on Indigenous Peoples because of their cultural and ecological significance and bridge between TEK and Climate Change Knowledges. In this research, it was seen that people had noticed differences in many local species indicating general shifts in biodiversity, but there were also certain individual species mentioned frequently by a large majority of participants, and it was these species which I chose to focus on for my CKIS case studies. These case studies looked at species from different habitats, including a terrestrial mammal (Sitka black-tailed deer), a marine fish (five species of Pacific Salmon) and terrestrial plants (salmonberry and several blueberry species), and the interview data results for each CKIS are summarised below.

For the deer CKIS, it was found that non-climatic changes such as forestry patterns (presence of old growth, logging) impacted how deer were able to respond to fluctuations in climate (Hanley 1993; Farmer and Kirchhoff 2007; Schoen and Kirchhoff 2007; USDA Forest Service 1997), but ultimately the weather variables of temperature and snow levels and their impacts on population and distribution were the predominant explanations of people's recognition of the availability of this resource and their ability to harvest deer. For example, during light snow years, deer not only make more use of logged areas where browse is not covered by deep snow, but such clearings may facilitate their movement higher up into the mountains to distance themselves from human settlements. However, when heavy snow years occur, the greater snow depth in the logged areas covers their browse and greatly hinders upland travel, making them vulnerable to starvation and die-offs, and may drive the deer lower in elevation, potentially making them easier to hunt, especially when they end up on the beach. Thus, temperature and precipitation in the form of amount of snow, and how deer respond to these variables, directly impact peoples' ability to use deer.

For the salmon CKIS, a reduction in the amount of snow led to reduced snowpack and less runoff in the spring. This, in turn, may lower stream levels such that salmon lack enough water to reach their upstream spawning areas. The smaller volumes of stream water also tend to be warmer, due to higher air temperatures and a lack of cold-water input from snow melt, further inhibiting salmon fecundity and viability. While increased rain fall might be thought to counteract the lack of snow, it can flow down the watershed at the wrong time of year (such as in the autumn, winter or summer) and may create other problems for salmon spawning and rearing habitats, such as erosion, blockages, and flooding. Warmer water temperatures–in fact any large variations of temperature range–have been shown to have impacts on spawning, incubation, and fry survival and movement (Scannell 1992), which in turn affects the number of adult fish that are available for harvesting in subsequent years. Warmer water also affects fish behaviour and disease vectors. Many of the fishermen said it was harder for them to catch fish as they come into the nearshore now, because when the fish swim towards the rivers to spawn, they are swimming in the deeper, colder water to escape the upper layers of warm coastal water, and thus often swim below the depth of deployed nets, hence reducing catches. Alternatively, some participants mentioned that they are now having to alter their fishing locations to be able to catch fish, such as setting their nets closer to the mouths of the rivers, as fish are forced to swim higher up in the water column due to decreasing depth instream.

For berries as CKIS, their response to changing weather conditions shows clear impacts on peoples' usage, including changes to the quality, quantity, and distribution of berry species throughout the gathering season. Berries were described as being increasingly swollen with extra water, or small and desiccated, depending on the amount of rain and sun. Both scenarios negatively affected the taste and quality, and thus peoples' interest in harvesting and eating them. Participants describe having to replace wild berries at feasts with store-bought berries, as it was more reliable and easier. Quantities of resources also were reported as varying according to climatic conditions, with many respondents reporting increasingly high interannual variability. In most cases, more extreme weather at either end of the spectrum, within a harvest year tended to result in reduced availability and quality and thus lower yields for harvest.

8.3 Research sub-questions

I developed these five sub-questions to complement my main research question.

1) My first sub-question was to ask if the participants in this research had noticed changes in the weather, and if they did, what weather patterns were happening.

This study shows that people have observed a wide range of weather changes throughout the study area, and many changes to biodiversity and landscape characteristics (some independent of weather changes) have been documented by local Indigenous experts as part of their livelihood engagements on the land and sea. Changes to the weather included people recognizing that temperatures had increased, leading to less snow than in their childhood, and more rain, although it was noted that periodically there are years with extraordinarily large amounts of snow. They also noted there were less 'sunny' days and more wet and warm days, and also an increase in the intensity and frequency of stormy weather.

2) My second sub-question asked if these observed weather changes were affecting how people accessed, harvested and prepared resources in their territory.

Interviews revealed that local people are sensing changes and uncertainty about the climate through their observations of weather. Interviewees reported unprecedented weather changes that are influencing the distribution and availability marine and terrestrial resources, their ability to harvest and preserve these resources, and even people's confidence and ease in moving about their territory to hunt, fish, or gather or visit other towns. Thus, these observed weather changes seem to be severely people's ability to use resources, as well as their safety when harvesting.

3) My third sub-question asked my participants about which local species they had observed to be experiencing some sort of change.

Changes to biodiversity include several examples of species completely disappearing (e.g., violets, orchids, migrating ducks and geese, bees, horseflies, frogs, toads) from local environments, as well as new species appearing to become established (e.g., giant squid, tropical fish, starlings, tall invasive grass, mackerel, various insects and small invasive herbaceous plants). Other species discussed had experienced range extensions or decreases, or simply variation along the NW Coast (e.g., moose moving onto islands from mainland, bear, elk, yellow cedar). This has led participants in this research to change what they harvest, such as shifting from moose to deer in some areas, or pursuing newer arrivals, such as tuna, an example of human adaptation to biodiversity change.

4) My fourth sub-question looked to link the changes that local people had observed to broader regional shifts in biodiversity across the Cascadia bioregion.

While many of these biodiversity changes are linked to weather changes, this is a complex ecosystem with many factors at play which influence biodiversity. Changes in the landscape include observations surrounding glacial retreat/disappearance, isostatic rebound, shifting tide levels, and erosion (due to both weather events and development). These changes further exacerbate the impacts of the weather on biodiversity changes. In every community, residents observed that many animals and plants are not following their usual behaviours (e.g., migration, flowering). While this is a broad statement, it reflects the regional focus of this article, showing that despite each community being distinct, there were common trends in the observations made by people throughout the entire study area, based on their observations of the natural environment around them. In many cases, this means locals are having to travel farther to harvest, and this travelling can be dangerous with more unpredictable weather conditions arising from climate changes. Weather patterns, animal behaviour, and welfare are tightly intertwined.

5) My fifth sub-question involved seeing how TEK and climate data can be used in conjunction to present a comprehensive picture of local climate change effects and inform adaptive responses, including knowledge transmission between generations, and capability for resilience into the future.

This question was not directly answered by my interview data, but my research project as a whole demonstrates the importance of collaborating and the different viewpoints afforded by each discipline. Not only did I discuss several situations where policies have been implemented that illustrate prior collaborations between TEK and western science, but my research provides a vehicle to collaborate in a new way, using important species knowledge in a climate context to inform at both local scales and regional scales. As well, I discussed how my participants transmit knowledge between generations, how knowledge is preserved, and how to implement resilience into the future. For example, transmission of knowledge is implicated in certain TEK principles, such as knowing about when it was safe to eat shellfish, and that these rules can sometimes no longer be trusted to provide accurate harvesting guidance with today's changing climate.

8.4 Limitations

This type of interdisciplinary research also has some limitations with regards to how to incorporate these quite diverse knowledge systems. While the importance and advantages of collaborating between knowledge systems was explained in depth above, in practice it is harder to make sure that every stakeholder has an equal say. Resilience not only connects knowledge systems but is also seen a "a bridge across areas of science and policy" (Brown 2016). However inadequate communication makes this tricky to employ, both between knowledge systems and between policy and users, and resiliency challenging to implement (Brown 2016). Additionally, there may be struggles between knowledge systems, where scientific and governmental knowledges can be seen to "contradict the user's [TEK] experience" (Dohrn 2013) or that local knowledge only gains status when 'validated' by scientific knowledge rather than being valid in its own right (Mantyka-Pringle *et al*. 2017; Murray *et al*. 2011) or having the power to invalidate scientific findings.

