Risk and Toolkit Structure in the Pacific Northwest

by

Alexander Allan

B.A. (Hons.), Simon Fraser University, 2015

Thesis Submitted in Partial Fulfillment of the
Requirements for the Degree of
Master of Arts

in the
Department of Archaeology
Faculty of Environment

SIMON FRASER UNIVERSITY
Summer 2019

Approval

Name:	**Alexander Allan**
Degree:	**Master of Arts**
Title:	**Risk and Toolkit Structure in the Pacific Northwest**
Examining Committee:	**Chair:** **Rudy Reimer** Associate Professor
	Mark Collard Senior Supervisor Professor
	Dennis Sandgathe Supervisor Lecturer
	Jon Driver External Examiner Professor
Date Defended/Approved:	July 3rd, 2019

Abstract

Identifying the factors that drive the variation in technological complexity among traditional societies is important for understanding human evolution. With respect to hunter-gatherers, the leading hypothesis focuses on environmental risk. It argues that risk affects toolkit complexity in such a way that high-risk environments lead to complex toolkits while low-risk environments result in the opposite. This hypothesis has been supported in analyses involving worldwide and continental samples of hunter-gatherers. However, Collard et al.'s (2011) test of the hypothesis using data from the Pacific Northwest failed to support it. For my thesis research I revisited Collard et al.'s study and sought to determine why their results departed from those of the worldwide and continental studies. My study had two parts. In the first, I replicated Collard et al.'s (2011) analyses with a larger dataset. The results of the analyses were largely consistent with those obtained by Collard et al. (2011): I found that the toolkits of the Coast and Plateau were not significantly different despite clear risk-relevant environmental differences between the sub-regions. However, I also found a significant positive correlation between some toolkit variables and the number of salmon species, which is not consistent with the risk hypothesis. In the second part of the study, I approached the evaluation of the risk hypothesis from a different direction. Specifically, I examined the correlation between the average complexity of the tools used to hunt a given species and estimates of the risk involved in capturing that species. I found that species that are difficult to capture and/or have restricted seasonal availability are associated with more complex tools, which is consistent with the risk hypothesis. I conclude from these two sets of results that commonly-used environmental variables like Net Primary Productivity and Effective Temperature are too coarse to accurately characterize the impact of risk on the toolkits of hunter-gatherers at a regional level. I also conclude that the richness and complexity of the toolkits of hunter-gatherers in the Pacific Northwest are not solely affected by risk. Other variables are important and require further investigation.

Keywords: Toolkit structure; Pacific Northwest; environmental risk; subsistence practices; technology

Dedicated to Dr. James Venart.

Acknowledgements

Many individuals and organizations have contributed to making this work a reality. First, and foremost, I would like to thank my supervisor Dr. Mark Collard. From the initial framing of the project through to the end Mark has been a vital resource and provided essential feedback at every turn. I'd also like to thank my other committee member Dr. Dennis Sandgathe for being so invested in this project from the beginning and always contributing valuable insights at meetings.

Outside of my committee there are many people who have assisted me in making it this far. In particular, Dr. Rudy Reimer and Thomas Royle were extremely generous with their time and expertise, helping along key aspects of this study. I'd also like to thank Rick A. Hoffman, John Spangler, Ed L. Jones, and Allan Scholz for generously responding to inquiries for data/expertise. Additionally, every member of my graduate cohort should be thanked for their support and for providing important feedback in the early stages of this project.

Finally, several organizations provided financial support over the course of this research. They include the Human Evolutionary Studies Program at Simon Fraser University, the Social Sciences and Humanities Research Council of Canada, as well as the Department of Archaeology at Simon Fraser University.

Table of Contents

List of Tables

List of Figures

Chapter 1.

Introduction

1.1. The Problem

Traditional, non-industrial societies differ markedly in the number and complexity of the tools they create and use. Some societies are capable of surviving with a small number of relatively simple tools, while others make use of numerous highly complex tools. Currently, the factors that drive this variation are the subject of considerable debate (Henrich 2004, 2006; Collard et al 2005, 2013, 2016; Read 2008; Powell et al. 2009; Fogarty and Creanza 2017)

Several hypotheses have been put forward to explain the cross-cultural variation in technological richness and complexity among traditional societies, but in the last few years attention has focused on two of them: the risk hypothesis and the population size hypothesis. The risk hypothesis focuses on the environmental context in which populations employ their technology. It argues that more extreme environments, where failure to capture resources is costlier, are likely to result in richer and more complex toolkits. In contrast, the population size hypothesis concentrates on the total number of individuals within a population that help maintain and develop technology. Skilled individuals, who are more likely to be present in larger populations, aid the population as a whole by maintaining complex technologies and creating improved versions of existing technology. Assuming that these successful individuals are subsequently copied by others in the population, through time larger communities are more capable of cumulative cultural evolution while smaller populations are more likely to suffer from maladaptive loss.

These hypotheses have both stimulated a considerable amount of research. While they are not explicitly mutually exclusive there is significant debate about the exact conditions under which either hypothesis best explains the available data. Empirical evaluations of the risk and population hypotheses using subsistence related technology have resulted in an interesting pattern. The variation in the toolkits of populations that rely on wild resources for the majority of their food are best explained by the risk hypothesis,

whereas the variation in the toolkits of predominantly agricultural populations are best explained by the population hypothesis (Collard et al. 2011b; Fogarty and Creanza 2017). This pattern has held for all ethnographic and archaeological case-studies of toolkit structure in food gathering populations, except for one case.

Nearly a decade ago Collard et al. (2011a) tested the risk hypothesis with data from a regional sample of populations living in the Pacific Northwest of North America. Specifically, they compared the subsistence toolkits of the Pacific Northwest's two major cultural areas, the Coast and the Plateau. The environmental variables Collard et al. (2011a) examined suggested that there are significant differences in risk between the Coast and Plateau, but they found no difference in the average complexity of the toolkits of the populations in the two subregions. This dataset was reanalysed by Collard et al. (2013b) using a different analytical approach but the basic result did not change: they did not find the predicted positive association between toolkit structure and proxies for environmental risk.

There are two obvious potential explanations for the fact that Collard et al.'s (2011a, 2013b) results diverged from the results of other studies that have examined the drivers of technological variation in hunter-gatherers. One possibility is that Collard et al. (2011, 2013b) failed to account for environmental risk adequately. The other is that risk is not the primary driving factor in toolkit structure in the Pacific Northwest. If risk is not the driving factor, it could be due to the smaller regional scale of the analyses or that other factors, like population size, have a stronger influence over toolkit structure in the Pacific Northwest than in other food-gathering populations (Collard et al. 2011a).

By determining which of these possibilities is more accurate I aim to build upon the existing theories of toolkit structure by offering a more detailed evaluation of what risk consists of and how technology is adapted in response to it. Here, I report a two-part study in which I attempted to ascertain which of the foregoing explanations is correct. In the first part of the study, I replicated Collard et al.'s (2011a, 2013b) analyses of the toolkits of Coast and Plateau populations with new and expanded dataset. In the second part of the study, I used the dataset to evaluate the risk hypothesis in a novel manner. While previous studies have focused exclusively on comparing the toolkits of populations, I utilized specific data on which species each tool was used to obtain to gain average tool richness and complexity associated with species across the Pacific

Northwest region as a whole. This framing offers a new perspective on toolkit structure. Since the risk involved in the capture of an individual species is more easily estimated than that of an environment more broadly I was able to investigate how accurate our risk proxy measurements were.