As I mentioned above when discussing the different terms used to refer to integrating Indigenous Knowledge and Scientific Knowledge, in this research I chose to use 'bridging' as I felt that best represented how I viewed the two knowledge systems to be connected. In short, it is clear that the validity of knowledge systems is linked to larger power relations, and even past colonialist mentalities of assimilation, which can deracinate and degrade TEK systems. Thus, it is important for scholars to develop an anthropological "double vision," or "two-eyed seeing," as an equitable way of "bridging" or "braiding" knowledge systems rather than more ethnocentric means of incorporation. Because there is a variety of terms, and no 'one' right or correct way to connect these knowledge systems the most important thing to keep in mind is that research aiming to bring together these knowledge systems are opening the doors to further collaboration and understanding for mutual benefit.

Regarding the applicability of CKIS to other regions and Indigenous Peoples, while these three species or functional groups were key species mentioned in this region and for the people where my research was conducted, these species choices may not be applicable for all regions, particularly if they are do not exist in a certain region. With appropriate selective criteria, however, other CKIS examples can be identified, such as for more southerly coastal, interior, and arctic peoples, or even for other continents, biomes, and Indigenous Peoples around the world. While not every species can function in a CKIS role, some other species that have high cultural and ecological importance and may prove to be CKIS in addition to the species I reported, but for other Indigenous people on the coast and in the interior of BC and Alaska, include mountain goat (*Oreamnos americanus*), cutthroat trout (*Oncorhynchus clarkii lewisi*), northern riceroot (*Fritillaria camschatcensis*), cloudberry (*Rubus chamaemorus*), devil's club (*Oplopanax horridus*), Pacific crabapple (*Malus fusca*), high bush cranberry (*Viburnum edule*), moose (Alces alces), black cottonwood (*Populus trichocarpa)*, bracken fern (Pteridium aquilinum), Labrador tea (*Rhododendron groenlandicum*), thimbleberry (*Rubus parviflorus*) and lingon berry (*Vaccinium vitis-idaea*) (Joseph 2012; Karst 2005; Kuhnlein and Humphries 2017; Turner 2014). When applying this concept to other ecosystems, researchers will need to identify the species in their chosen region that represent cultural importance, keystone status, and indicator traits.

8.5 Future Research

Significant impacts on all the CKIS described throughout this thesis are evident as a result of climatic change. However, despite all these impacts, at the same time I found participants responding to these impacts in practical ways, and prioritizing their responses in different ways, albeit with various limitations. For example, while people are able to somewhat adjust how and when they go out fishing due to inclement weather or fish behaviour change, or they can freeze resources to preserve them at any time of year or in any weather, other factors such as holiday time from work or the governmental control of fishing seasons affects how much they can modify their behaviour to prioritize their responses to these new changes. Thus, the results from this research suggest some prioritizing; however, more investigations are needed to fully understand the ramifications of how people can prioritize within modern governmental and lifestyle constraints.

While I only considered three species/functional groups of CKIS in this study, other CKIS can be chosen, which inhabit similar or divergent landscapes and ecozones, such as those species suggested earlier in this chapter. A programme of CKIS species investigations could be developed as a part of a comprehensive research, monitoring, and evaluation (and perhaps restoration) programme for addressing climate change, and biodiversity and human responses to its impacts, in the Northwest Coast Region and other regions. As more research is conducted looking at weather baselines in the Pacific Northwest and the nature of faster paced changes in the present 'Anthropocene' versus earlier epochs, and more collaborative co-management partnerships arise, an even better understanding of the intersections and correlations between Indigenous observations of the earth system and climate data can be achieved. To strengthen adaptation and resilience strategies, it is vital for different organisations to work together to use all relevant knowledge systems and create a unified learning system for responding to changes in CKIS and other climate feedbacks. This includes not only scaling up and scaling down knowledge systems to provide meaningful local feedbacks, but also scaling across systems so that local knowledge can be situated into a regional context of understanding and responding to climate change. For example, salmon have large migratory ranges, so while the regional view examines the entire life cycle, from egg to ocean, and back to spawning, local knowledge will provide the closer lens to specific parts of the lifecycle that directly interact with human populations so that local peoples can adapt to the shifting patterns and use these knowledges to inform responses to future changes. Even berries, that are stationary, are impacted by broader regional weather shifts, but adaptation has to be addressed in a local way.

Future research should involve continuing to find common ground so that each stakeholder can work together for a resilient response to co-manage resources in the face of climate change and understand and respond to climate change impacts and how to integrate

Indigenous Knowledge more fully in policy decisions (Martin *et al*. 2017). Management regimes are going to have to adjust to these ecological and cultural changes that are manifesting due to climatic changes, observed especially through TEK, and arrive at sensible and just policy and management decisions that will allow people to maintain their cultural livelihoods while preserving ecosystem function. For example, the TEK observations of deer responses to climatic changes may lead to management decisions to alter when the hunting season opens and closes, or observations surrounding salmon may mean limiting the number of salmon that can be harvested before they have spawned out. While it is beyond the scope of this thesis to fully address these questions, the lenses I have applied and the bridges I've constructed between these knowledge sources allows us to imagine and anticipate changes. Indeed, as I have shown, Indigenous peoples are already making adjustments to climate, based on their own systems of resilience and adaptation.

The significance of this research to both the ethnoecological and climate/ecological disciplines is that it shows how to situate academic enquiry at the junction of different knowledge systems in order to more effectively bridge them, including climate science and TEK, in practical ways that will readily inform both knowledge systems, as well as regional policy and local responses. Undoubtedly, this approach will also raise important new questions for investigations, particularly in how to apply this knowledge integration to practical policy implications.

8.6 Conclusion

My findings demonstrate that Peoples on the Northwest Coast are, and have been, experiencing and adapting to climatic changes through continued interactions with their changing ecosystems and biodiversity over many thousands of years. Climate change impacts are not the only stressors affecting Indigenous Peoples in coastal ecosystems, but rather just one of many challenges they are facing, including: commercial and sports fishing pressures on subsistence, logging and deforestation, pollution (sewer outfalls, boats), and inappropriate state/provincial regulations governing cultural practices made without collaboration between Indigenous communities and governmental bodies. Adaptation and resilience strategies must also take these non-climatic factors into account.

The CKIS examples used in this thesis demonstrate how local observations of a cultural keystone indicator species can reveal how weather conditions and peoples' interactions with ecosystems relate to climatic changes. I have demonstrated how CKIS can be used as proxy measures to understand climatic shifts in a locally relevant context.

An emphasis on CKIS provides an opportunity to advance the inclusion of Indigenous knowledge and TEK into climate research and posit ways of dealing with the totality and complexity of what Indigenous Peoples have to deal with in a meaningful, positive, and empowering way. At this stage, it is not enough to simply instigate "measures to reduce or moderate the negative effects of climate change" (Ford *et al*. 2010), there need to be proactive ways to collaborate between knowledge systems to create resilience, and I argue throughout this thesis that using CKIS examples are not only a useful lens for understanding climate change impacts, but also for incorporating TEK into shaping adaptive and resilient responses to climate change and the co-management of resources (Murray *et al*. 2011; Pinkerton et al. 2014; Raymond-Yakoubian *et al*. 2017; Reyes-García *et al*. 2019). Examples of how communities are practically addressing a resilient approach to resource management are the co-management examples mentioned in the salmon chapter, such as the Alaskan/Hydaburg partnership, Sustainable Southeast Partnership and the Marine Partnership Plan, and the harvesting of gull eggs referred to in chapter 7. These partnerships, along with numerous other examples throughout the PNW which are not directly related to the resources or communities discussed in this research, and thus not covered, are made up of governmental, scientific, and tribal entities and draw on Indigenous knowledge to monitor, adapt, and preserve salmon stocks and other watershed resources to be able to use them into the future, and will have importance for policy implications. Additionally, because this research was conducted on a regional (vs. community) basis, a diverse set of impacts and responses were recorded, that you wouldn't have had with just one community. Even though species did respond differently in different locations, my results show overall similarities that illustrate a regional overview of the TEK network for resilience between humans and other species.