The rest of this chapter sets up the current state of the debate about the drivers of variation in toolkit structure. First, I outline the key terms that have been used in recent work on toolkit structure. Next, I review the various hypotheses that have been proposed to explain the variation in the richness and complexity of traditional toolkits. This is followed by a detailed exploration of the more recent theoretical debates surrounding toolkit structure as well as the numerous empirical studies that have tested the various hypotheses to varying degrees of success. With this foundational background established, I then provide a detailed description of the past studies of the Pacific Northwest as a region that have not supported the risk hypothesis. Encompassed in this is also a sketch of the two distinct areas of the Pacific Northwest: the Coast and the Plateau. This leads to the final section of the chapter in which I outline the goals of this particular study.

The remainder of the thesis reflects the two-part structure of the study. In Chapter Two I present the methods and results of the first set of analyses by which I recreated the analyses used by Collard et al. (2011a) with additional data. In Chapter Three I utilised the species specific data to evaluate how we estimated environmental risk in the second chapter. Chapter Four offers a general discussion of the findings and significance of the study, as well as suggestions for future research. Lastly, in Chapter Five, I summarize the conclusions I draw from the results of my thesis research.

1.2. Methods of Toolkit Quantification

Quantifying the technology of small-scale societies was pioneered by the well-known American anthropologist Wendel Oswalt (1973, 1976). To maximize the utility of cross-cultural comparison, Oswalt constrained his technological studies to tools that were used in the direct acquisition of food resources. He referred to these as “subsistants,” and referred to the set of subsistants used by a group as its “toolkit.” In his subsequent studies of subsistants Oswalt provided the theoretical and methodological foundations

for the cross-cultural comparison of subsistence technology—namely: a typology of subsistant types, and several variables for quantifying toolkit richness and complexity.

The typology proposed by Oswalt divides subsistants into four categories: 1) instruments, 2) weapons, 3) tended facilities, and 4) untended facilities. Instruments are hand-held tools used in the acquisition of resources incapable of significant evasive movement and that are generally harmless to people. The most obvious example of an instrument is a digging stick. Weapons consist of hand-held tools that are “designed to kill or maim species capable of significant motion” (Oswalt 1976:79). Examples of a weapon would be a harpoon or a bow and arrow. Facilities are forms that control or constrain the movement of a species to the benefit of humans. They can either require the presence of a human actor to function, and are thus “tended”, or they can be functional without direct human involvement and are therefore “untended”. An example of a tended facility is a corral into which deer are driven, while a deadfall trap is an example of an untended facility.

In order to quantify the complexity of individual subsistants and overall toolkits an additional concept is necessary: the technounit. A technounit is an “integrated, physically distinct, and unique structural configuration that contributes to the form of a finished artifact” (Oswalt 1976:38). Put more simply, technounits are the individual component parts of a subsistant.

Using subsistants and technounits as foundational units, Oswalt proposed three variables that allow for the quantification of toolkit structure: Total Number of Subsistants (STS), Total Number of Technounits (TTS), and the Average Number of Technounits per Subsistant (AVE). STS is the total number of unique individual tools used in the acquisition of food resources (Torrence 1983, 1989, 2000; Shott 1986). As such, it is a measure of the richness of a group’s subsistence toolkit. TTS and AVE attempt to capture the complexity of the toolkit. TTS is defined as the total number of component parts in the entire toolkit, while AVE is the average number of components per tool in a given toolkit (Oswalt 1976; Torrence 1983, 1989, 2000).

Recently Henrich (2006) proposed an additional toolkit variable. This new variable incorporates the tool typology categories—the sum of the technounit counts for the most complex instrument, weapon, tended facility, and untended facility in a toolkit (MXT). By

limiting the scope of the variable, MXT allows us to analyze and compare only the most complex elements of toolkits cross-culturally.

1.3. Hypotheses to Explain Cross-Cultural Variation in Toolkit Structure

Research on the causes of the cross-cultural variation in toolkit richness and complexity has focused on four main hypotheses: 1) the nature of resources exploited, 2) risk of resource failure, 3) residential mobility, and 4) population size. The first hypothesis, nature of resources exploited, was proposed by Oswalt (1973, 1976), following an analysis of the subsistence toolkits of a worldwide sample of 20 hunter-gatherer populations. Oswalt's (1973, 1976) hypothesis focuses on the degree of reliance on mobile resources. He reasoned that because resources with higher degrees of mobility are more difficult to capture, reliance on them will necessitate use of more complex tools. These differences in mobility are also magnified in the degree of reliance on aquatic resources, with populations more reliant on aquatic resources having a higher toolkit complexity than populations that primarily hunted terrestrial animals (Oswalt 1976:192). This distinction between terrestrial and marine animals was later highlighted by Osborn (1999) who argued that understanding the organizational demands of terrestrial and marine hunting was critical to understanding patterns in toolkit structure.

The risk hypothesis was developed by Torrence (1983). Initially Torrence framed her hypothesis in terms of time stress, theorizing that as time stress increased hunter-gatherers could be expected to develop more specialised tools because such tools are on average more effective than generalized ones. Because specialized tools also usually have more component parts than generalized tools, toolkit richness and complexity can be expected to increase. Using latitude as a proxy for time stress, Torrence tested the hypothesis on the same sample of 20 hunter-gatherer populations used by Oswalt (1976). Torrence found a significant positive correlation between toolkit richness and complexity on the one hand, and latitude on the other. Torrence argued that this correlation reflected a decrease in the number of edible plants as latitude increased. This leads to an increased reliance on animal resources that increases pursuit time due to their greater mobility (Torrence 1983).

In subsequent publications Torrence (1989, 2000) converted the time stress hypothesis into one based on risk of resource failure. She defined risk as “the effects of stochastic variation in the outcome associated with some behaviour” (Torrence 1989:59). Using this definition Torrence (1989) argued that time stress was only a proximate cause of variation in toolkit structure. Instead, the driving factor in toolkit structure was the potential costs of failing to meet dietary requirements. This potential cost of failure fluctuates largely based on environmental conditions (Torrence 2000). Most pertinent to subsistence activities are conditions that influence the availability of food resources. Resource availability varies depending on environmental conditions which can be divided into three dimensions: temporal variation, spatial variation, and mobility. The first two simply reflect a resource’s distribution patterns in a given landscape, whereas mobility reflects attributes of the resource itself and how likely it is to avoid capture through evasive action. For Torrence (1989), risk arises with a higher degree of dependency on highly mobile resources and/or those that are available for limited durations of time seasonally, conditions more typical of high latitude areas. The notion of risk as the driving factor in toolkit structure as well as a composite variable reflecting multiple ecological factors relating to seasonality is central to the risk hypothesis. In response to a high environmental risk where the potential fitness cost of failure to capture a given resource is high, the risk hypothesis predicts that populations are more likely to develop richer and more complexity toolkits (Torrence 1989).

Residential mobility has also been proposed as a major limiting factor on toolkit richness, through the imposition of carrying costs. Shott (1986) argued that the richness and complexity of subsistants cannot increase indefinitely in order to meet the functional demands of a given cultural context without a simultaneous increase in the ability to carry tools. These potential carrying costs are argued to have constraining effects on toolkits, with populations that move frequently and/or over long distances expected to possess less rich toolkits than those that move less frequently. With higher mobility limiting the potential richness of a toolkit, Shott (1986) theorized that such toolkits would be characterized by more generalized tools, resulting in lower average tool complexity.

Population size was developed as an explanatory model for toolkit structure independently by Shennan (2001) and Henrich (2004). In both cases it was the result of cultural evolutionary models that treated cultural transmission, or the passing on of cultural traits, as being comparable to genetic transmission. This process of cultural

transmission can then be subject to selective pressures if the acquired trait increases the reproductive fitness of those adopting it, or if the adopters of cultural traits are actively choosing to imitate ‘successful’ cultural traits present in the existing population.