Finally, understanding human responses to biodiversity change through CKIS also helps move adaptation studies beyond vulnerability-based approaches (Cameron 2012; Ford 2009; Ford and Smit 2004; Ford *et al*. 2006; Ford *et al*. 2018) towards strength-based, resilience centred, approaches (Biggs *et al*. 2015; GRAID 2020; Ford *et al*. 2020; Resilience Alliance 2019; Stockholm Resilience Centre 2019; Wyllie de Echeverria and Thornton 2019) which favour not only local knowledge but culturally-important species that are crucial to understand the impacts of climate change and important lenses through which to envision potential adaptation opportunities and to create resilient social-ecological ecosystems.

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University of Oxford

CENTRAL UNIVERSITY RESEARCH ETHICS COMMITTEE (CUREC)

CUREC/1A Checklist for the Social Sciences and Humanities

The University of Oxford places a high value on the knowledge, expertise, and integrity of its members and their ability to conduct research to high standards of scholarship and ethics. The research ethics clearance procedures have been established to ensure that the University is meeting its obligations as a responsible institution. They start from the presumption that all members of the University will take their responsibilities and obligations seriously and will ensure that their research on human subjects is conducted according to the established principles and good practice in their fields and in accordance, where appropriate, with legal requirements. Since the requirements of research ethics review will vary from field to field and from project to project, the University accepts that different guidelines and procedures will be appropriate. Please check the CUREC website to ensure that you have the correct form for your project.

This form does not cover research governance, satisfactory methodology, compliance with the requirements of publishers when administering their tests or questionnaires, or the health and safety of employees and students. As principal investigator, it is your responsibility to ensure that requirements in these areas are met. Please carry out a risk assessment of the project, in consultation with all researchers involved, using the checklist and CUREC's other documentation.

The use of an asterisk in this form indicates a phrase defined in the glossary. The glossary and further information on the University's research ethics procedures are available from the CUREC website:

www.admin.ox.ac.uk/curec

This form is designed largely for research that falls within the Divisions of Social Sciences and Humanities and which does not involve a high level of risk to the subjects. Elite interviews, field work and oral history are included in the CUREC process. Please take a moment to read through it and if you have any questions or doubts as to whether it is the appropriate form, please review Section A or consult the CUREC website.

Note on anonymised data and audit: you do not need to obtain ethical approval for your study if:

- you are using previously collected **anonymised data** about people which neither you nor anyone else involved in your study can trace back to the individuals who provided them (e.g. census data, administrative data, secondary analysis). Please refer to the definition of *personal data in the glossary and FAQ A4 for further guidance; or
- you are conducting research on behalf of or at the request of a service provider that matches the definition of *audit in the glossary.

If your research is audit or uses prior-anonymised data, please check this box: ☐

You do not need to seek ethical approval from CUREC, and you do not need to complete any more of this form. However, please check with your department's requirements, as some departments require you to lodge this form with them.

Office use only: IDREC Ref. No. ________________

Date of confirmation that checklist accepted on behalf of IDREC: // //

SECTION A	Yes	No
1) Are you using research methodologies commonly used in biomedical or behavioural laboratory sciences?		X
2) Is there a significant risk that the research will induce anxiety, stress or other harmful psychological states in participants that might persist beyond the duration of any test or interview in which they are participating?		X
3) Will the research involve human participants recruited by means of their status as present or past NHS patients or their relatives or carers?		X
4) Does the research involve *human participants aged 16 and over who do not have *capacity to consent for themselves? See the Mental Capacity Act 2005		X
5) Is the study to be funded by the US National Institutes of Health or another US federal funding agency?		X

If you answered 'yes', please **stop** work on this checklist and

- **for questions 1 and 2**, complete CUREC/1 instead (available from www.admin.ox.ac.uk/curec);
- **for questions 3 and 4**, submit your proposal to the appropriate NHS ethics committee (see www.nres.nhs.uk and www.admin.ox.ac.uk/researchsupport/=ctrg for further information);
- **for question 5**, or **if you answered 'yes' to questions 1, 2 or 4 and your research will take place outside the EU and is a biomedical study**, submit your proposal to OXTREC, which uses separate documentation. **Applications to OXTREC using this form will not be accepted.** If your research is not a biomedical study and does not have US funding, but will take place outside the EU, you may use this form to submit your application for approval to the Social Sciences and Humanities IDREC.

If you have answered 'no' to all questions in Section A, please complete Sections B-E. This form and any supporting materials should be typewritten.

SECTION B

****Principal investigator/ supervisor/student researcher (title and name):***	***Victoria Wyllie de Echeverria***
Name of supervisor (STUDENT RESEARCH PROJECTS ONLY):	***Dr. Thomas Thornton***
Degree programme, e.g. DPhil, MPhil, MSc (STUDENT RESEARCH PROJECTS ONLY):	***DPhil***
Department or institute:	***Environmental Change Institute, School of Geography and the Environment***
Address for correspondence (if different):	**School of Geography and the Environment** Oxford University Centre for the Environment University of Oxford South Parks Road Oxford, OX1 3QY United Kingdom
Email and phone contact:	***victoria.wylliedeecheverria@ouce.ox.ac.uk; 07532 078078***

Title of research project:	**Using Pacific crabapple (*Malus fusca*) as an ecocultural keystone indicator species to link interactions between cultural and biological diversity on the Pacific Coast of North America in the face of climatic change**

Title and brief lay description of *research (about 150 words), plus description (about 200 words) of the nature of participants (including the criteria for inclusion/exclusion & method of recruitment, how professional guidelines are being applied (if applicable) and use to which the results/data will be put.

Please describe how you will obtain informed consent, citing and attaching, where applicable, documentation produced in support of your application such as generic recruitment and advertisement material, participant information sheet(s), consent form(s) and debriefing document(s).

The purpose of this project is to research how changes in weather patterns influence the ability of Indigenous and local people on the coasts of British Columbia and Alaska to harvest traditional foods and travel around their territory. Using interviews and field observations of harvesting locations, I will learn about traditional ecological knowledge from Indigenous and local people to learn how they have personally experienced changing weather patterns, how these changes have affected them, how they have adapted to these changes, and what they might expect to experience into the future. I will be focusing this knowledge about environmental change around Pacific crabapple (*Malus fusca*), an ecologically and culturally important indicator keystone species as a touchstone for a broader social-ecological relationship to seeing how broader environmental changes cascade through both biological and cultural ecosystems.

The people that will be interviewed in this project include elders (usually over 60 years old) and other adults that hold knowledge of harvesting traditional foods and changes to weather and harvesting patterns over their living memory. Within this group, specific participants will be picked because they hold an important knowledge repository. The participants will be found either because they were identified as significant knowledge holders by someone else, or have approached me themselves, and then will be asked if they would like to participate. Interviews will be conducted in a semi-structured format. In my research and interview protocols I will be following ethics guidelines laid out by The International Society of Ethnobiology in their "Code of Ethics". The resulting interview data will be merged with data collected by examining weather and aerial photo records to create a comprehensive picture of how environmental changes have been occurring on the landscape, and how local Indigenous people have noticed and adapted to these changes. This local knowledge is important to record before these elders die and the knowledge is lost with them, and also in-depth localized knowledge can be extremely useful in fine tuning policy decisions. Changes in this coastal system are understudied, and yet this ecosystem is changing quite rapidly. This research will help contribute to this growing body of knowledge.

Please find attached to this application 3 appendices: A community introduction letter, a project information letter (for each participant) and an informed consent form. Written consent forms should suffice, as people can either read and write, or they have a proxy.

List actual or probable location(s) where project will be conducted, if known:	Indigenous communities on the coasts of northwestern British Columbia, Canada, and southeastern Alaska, U.S.A., belonging to several First Nation groups. Probable Nations to be approached include that Gitga'at Nation, the Haida Nation, The Haida Kaigani Nation and the Tlingit Nation, but specific plans are still being finalized.