Shennan (2001) offered two models of population size’s impact on cultural evolution, one based on haploid transmission (from one parent to one offspring), and the other on both haploid transmission and oblique transmission (from adults other than parents to offspring). In both models, during the transmission process innovations occur that can be either beneficial or deleterious. These innovations then influence the fitness of the receiving individual and thus its capacity to pass on its traits. Shennan (2001) found that in both the simple parent-offspring model and the modified oblique transmission model larger populations had a major advantage over smaller ones. Due to the smaller pool of possible imitators, smaller populations are more likely to maintain innovations that are less beneficial, whereas larger populations are much less vulnerable to deleterious sampling effects.

Henrich (2004) developed a model of cumulative cultural adaptation using slightly modified transmission mechanisms. Each individual in a given population has a skill level representing how proficient they are at a given task. Subsequent generations then learn the skill from the most-skilled member of the population, but the learning process is subject to error and not all individuals are equally capable of learning. In the model the success of the learning process depends on the drawing of a random number from a normal, Gumbel or logistic probability distribution which is centred on the mean/mode copy error. It is here that the population size and the complexity of the learned skill become central.

Henrich (2004) defines population size as all possible individuals that a given individual might interact with, which may extend beyond a narrowly defined ‘society’ population. According to Henrich’s (2004) model, the larger the population, the faster adaptive evolution proceeds. Larger populations, by the simple fact of having more learners, will be more likely to draw a number from the far right of the distribution and therefore either match or exceed the skill level of the parent generation. Smaller populations, without many learners will be less likely to match the skill of the parent generation. Subsequently, over multiple generations, a smaller population may suffer from skill decline reflected in lower cultural complexity.

The complexity of the learned skill remains important because more complex skills require a higher threshold of skill to be maintained within a population. This makes the maintenance of complex skills more difficult than simple skills so that after a hypothetical reduction in population size complex skills will be lost at a faster rate than simple ones.

The population hypothesis, thanks to Shennan's (2001) and Henrich's (2004) models has proven to be influential. Population size has been proposed as the driving factor in explaining a wide ranging of archaeologically observed phenomena. For example the advent of behavioural modernity in Africa, Eurasia, and Australia (Shennan 2001; Brumm and Moore 2005; James and Petraglia 2005; Powell et al. 2009; Langley et al. 2011), the loss of technology like the bow-and-arrow in Northern Europe during the LGM (Riede 2008; Dev and Riede 2012), or long-term material cultural stability during the Acheulian, Middle Palaeolithic, and Middle Stone Age (Premo and Kuhn 2010; Hopkinson et al. 2013).

Additionally, a series of additional models have been published offering either extensions of the Henrich model (Powell et al. 2009; Mesoudi 2011; Kobayashi and Aoki 2012; Nakahashi 2014) or new additional models (Premo and Kuhn 2010; Grove 2016; Fogarty and Creanza 2017). Of those models that serve as extensions to Henrich's (2004) model, Powell et al. (2009) is the most significant. Powell et al. (2009) altered the original model in two significant ways: a two-stage cultural transmission process, and a metapopulation aspect including subpopulations. The two-stage cultural transmission process involved an initial phase with offspring learning from their same-sex parent before a second stage where they could improve their skill level by selecting another cultural parent later in life and update their skill level if the new cultural parent has a higher skill value. The inclusion of subpopulations allows for the modeling of extended transmission between separate groups, something that was not considered in the single, unstructured population in Henrich's (2004) model. These changes resulted in similar results in terms of the transmission process and population size to Henrich (2004) as well as the significant finding that migration has the same effect as increasing the size of a single isolated population.

Grove (2016) found a similar relationship between mobility and population size with simulations based on the ideal gas model. In this model encounter rate was argued to be the key variable in determining cultural complexity, of which population density and

mobility are simply proxies for. Additional models from Premo and Kuhn (2010); and Fogarty and Creanza (2017) have begun to factor in environmental influences with agent-based models showing the potential influence of local extinctions and cultural niche construction.

1.4. Testing the Hypotheses

Following the popularisation of the population hypothesis, academic debate about the evolution of traditional technology has primarily focused on the risk and population hypotheses. The population hypothesis has been criticized in relation to the underlying assumptions involved in the models used by Henrich (2004) and others. Additionally, attempts to test the hypotheses using empirical experimental, archaeological, and ethnographic data have offered insights into what drives toolkit structure. I will first deal with the theoretical criticisms of the population hypothesis models before turning my attention to the empirical tests.

First, a major criticism of Henrich (2004) stems from its interpretation of indigenous Tasmanian culture. Henrich (2004) offers an interpretation of the perceived loss of cultural complexity in the case of the societies of Tasmania following its isolation from the Australian mainland at the end of the last glacial epoch. With the loss of cultural exchange between Tasmanians and those in Southern Australia, Henrich argues, the effective population size was lowered considerably, and so more complex technologies could not be maintained and were lost over time while more simple tools were maintained. Yet these interpretations of the Tasmania archaeological record have been contested and are given no sound empirical support in the paper itself. There is little to no support for a reduction over time in the complexity of Tasmanian tools or for their toolkit being uniquely small compared to other Australian aboriginal populations (Collard et al. 2016:4-5). The few cases of tool type loss have been argued to be better explained by adaptation to the changing climatic landscape during the Holocene (Read 2006:171-173).

More broadly, theoretical criticisms have focused primarily on three aspects of Henrich's (2004) model: the mechanism of cultural transmission, how the model treats skill level, and unrealistic parameter values. Henrich's (2004) model makes several important assumptions about how cultural transmission occurs and how that process changes as

population size changes. The foundational assumptions in Henrich's (2004) model concerning transmission are that the most skilled, or close to the most skilled, individuals can be both successfully identified and copied by a given imitator within the population. Read (2006) has pointed out that the critical aspect of these assumptions is that they necessitate that the pool of possible models from which the imitator is selecting increases with overall population size. However, if one assumes that each imitator only has access to individuals within the circle of those with whom they regularly interact then that circle does not necessarily have to expand if the overall population of the entire society expands. In Henrich's (2004) model it is not clear how one would navigate identifying and imitating the most skilled individual in a population of several thousand or more.

This angle of criticism is further explored in Vaesen et al. (2016) where the authors argue that Henrich's (2004) original model ignores alternative types of transmission, and when these alternative models are included the observed relationship between population size and cultural complexity is reduced or disappears entirely. These arguments are largely based on separate modeling work done by Vaesen (2012) which show that under conformist transmission (i.e. copying the most common behaviour) and vertical transmission (i.e. copying from a same-sex parent) there is no association between population size and skillfulness. Additionally, unbiased transmission (i.e. random copying) only produces a relationship between skillfulness and population size in a specific range. These criticisms of Henrich's (2004) model are particularly compelling when you take into consideration the breadth of ethnographic data indicating considerable variation in type of transmission in small-scale societies. Most relevant ethnographic evidence indicates the dominance of either vertical transmission (e.g. Hewlett and Cavalli-Sforza 1986; Ohmagari and Berkes 1997; Hattori 2007; Boyette 2013) or some combination of vertical transmission in early childhood and horizontal and/or oblique transmission playing a larger role later in childhood/adolescence (e.g. Aunger 2000; Macdonald 2007; Tehrani and Collard 2009; Demps et al. 2012; Kline et al. 2013). With a wide range of diversity of transmission models in known populations, drawing conclusions based on assumed transmission models is problematic. Without clear evidence of imitators in hunter-gatherer groups choosing the most-skilled as models, the assumptions concerning cultural transmission in Henrich's (2004) model remain tenuous.

Critics of Henrich's (2004) model of population size and complexity have also focused on how the model treats skill and task performance. In both Read (2006) and Vaesen et al. (2016) the authors argue that Henrich's model incorrectly treats skill as a fixed value. This is inconsistent with what is known about how repeated practice influences skill over time (Ericsson and Chamess 1994). Additionally, Read (2006) has teased apart the concept of task performance into its component parts. The knowledge needed to do a task, as well as the transmission of this knowledge, does not necessitate the actual motor skills required to do the task. One can have the knowledge of a task, and pass that knowledge on, without having the motor skills to do the task themselves, which does not seem to be considered in Henrich's (2004) model as a possibility.