If your research involves overseas travel or fieldwork, have you completed and returned a travel risk assessment form? (Bear in mind that this may be necessary to ensure that the travel or fieldwork is covered by the University's travel insurance – see http://www.admin.ox.ac.uk/finance/insurance/travel/.)	**YES**
Anticipated duration of project:	__3__ months
Anticipated start date:	01 / 08 / 2014
Anticipated end date:	01 / 11 / 2014
Name and status (e.g. 3rd year undergraduate; post-doctoral research assistant) of others taking part in the project:	None to date; potantially members of the local communities
Please indicate what training on research ethics the researchers involved with this study have received, e.g. the title of the online or in-person course, and date completed (online training available at www.admin.ox.ac.uk/researchsupport/integrity/human/):	Attended Oxford University's ethics workshop, Nov, 2013. SOGE DPhil Training seminar, 12 November 2013, lecture on ethics process by Dr. Thomas Jellis Ethics process (for M.Sc. research) at the University of Victoria, Victoria

SECTION C

Methods to be used in the study (**tick** as many as apply: this information will help the committee understand the nature of your research and may be used for audit).

	Please tick
Interview	X
Questionnaire	
Analysis of existing records	
Participant performs verbal/paper and pencil/computer based task	
Measurement/recording of motor behaviour	
Audio recording of participant	X
Video recording or photography of participant	X
Physiological recording from participant	
Participant observation	X
Covert observation	
Systematic observation	
Observation of specific organisational practices	
Other (please specify)	

SECTION D

Have you read one or more of the following professional guidelines and do you undertake to use the principles listed there as a guide for your own work? Please note that this is not intended to be an exhaustive list. Links to the guidelines listed below are included on the CUREC website.

	Please tick
British Society of Criminology: Code of Ethics for Researchers in the Field of Criminology [www.britsoccrim.org/codeofethics.htm]	
British Educational Research Association Ethical Guidelines for Educational Research [www.bera.ac.uk/guidelines]	
Academy of Management's Code of Ethics [www.aomonline.org/aom.asp?ID=&page_ID=242]	
Association of American Geographers Statement on Professional Ethics [www.aag.org/cs/resolutions/ethics]	
Oral History Society of the UK Ethical Guidelines [http://www.oralhistory.org.uk/index.php]	
American Political Science Association (APSA) Guide to Professional Ethics in Political Science (Section H) [www.apsanet.org/content_9350.cfm]	
Political Studies Association Guide to Good Professional Conduct [www.psa.ac.uk/psa]	
British Psychological Society Code of Ethics and Conduct [www.bps.org.uk/what-we-do/ethics-standards/ethics-standards]	
Ethics Guidelines of the Association of Social Anthropologists of the UK and Commonwealth [www.theasa.org/ethics/guidelines.shtml]	
Social Research Association: Ethical Guidelines [http://the-sra.org.uk/sra_resources/research-ethics/ethics-guidelines/]	
Statement of Principles of Ethical Research Practice from the Socio-Legal Studies Association [www.slsa.ac.uk/content/view/247/270/]	
Statement of Ethical Practice for the British Sociological Association [www.britsoc.co.uk/about/equality/statement-of-ethical-practice.aspx]	
Other professional guidelines (please specify): ***The International Society of Ethnobiology, Code of Ethics [http://ethnobiology.net/what-we-do/core-programs/ise-ethics-program/code-of-ethics/code-in-english/]***	**X**

SECTION E

Please put a tick in the yes/no column as appropriate to indicate your response.

1) Will you obtain informed consent according to good practice in your discipline before participation?	**Yes**	**No**
	X	
2) Will you ensure that *personal data collected directly from participants or via a *third party is held and processed in accordance with the provisions of the Data Protection Act?	**Yes**	**No**
	X	
3) Does the research involve as participants *people whose ability to give free and informed consent is in question?	**Yes**	**No**
Note: participants aged under 16 are generally considered to require consent of a parent or guardian (only answer 'no' to this question if you can cite one of the protocols listed under 'children'). For participants aged 16-17, consult FAQ C13		**X**

	Yes	No
4) As a consequence of taking part in the research, will participants be at serious risk of rendering themselves liable to criminal prosecution (e.g. by providing information on drug abuse or child abuse)?		X
5) Does the research involve the *deception of participants, as part of the investigation/experiment?	Yes	No
		X
If any of your answers above are in a shaded box, please indicate whether those aspects of your project are fully covered by the following.		
6) Research protocol(s) which has/ve received IDREC/CUREC approval?	Yes	No
If yes, please give protocol number(s):		
7) Professional guidelines that you will be following, as noted under Section D?	Yes	No

If any of your answers in Section E are in a shaded box and are not covered by a protocol or by professional guidelines, please complete CUREC/2, available to download from the CUREC website. Then submit both this form (you need not complete section F) and the CUREC/2 to the Social Sciences and Humanities IDREC.

If all your answers in Section E are in the unshaded boxes or your answers in shaded boxes are covered by a protocol or professional guidelines, complete Section F and submit this form and any accompanying documents to the Social Sciences and Humanities IDREC or to the relevant officer/committee at departmental level (see notes and address below).

FINAL CHECK

Please check each of the following before submitting the checklist. **If the appropriate supporting documentation is not included with your application, you will then be asked to provide this separately. This may well delay the ethical review process, and thus the start of your research.**

Have you completed Sections A-E? ☒

Have you defined all technical terms and abbreviations used? ☒

If you have produced any documentation in support of your application (which might include questionnaires, participant information, consent forms/form or note of procedure for recording oral consent, advertisements and surveys), have you attached a copy of these? ☒

Are all pages (including appendices and attachments) numbered? ☒

SECTION F

You can submit this checklist by email and/or as a signed hard copy; if it is being sent by email only, the checklist, and any email from the head of department or nominee separately endorsing its submission, must be sent from a University of Oxford email address (i.e. as a minimum, the checklist and supporting documents must be submitted by the head of department or nominee indicating his/her approval from a University of Oxford email account).

Complete this section only if you do not need to submit form CUREC/2.

I understand my responsibilities as principal researcher/supervisor/student researcher as outlined in the CUREC glossary and guidance on the CUREC website.

I declare that the answers above accurately describe my research as presently designed and that I will submit a new checklist should the design of my research change in a way which would alter any of the above responses so as to require completion of CUREC/2 (involving full scrutiny by an IDREC). I will inform the relevant IDREC if I cease to be the principal researcher on this project and supply the name and contact details of my successor if appropriate.

Signed by principal researcher/supervisor/student researcher: Victoria Wyllie de Echeverria ……………………………………

Date:…2 July 2014

Print name (block capitals)……VICTORIA RAWN WYLLIE DE ECHEVERRIA…

Signed by supervisor:… [signature] (for student projects)

Date:…1 July 2014………………

Print name (block capitals)……THOMAS F THORNTON………………………………………………

I understand the questions and answers that have been entered above describing the research, and I will ensure that my practice in this research complies with these answers, subject to any modifications made by the principal researcher properly authorised by the CUREC system.

Signed by associate/other researcher: ………………………………………………………………….

Print name (block capitals)………………………………………………………………………………

Date ………………

I have read the research project application named above. On the basis of the information available to me, I:

(i) consider the principal researcher/supervisor/student researcher to be aware of her/his ethical responsibilities in regard to this research;

(ii) consider that any ethical issues raised have been satisfactorily resolved or are covered by relevant professional guidelines and/or CUREC approved protocols, and that it is appropriate for the research to proceed without further formal ethical scrutiny at this stage (noting the principal researcher's obligation to report should the design of the research change in a way which would alter any of the above responses so as to require completion of a CUREC/2 full application);

(iii) am satisfied that the proposed project has been/will be subject to appropriate *peer review and is likely to contribute something useful to existing knowledge and/or to the education and training of the researcher(s) and that it is in the *public interest.