Lastly, Read (2006) has questioned the parameter values that were chosen by Henrich (2004) to represent the "lower bound" of skill level that would be required for the maintenance of a skill. These values are very important as they produce the key predictive aspect of Henrich's (2004) model regarding the influence of population size on maintaining cultural complexity. However, the values he chose are unrealistically high which results in overestimating the population size that would be required to maintain a particular skill over generations. Instead Read (2006) offers an alternative method for determining the parameter values based on percentiles. When these more realistic figures are used, it appears that almost any hunter-gatherer group of around 20-30 individuals would have individuals present that would be capable of skill level high enough to maintain even the most complex of tools and tasks.

Now moving beyond theoretical criticisms of the population hypothesis, most debate surrounding the factors influencing cultural and technological complexity have focused on empirical tests of the varying hypotheses. Notably within this debate the most common criticism of the continuing use of the population size hypothesis to explain observed changes in cultural complexity is a lack of consistently demonstrated empirical support. This is particularly true when applying the population size hypothesis as an explanatory model for hunter-gatherer populations (Read 2006; Collard et al. 2013a, 2016; Vaesen et al. 2016). To survey the current shape of this ongoing debate I will organise my review into three types of study: experimental studies, cross-cultural ethnographic studies, and archaeological studies.

Laboratory experiments have offered an avenue of testing hypotheses of technological and cultural complexity by controlling for and isolating variables of interest. At this point this avenue remains relatively unexplored, particularly since the existing experimental studies have only tested the population size hypothesis without the inclusion of additional hypotheses. Experiments on the influence of demographics on cultural complexity has yielded some informative, albeit inconclusive, results. For example, access to more demonstrators or examples have helped maintain and increase cultural complexity in certain contexts (Kempe and Mesoudi 2014; Muthukrishna et al. 2014), while being a member of a larger group made cultural deterioration less likely and technological improvements more frequent (Derex et al. 2013).

Despite these findings not all experimental studies have supported the positive correlation between demographic size and cultural complexity. In the context of technological adaptation, studies tracking the transmission of paper airplane design across multiple generations found that despite larger populations having more variance there was no cumulative advantage (in terms of distance flown) for larger cohort sizes (Caldwell and Millen 2010; Fay et al. 2019). This suggests that access to a large number of potential models may in some cases overwhelm an individual's working memory, resulting in more difficulty selectively copying successful models. Similarly, an analyses of complexity in folktales found no clear relationship between population size, suggesting that the relationship between demographics and cultural complexity may be domain dependent (Acerbi et al. 2017). Together these experiments suggest that the relationship between demographics and cultural complexity are not straightforward.

The results of archaeological and ethnographic tests of the hypotheses fit into a relatively simple pattern. A clear difference between studies of food-producing populations and those of food-gathering populations in regards to which hypothesis is best supported by the available evidence. I will begin with a survey of the data relating to food-producers before moving on to food-gatherers.

Food producers are typically defined as populations that derive a majority of their food from pastoralism, horticulture, or intensive agriculture (Collard et al. 2011b). This method of categorization allows for a wide purview when testing potential influences on cultural complexity from small scale farmers to post-industrial advanced economies. Studies concerning the latter have linked increased "innovation rate" as measured by patents-

per-capita with both employment density and metropolitan population in surveys of metropolitan areas in the United States of America (Bettencourt et al. 2007; Carlino et al. 2007).