(iv) confirm that this checklist (and associated research outline) has been reviewed by the Department's Research Ethics Committee (DREC)/equivalent body, and attach the associated report from that body.

Signed:…………………………………………..
(Head of department or nominee e.g Chair of DREC, Director of Graduate Studies for postgraduate student projects)

Print name (block capitals)……………………………………………………………………………

Date:……………………

If your research involves participants recruited by means of their status as current or former NHS staff, or the research will, in whole or in part, be carried out on NHS premises, use NHS facilities or assess NHS facilities or services, please see FAQ B3 (www.admin.ox.ac.uk/curec/faqs/).

Please check with your department about its procedures for the approval of CUREC forms. If your department indicates that the checklist should be submitted directly to the IDREC, please send it, together with any supporting documentation, to the following address(es), keeping a copy for yourself:

Secretary of the Medical Sciences IDREC Email: ethics@medsci.ox.ac.uk
Research Services
University of Oxford
Wellington Square
Oxford, OX1 2JD

Secretary of the Social Sciences and Humanities IDREC Email: ethics@socsci.ox.ac.uk
Research Services
University of Oxford
Wellington Square
Oxford, OX1 2JD

IDRECs and/or CUREC will review a sample of completed checklists and may ask for further details of any project.

Revised July 2013

Appendix 2a. Introduction Letter

Hello,

Thank you for taking the time to read this. My name is Victoria Wyllie de Echeverria, and I am currently doing a Ph.D. degree at the University of Oxford. I am studying under the guidance of Tom Thornton, who some of you may know as he has worked with the Tlingit for several years. In this letter, I would like to introduce myself to you and describe my research project.

I grew up on Shaw Island, a small rural island in the San Juan Islands of Washington State with a population of about 200. My parents are marine scientists and helped me in develop a strong interest in plants when I was young. When I went to university, I continued with this fascination of learning about how people relate to the plants around them. During my undergraduate and Masters degrees I worked with a professor at the University of Victoria, Nancy Turner. You may know her as she works closely with several Indigenous First Nations along this coast, learning about their plant knowledge. Through Nancy's guidance over the last ten years, in addition to classroom learning at the university, I have also been learning from numerous Indigenous elders in the Kwakwa̲ka̲'wakw Nation and the Gitga'at Nation. Kwakwa̲ka̲'wakw elders include Hereditary Clan Chief and Potlatch speaker Adam Dick (Kwaxsistalla), Daisy Sewid-Smith (Myanilth), Kim Recalma-Clutesi (Ogwilowgwa). Gitga'at elders include Hereditary Clan Chief Albert Clifton, Hereditary Clan Chief Ernie Hill, Jr., Clan Matriarch Helen Clifton, Margaret Reece, Belle Eaton, and Elizabeth Dundas, among others. I value their guidance greatly, and consider them to be important teachers in my life.

I did my Masters research in Hartley Bay, BC, where I was interviewing Gitga'at knowledge holders about how they tell the different varieties of crabapples apart and how they harvest and use this plant. During these interviews, people raised concerns about how the changing weather was affecting their ability to travel around their territory and to harvest many food resources, including crabapples.

For my Ph.D. research now, I have decided to see if other people besides the Gitga'at have similar concerns about changing weather conditions. One way the impacts of these weather changes can be looked at is by focusing on recording local knowledge concerning changes to the harvesting of crabapples, as they have been an important food source for people and animals along the coast and hold important roles in the ecosystem. I am interested to learn how these changes in weather are affecting crabapples, and how this in turn affects people, other plants and animals. To record this traditional knowledge, I plan to interview elders and other knowledge holders in several communities along the coast who have noticed changes in the weather during their lifetime, and how these changes have affected them, the community, and the environment around them.

If helping in my work sounds interesting, and you are willing to be interviewed to share your knowledge, or know someone else who would be interested, email me at **vic.wyllie@gmail.com** or phone me at **(778) 260-0403**. I greatly appreciate your assistance in my project, and look forward to learning from you.

Thank you very much for your time,
Sincerely, Victoria

Appendix 2b. Project Cover Letter

Using Pacific crabapple (*Malus fusca*) as an ecocultural keystone indicator species to link interactions between cultural and biological diversity on the Pacific Coast of North America in the face of climatic change

By Victoria Wyllie de Echeverria, Ph.D. Candidate, Environmental Change Institute, University of Oxford

For my Ph.D. project, my objective is to research how changes in weather patterns influence the ability of Indigenous and local people on the coasts of British Columbia and Alaska to harvest traditional foods and travel around their territory. In my previous work and those of other researchers, local people have commented that they have noticed changes in weather patterns and some of the effects this has had. It was been well documented that coastal ecosystems can be highly affected by climatic change, and are changing rapidly. However, it has not been fully investigated to what extent these changes have affected local people to date, and how they will continue to affect people into the future.

Because coastal ecosystems are quite complex, I will be narrowing my focus by using Pacific crabapple (*Malus fusca*), an ecologically and culturally important indicator keystone species as a touchstone for a broader social-ecological relationship to seeing how broader environmental changes cascade through both biological and cultural ecosystems.

To examine how environmental changes can be studied through the application of looking at a single species, I will be using methodological techniques from several disciplines. First, I will be conducting interviews with Indigenous and local people to learn how they have personally experienced these weather changes, how these changes have affected them, how they have adapted to these changes, and what they might expect to experience into the future. Secondly, I will be comparing photographic and weather pattern time-series datasets of the area to track landscape changes quantitatively.

I will be using these two worldviews to look at a variety of spatial and temporal scales to answer the following research questions:

1) The linkages between cultural and biological diversity in this region, as seen through the ecological and cultural role of Pacific crabapple;

2) How these two forms of diversity alter and co-adapt in relation to each other as the environment changes – a phenomenon which seem to be particularly tied to climatic change, and

3) How these past and current changes will continue to affect both the local people and the landscape into the future, and how local people can adapt to these changes, particularly the ability to harvest resources

Viewing these questions through multidisciplinary and multicultural lenses will allow for a more comprehensive understanding of coastal zone changes at the landscape scale. The ultimate goal of this project is understand how environmental change is affecting local peoples, and, by creating predictive models of local environmental change, provide critical information on ways they can or cannot apply strategies from the past to adapt to probable future coastal environmental changes.

Appendix 2c. Consent form

Victoria Wyllie de Echeverria,
Environment Change Institute,
School of Geography and the Environment
University of Oxford, South Parks Road,
Oxford, OX1 3QY. United Kingdom.
Email: victoria.wylliedeecheverria@ouce.ox.ac.uk
Or xxxxxx@gmail.com
British cell number: +44(0) XXXX XXXXXX
Local cell number: (XXX) XXX-XXXX

Project title: Using Pacific crabapple (*Malus fusca*) as an ecocultural keystone indicator species to link interactions between cultural and biological diversity on the Pacific Coast of North America in the face of climatic change

You are invited to participate in this study being conducted by Victoria Wyllie de Echeverria. Victoria Wyllie de Echeverria is a graduate student in the School of Geography and the Environment at the University of Oxford and you may contact her at the phone number and email listed above.

As a graduate student, I am required to conduct research as part of the requirements for my Ph.D. degree. This research is being supervised by Dr. Tom Thornton (University of Oxford). You may contact him at +44(0)1865 275877 or thomas.thornton@ouce.ox.ac.uk.

Purpose and Objectives

The purpose of this project is to research how changes in weather patterns influence the ability of Indigenous and local people on the coasts of British Columbia and Alaska to harvest traditional foods and travel around their territory. In my previous work and those of other researchers, local people have commented that they have noticed changes in weather patterns and some of the effects this has had. It was been well documented that coastal ecosystems can be highly affected by climatic change, and are changing rapidly. However, it has not been fully investigated to what extent these changes have affected local people to date, and how they will continue to affect people into the future.
To do this, I will be conducting interviews and field observations of harvesting locations with Indigenous and local people to learn how they have personally experienced these weather changes, how these changes have affected them, how they have adapted to these changes, and what they might expect to experience into the future. I will be focusing this knowledge about environmental change around Pacific crabapple (*Malus fusca*), an ecologically and culturally important indicator keystone species as a touchstone for a broader social-ecological relationship to seeing how broader environmental changes cascade through both biological and cultural ecosystems.

Importance of this Research

This research is important because it will help to elucidate the close relationship that some indigenous cultures held with certain "cultural keystone" species. By learning from elders the knowledge they hold in this respect, it will lead to greater understanding about cultural links to natural systems and thus, of biocultural diversity. The ultimate goal of this project is understand how environmental change is affecting local peoples, and, by creating predictive models of local environmental change, provide critical information on ways they can or cannot apply strategies from the past to adapt to probable future coastal environmental changes.

Participant Selection
You are being asked to participate in this study because either you are hold knowledge regarding environmental change in your community, you were referred to me by somebody else, or you have approached me yourself about participating in this study.

What is involved
If you agree to voluntarily participate in this research, your participation will include between one to several interviews of one to two hours in length, in your home or another location where you are comfortable in your home community. The interviews will be one-to-one, unless you would like a family member or close friend in attendance, if I need help translating, or if a group interview is held. If you are interested in coming out to the field site, I would welcome your knowledge, but participation in the field component is not mandatory.

I would like your permission to record audio (tape-record) during the interviews. Written notes and observations will also be recorded. A transcription will be made of any recorded tapes for you to approve before being included in this study.

I would also like your permission to take photos during the interviews of you, especially when we are out in the field or you are demonstrating a technique visually, and possible video record interview sessions.

Inconvenience
Participation in this study may cause some inconvenience to you, including the amount of time required for the interviews, but I will attempt to lessen these effects by making interviews pleasant and enjoyable, and I will monitor your energy levels. If you decide to travel to harvesting locations, you may experience tiredness, but again I will attempt to minimize that, and it is likely that traveling for this project would require no greater amount of time or energy than then you would normally expend in your day-to-day life.

Risks
There are some potential risks to you by participating in this research and they include you becoming tired while participating in activities such as interviews and field trips. It is also possible that you might experience emotional stress and sadness when talking about the loss of traditional food and culture, loved ones previously involved in cultural activities who have passed away, and environmental degradation. To prevent or to deal with these risks I will carefully observe you while I am working with you to monitor your energy levels and state of mind, and I may also ask relatives or friends to assist if you anticipate that a particular interview or trip might cause higher than normal risks. If you wish to share an emotional story, I will listen with compassion and understanding. If either you or an assisting friend or relative implies that you should stop the activity at any time, I will do so, and make sure that you get to rest as soon as possible. If you agree and feel better, I would resume interviewing on another day. If we are not in your home (i.e., if we are traveling or out in the field), I will make sure to have chairs, blankets, food, drinks and other amenities to make you comfortable. If you become emotionally troubled by a topic, I will let you take the conversation where you would wish, such as changing the topic or providing support and comfort while you share an experience. If you wish, friends or relatives can be present in the interview to make you feel more comfortable.

Benefits
The potential benefits of your participation in this research include most likely gaining benefits because you will be recognized for your knowledge, both within and outside your home community. You will also be provided with compensation for your time. This research is important to society because by recording this knowledge we will be documenting local knowledge at a local level, and how this is actually affecting people that live off the land. This research will also contribute to the state of knowledge because it will help elucidate links between the social and physical sciences with regards to key food plant species and help document an important aspect of bio-cultural diversity.

Compensation
As a way to compensate you for any inconvenience related to your participation, you will be given appropriate compensation depending on the protocols in place in the community of Hartley Bay, but will mostly likely consist of an honorarium of approximately $25/hour or a gift of equivalent value to individual participants. If you agree to participate in this study, this form of compensation to you must not be coercive. It is unethical to provide undue compensation or inducements to research participants. If you would not participate if the compensation were not offered, then you should decline.

Voluntary Participation
Your participation in this research must be completely voluntary. If you do decide to participate, you may withdraw at any time without any consequences or any explanation. If you do withdraw from the study your data will be used in the analysis only if you agree to this, with any stipulations you choose to make on the material. Material may be removed outright or portions can be kept in, depending on your wishes, including your name being removed from the material, but some of the information staying in. If the data has already been collected, full compensation will be given to you, but if you have not been interviewed yet, compensation will not be provided.

On-going Consent
Since I anticipate that this research will require several interviews over the course of a few months, I would like to request your permission for on-going consent. After the initial interview, I would like to come back for follow-up interviews close to when the initial interview occurred, and also come back at longer intervals over the next couple years, either in person or over the phone/internet. At each subsequent interview, I will ensure that your consent continues and remind you that you can withdraw at any time from these interviews. You will be given an additional letter of consent if the time period between the interviews is more than a year, to indicate your continued participation.

Anonymity
Anonymity will not be protected when gathering the data or disseminating of the results of this study. This means that you will be associated with the information that I learn from you. If you have a problem with this, I will attempt to preserve your anonymity. If you are not comfortable with the levels of anonymity that I will be able to provide, then your information will be left out of the research.

Confidentiality
Your confidentiality and the confidentiality of the data is not going be protected in this study, which means that you will be associated with your data during this study. If you have a

problem with this, I will attempt to preserve your anonymity. If you are not comfortable with the levels of anonymity that I will be able to provide, then your information will be left out of the research. Copies of transcripts, audio and video recordings, written notes and photographs be kept secure in my files at the University of Oxford and some portion of them at a couple museum archives that provided grant monies. When the research has been completed, copies will also be held in your local community and if you would like copies of any of your data, that can also be arranged. While the interviews and knowledge as a whole will be associated with you, you can ask to have certain portions of the interviews kept private, such as information about the whereabouts of your personal harvesting sites. This information will only be cited generally in any publications and other presentations, and not linked to you personally or with a geographical location. I will also only visit these places by permission, and will not return to these areas if not given permission to do so.

Dissemination of Results
Results from this study could be presented in several ways. It will definitely be included in my Ph.D thesis, both a version for the university and a community version, and directly to the participants in this study (such as you). Other ways it could be disseminated are through publishing books, chapters or articles, presentations at scholarly meetings and on Internet sites and other media.

Commercial Use of Results
It is not my intention to have this research lead to a commercial use. However, this research and the resulting information may be used to help inform local policies, such as how governmental agencies manage resources. Since I am also merging local Indegenous knowledge with climate and weather data and information, including models of what future conditions might look like, it will be very important for policy makers to take into account the knowledge that local people hold. However, protocols and agreements would have to be carefully worked out between your community and any intended enterprise, including policy. A Code of Ethics has been implemented by the International Society of Ethnobiology and other organizations to help guide and protect indigenous rights in this kind of situation.

Disposal of Data
Data from this study will be destroyed only if you request it. I will personally keep all the data until the completion of the project and then I will store it in accredited archives (perhaps the University of Victoria Special Collections, but this location is yet to be determined), and in my own personal archives, dependent on your personal wishes and the wishes of the community. Your local community will also receive copies of all data for the community archives, and if you would like a copy, that can be arranged as well. If you would like your data destroyed, this will be done through shredding papers, secured disposing of cds and recorded files and permanently erasing digital files from computers and memory sticks.

Contacts
Individuals that may be contacted regarding this study include Victoria Wyllie de Echeverria, the main researcher, and Dr. Tom Thornton, her supervisor, at the phone numbers and emails listed above. In addition, you may verify the ethical approval of this study, or raise any concerns you might have, by contacting the **University of Oxford CENTRAL UNIVERSITY RESEARCH ETHICS COMMITTEE (CUREC)** ethics@socsci.ox.ac.uk

Your signature below indicates that you understand the above conditions of participation in this study and that you have had the opportunity to have your questions answered by the researchers.

Visually Recorded Images/Data Participant to provide initials:

Photos may be taken of me for: Analysis _______ Dissemination* ________

Videos may be taken of me for: Analysis _______ Dissemination* _________

*Even if no names are used, you may be recognizable if visual images are shown in the results.

After this consent form is signed, you will receive one copy, along with a copy of the Information Sheet, and the research will retain the other copy.

I, _________________________________ on this ____ of ________________:
(participant's full name) (day) (month and year)

PLEASE SELECT STATEMENT:

❑ have read and understood the **information sheet** provided by Victoria Wyllie de Echeverria on her research entitled: Using Pacific crabapple (*Malus fusca*) as an ecocultural keystone indicator species to link interactions between cultural and biological diversity on the Pacific Coast of North America in the face of climatic change**.** (*please check box if you agree)*

❑ am aware that my participation one or more interviews or focus group discussions with Victoria Wyllie de Echeverria is completely voluntary, that I can withdraw participation at any time without consequences. (*please check box if you agree)*

❑ am aware that the information that I provide in this interview or focus group discussion with Victoria Wyllie de Echeverria is completely voluntary. I am aware that I can withdraw information at any time and that I have the right to review and edit all publications and presentations pertaining to the specific information that I provide in the interview or focus group discussion. (*please check box if you agree)*

I ❑ do ❑ do not consent (*please check one box*) that this interview or focus group session with Victoria Wyllie de Echeverria be recorded on audio cassette. I am aware that the interview or focus group discussion can proceed without being recorded on audio cassette. Even if I do consent to have this interview or focus group discussion audio-recorded, I am aware that I am free to request that the audio recording be turned off at any point during the interview or discussion.

I ❑ do ❑ do not consent (*please check one box*) that this interview Victoria Wyllie de Echeverria be recorded on video cassette. I am aware that the interview or focus group discussion can proceed without being recorded on video cassette. Even if I do consent to have this interview or focus group discussion video-recorded, I am aware that I am free to request that the video recording be turned off at any point during the interview or discussion.

I ❑ do ❑ do not consent (*please check one box)* that this interview Victoria Wyllie de Echeverria be photographed and that photographs from this interview or taken at other times, with my consent, may be used in publications and presentations pertaining to the specific information that I provide in the interview or focus group discussion or during related events. Even if I do consent to have this interview or focus group discussion photographed, I am aware that I am free to request that photographs not be taken at any point during the interview or discussion, or during other related events.

I ❑ do ❑ do not consent (*please check one box)* to having my name associated with the traditional ecological knowledge I provide in publications and presentations prepared by Victoria Wyllie de Echeverria, and be credited in the results of this study.

I ❑ do ❑ do not consent (*please check one box)* to having my responses attributed to me by name in the results of this study by Victoria Wyllie de Echeverria.

I ❑ do ❑ do not consent (*please check one box)* that my information from this project may be used for future projects conducted by Victoria Wyllie de Echeverria that are related to traditional preparation, harvest, and management of food plants and other culturally important resources.

I ❑ do ❑ do not consent (*please check one box)* that my information from this project related to traditional preparation, harvest, and management of food plants and other culturally important resources may be placed in an Archives at the University of Oxford by Victoria Wyllie de Echeverria.

I ❑ do ❑ do not consent (*please check one box)* that my information from this project related to traditional preparation, harvest, and management of food plants and other culturally important resources may be placed in an Archives or cultural resource library or centre in your community by Victoria Wyllie de Echeverria.

I ❑ do ❑ do not consent (*please check one box)* that the researcher, Victoria Wyllie de Echeverria, can retain my information from this project for her own records, to be kept in a secure location by her.

_______________ (Participant to provide initials)

______________________________	______________________________	________________
Name of Participant	*Signature*	*Date*

A copy of this consent will be left with you, and a copy will be taken by the researcher.

Appendix 3. Interview Questions

Interview Questions – first I would like to ask you a few general questions, and then I would like to focus on one particular Cultural Keystone Species, Pacific crabapple, before widening out to talk about changes to the general ecosystem

Knowledge Holder:____
Date of Interview:___________________________________
Time:____________________
Location of interview:____

1) Personal information:
    a. Name
    b. Age
    c. Nation and clan belong to
    d. Community/ies lived in

2) Have you noticed that weather has changed in your lifetime?
    a. What have these changes been? (weather patterns (more rain, unpredictable weather, rising tides), landscape make up, plant and animal species)
    b. Have these changes become more noticeable or intense [in terms of impacts] over your lifetime?
    c. Have these changes been occurring before your lifetime, i.e. stories from elders, when you were learning?
    d. Why do you think these changes are happening?

3) Are these changes in climate/weather seasonal fluctuations or progressive change and how can you tell?

4) What aspects of the environment are changing the most? (plant or animal species, or landscapes, etc.)

5) Cultural Keystone Species, Pacific crabapple
    a. How do you use crabapples? (Food, trade, cultivation (orchards) traditional stories, ceremonial uses, landscape management, technology, medicine, etc…)
    b. Do you take care of crabapple trees/places? How?
    c. Are crabapples changing their distribution?
        i. Increasing of disappearing?

ii. Why? (not picked, water rising (only salt, or salt and amount of water), lots rain)
iii. Where?
iv. Do you recognize more than one kind? If so, have you noticed any differences to how they tolerate changes?
v. How have the distributions changed?
vi. How has the abundance changed?
vii. How have the uses changed? (importance, extent, distribution)
viii. Are there changes to the amounts being harvested? If so, is this because there is less gathering in general, or because crabapple distributions are declining?
    1. If less gathering, why?
ix. What are the indications of when you can harvest crabapples (phenological indicators)? Have these indicators or the timing of these indicators changed?

d. What animals eat and live around crabapples?
e. Besides food, how else are crabapples important? (Ecological roles)
f. What are the connections between crabapples and other plants and animals and the landscape?
    i. Have these connections changed?
    ii. How do the changing distributions change animals and other plants?
    iii. How have changes in distribution/abundance, etc changed the landscape?
g. Are there places you know of that are named after crabapples?
    i. What are they?
    ii. Where are they?
    iii. Why are they?
h. Is your relationship to crabapples changing with the climate changes?
i. Do you think crabapples could be considered indicators of change (on the forefront)?
j. Can you point out any areas where change has occurred to crabapples on the map?

6) How have these changes in the general climate affected the makeup of the landscape? (e.g. slides, flooding, etc.)

7) Have these changes affected how you move around your territory for travel, subsistence, and so on, and how have your patterns changed?

8) How have harvesting cycles changed
    a. The plant and animal species you harvest? (what people are eating now- eating different things or quantities now because of weather change, or in general)
    b. Distribution of these species over time?

c. Abundance of these species over time?
d. Growth patterns of these species over time?
e. Access and ability to harvest food?
f. Ability to process food?
g. The timing of when you harvest, process and store food? (earlier or later)
    i. If it's changed, how does it sync up with the seasonal round or calendar (names for resources in seasons)
h. Do you have to travel further to get stuff now?

9) Can you give me any specific examples you can think of with locations (slumps, flooding, rotting/unripe berries, changes in animal patterns/species)

10) Can you give me any exact numbers of change? (tide height rise, amount of rainfall, etc.)

11) Can you point out these areas of change of a map?

12) Connections
   a. Which resource is the most affected/shows the most changes/is the most impacted
   b. Does this resource affect other species? In what way? Affect patterns of harvesting, processing, etc
   c. Have you noticed new species appear? (NOTE: Sea otters were reintroduced on purpose – not changing climate)
      i. Totally new, or just out of season?
      ii. When did they appear?
   d. Have any declined/disappeared? When?

13) Ecosystem Services/Reciprocity
   a. What benefits or resources do you get from the ecosystems of estuaries and rivers as a whole? (food, water)
   b. how do you take care of these resources? Do you see yourself as giving back to them?
   c. Are there ceremonies around proper protocol for harvesting, care of the environment, etc to ensure respect and continuity of resources?
   d. Are there prescriptions or prohibitions associated with harvesting practices?
   e. Are there old sayings, ceremonies, taboos, about how to care for the land?

14) Timescale of environmental change
   a. How fast are events happening?

b. Have there been one or more big events (tidal waves, ferry sinking) or all gradual?
c. Do you think the changing weather has decreased food harvesting more than would happen normally? Is it harder to navigate?
d. How is your life personally changing because of these changes?
e. How has your diet changed? Is this only because of climate change?
f. Are young people carrying on the traditions? Is this because of the climate change not allowing them to harvest, or because they are doing other things? If not, how do you think not harvesting food will affect future generations?

15) Adaptation to environmental change

a. How have you adapted to changes in the past in your lifetime?
b. How have people adapted to changes from your grandparents time? What have they told you about changing?
c. Do you see these adaptations working now? And into the future?
d. Are there stories or legends about change in the far distant past (lack of food or starvation, floods, clan migrations, mountains moving)

16) Policy

a. Have you talked to anyone else about these changes? (Particularly state/provincial/federal or tribal governments)? If so, have they listened to you?
b. Have any policy changes happened (state or federal laws) that compensate for climate change, and take in account local indigenous knowledge, to your knowledge?
c. Is there any management here (locally) that takes TEK into account?
d. Do you feel your knowledge of changes are taken into consideration by policy makers?
e. Is other peoples ‘indigenous knowledge taken into consideration?
f. How do you want your knowledge recognized?

Appendix 4a. Named Interview participants

Wished to be identified with their observations, highlighted in light green denotes married couples. * (in tables Appendix 4a and 4b) indicates a group interview in Skidegate.

Initials	Name	Community	Gender	Age/ age range
DA	Doris Auckland	Metlakatla, BC	Female	93
LB	Lionel Bean	Kake, AK	Male	-
NB	Nancy Bean	Kake, AK	Female	-
AB	Arnie Bellis	Old Massett, BC	Male	61
LB	Lorna Berekoff	Skidegate, BC	Female	-
CB	Catherine J. Bolton	Hoonah, AK	Female	30s-40s
DB	Donald W Bolton	Hoonah, AK	Male	30s-40s
DBr	Diane Brown	Skidegate, BC	Female	-
RB	William R (Robin) Brown	Old Massett, BC	Male	81
WB	Wilbur G. Brown, Sr.	Kake, AK	Male	81
AC	Anthony Christianson	Hydaburg, AK	Male	37
DC	Delores Churchill	Ketchikan, AK; family from Old Massett, BC (and interviewed there)	Female	-
HC	Helen Clifton	Hartley Bay, BC	Female	80s
ACo	Alma P. Cook	Klawock, AK	Female	90
WC	Wanda J. Culp	Hoonah, AK	Female	66
RD	Reg Davidson	Old Massett, BC	Male	60
GD	George L. Davis	Juneau, AK (originally from Kake)	Male	-
AD	Agnes Davis	Juneau, AK (originally from Kake)	Female	-
JD	June Degnan	Juneau, AK	Female	-
SD	Sherri Dick	Old Massett, BC	Female	56
GE	Gwaii Edenshaw	Old Massett, BC	Male	-
ME	Margaret Edgars	Old Massett, BC	Female	-
LG	Leo Gagnon	Old Massett, BC	Male	-
CG	Captain Gold [Richard Solomon Wilson]	Skidegate, BC	Male	-
KG	Kenneth J. Grant	Hoonah, AK	Male	Over 70
AG	Adam Greenwald	Hoonah, AK	Male	87
EG	Ester Greenwald	Hoonah, AK	Female	-
LKG	Lori Kay Guinard	Hoonah, AK	Female	52
MG	Mary E. Guthrie	Klawock, AK	Female	65
FH	Fred Hamilton	Craig, AK	Male	-
EHA	Earnestine Hanlon Abel	Hoonah, AK	Female	-
MH	Merle Nancy Hawkins	Ketchikan, AK	Female	55
CJ	Charles Jack Jr.	Hoonah, BC	Male	-
JJ	Joel Jackson	Kake, AK	Male	58
MJ	Michael Jackson	Kake, AK	Male	60
OJ	Owen James	Hoonah, AK	Male	-

MJo	Marlene Johnson	Juneau, AK (originally from Hoonah)	Female	-
CJo	Cliff Johnson	Juneau, AK	Male	-
SJ	Sphenia Jones	Old Massett, BC	Female	
CoJo	Cora Joseph	Klawock, AK	Female	71
EK	Evans Kadake	Kake, AK	Male	78
MK	Marvin Kadake	Kake, AK	Male	-
EKa	Ernestine Kato	Klawock, AK	Female	75
VLC	Vickie Le Cornu	Hydaburg, AK	Female	-
JL	Jack Litrell	Old Massett, BC	Male	-
HM	Harold Martin	Juneau, AK (originally from Kake)	Male	80
JM	Jacque Martin	Juneau, AK (originally from Kake)	Female	-
JMa	James Martinez	Klawock, AK	Male	81
AM	Alice Montjoy	Old Massett, BC	Female	-
JMo	John Morris	Juneau, AK	Male	
CN	Charles N. Natkong	Hydaburg, AK	Male	-
FN	Fanny Nelson	Metlakatla, BC	Female	-
RN	Robert Nelson	Metlakatla, BC	Male	-
MOl	Marie Olson	Juneau, AK	Female	-
MO	Margaret O’Neil	Hydaburg, AK	Female	61
TP	Theodore O. Peale	Hydaburg, AK	Male	54
PP	Pearle Pearson*	Skidegate, BC	Female	-
OP	Olive Pollard	Skidegate, BC	Female	-
BR	Betty Richardson	Skidegate, BC	Female	-
CR	Crystal Robinson	Old Massett, BC	Female	-
JR	June Russ	Old Massett, BC	Female	-
MR	May Russ	Old Massett, BC	Female	-
TR	Teresa Russ	Old Massett, BC	Female	-
CRy1	Charlene Ryan	Metlakatla, BC	Female	-
CRy2	Clifford Ryan	Metlakatla, BC	Male	-
LS	Larry Sanders	Hoonah, AK	Male	-
FS	Frances Sanderson	Hydaburg, AK	Female	86
RS	Robert Sanderson	Hydaburg, AK	Male	79
MES	Mary Ellen Skinna	Klawock, AK	Female	-
MS	Mary Swanson	Old Massett, BC	Female	-
GW	Geraldine P. Wallace	Hoonah, AK	Female	-
EW	Emily Watts	Old Massett, BC	Female	-
SW	Sandra (Cindy) Williams	Skidegate, BC	Female	-
HWi	Harriet Williams	Kake, AK	Female	84
HW	Harvey Williams	Skidegate, BC	Male	-
RW	Rolly Williams	Old Massett, BC	Male	53
MY	Myrna Yates	Craig, AK	Female	-
CY	Carol Young*	Skidegate, BC	Female	-

Appendix 4b. Anonymous Interview participants

Initials	Name	Community	Gender	Age/ age range
A1		Old Massett, BC	Male	-
A2		Old Massett, BC	Male	-
A3		Skidegate, BC	Male	-
A4		Hoonah, AK	Female	-
A5	*	Skidegate, BC	Female	50s
A6		Old Massett, BC	Female	25
A7		Old Massett, BC	Female	-
A8		Ketchikan, AK	Male	-
A9		Juneau, AK (originally from Kake)	Male	-
A10		Hoonah, AK	Female	72
A11		Kake, AK	Female	77
A12		Hoonah, AK	Male	-
A13		Juneau, AK	Female	-
A14		Old Massett, BC	Female	-
A15		Old Massett, BC	Male	-

Appendix 4c. Interview participants that worked for governmental organisations.

Initials	Name	Location	Agency
TF	TerryLee Fiske	Hoonah, AK	US Forest Service
LK	Linda Kruger	Juneau, AK	US Forest Service
MBM	Mary Beth Moss	Hoonah, AK	US Forest Service