In studies of small-scale food producing populations results have been similarly supportive of the population size hypothesis. Kline and Boyd (2010) tested the population hypothesis using data from Oceania. They argued that previous studies had used population data without accounting for the potential influence of inter-group contact. Based on the modelling of Powell et al. (2009) inter-group contact should be an important factor in driving technological complexity and is not captured in population figures of individual groups alone. To remedy this, their study used data from ten Oceanic small-scale food-producing cultures that included both population size and contact rate. Because Oceania is composed on many small and isolated islands, contact rate was a more feasible variable to include. Technological complexity was measured through the number and complexity of marine foraging tools. Kline and Boyd (2010) found that population size had a significant impact on technological richness and complexity, even when controlling for environmental risk and ethnographic research intensity.

Two other studies (Collard et al. 2011b, 2013b) tested both the population size and risk hypotheses. Using global samples of 45 and 40 small-scale food-producers respectively, the studies found that population size (as collected from the Human Relations Area Files) significantly correlated with both toolkit richness and complexity.

While most research of cultural complexity in food producing populations has supported the population size hypothesis, some archaeological research has offered an alternative perspective on population size's role in social complexity. Nelson et al. (2011) studied changes in cultural diversity of pottery styles over the course of seven centuries across four regions of the American Southwest. Interestingly, the study produced results that indicate that high population densities can limit cultural diversity. The authors suggested that this was likely due to the pressures of social conformity.

I will now shift focus to what previous studies have found in relation to food-gatherers and technological complexity. In a study of 20 global hunter-gatherer populations Collard et al. (2005) tested all four of the hypotheses and found a correlation with environmental

risk, represented by the proxy measurement of effective temperature (ET). Evaluating the same sample of hunter-gatherers Read (2008) found support for another proxy measurement for environmental risk, the length of growing season (GS), along with some influence of residential mobility.

More recent studies have tested the hypotheses further, particularly the risk and population hypotheses, by increasing the number of populations studied. In studies of 34 global populations (Collard et al. 2011b), 85 Western North American populations (Collard et al. 2013b), and 49 global populations (Collard et al. 2013a) the risk hypothesis was further supported through correlations between various proxies of environmental risk (Latitude, ET, mean rainfall during driest month, and mean rainfall during wettest month) and technological richness and complexity. Notably, none of these studies found evidence supporting the population size hypothesis for food-gathering populations.

Outside of ethnographic studies, there have been some archaeological studies of past food-gathering populations that have purported to offer evidence in the debate surrounding technological and cultural complexity. Rarely are these archaeological studies explicit tests of more than one hypothesis, but they still offer a perspective on how these hypotheses have been considered and applied within archaeology.

A major area of focus for archaeological analyses of cultural complexity has been the emergence of modern human behaviour reflected in an increased presence of complex technology and symbolism during the Upper Palaeolithic/Late Stone Age transition. The suite of characteristics associated with this transition do not appear as a homogenous unit. Accordingly, any model purporting to explain the transition must contend with heterogenous spatial and temporal emergence of cultural and technological traits (Bar-Yosef 2002). Additionally, in Africa current archaeological evidence suggests that some traits appear earlier, sporadically between 90-70 kya, before a more stable and widespread reappearance ~40 kya (McBrearty and Brooks 2000; Henshilwood et al. 2002).

These cultural changes have been argued by some to reflect major biological changes in cognitive sophistication, including the origin of language (Mellars 1991; Mithen 2005). Recently demographic changes and influences have been increasingly cited as a major

driving factor in behavioural modernity. For example, demographic changes have been attributed as a driving factor for the appearance of traits representative of behavioural modernity in Sahul (O'Connell and Allen 2007), the Mediterranean (Stiner and Kuhn 2006), and Europe as a whole (Mellars 2005).

Shennan (2001) explicitly offered his model of cultural complexity and population as a potential avenue in explaining the origins of modern human culture. While not carrying out an empirical analysis, Shennan (2001) suggested that his model could be used to demonstrate demographic's key role in the appearance of modern human culture.

Powell et al. (2009) took this a step further with a model of cultural complexity as well as an archaeological test of the theory. Their analysis was two step. First, they used a global dataset of DNA sequences to estimate when different regions would have reached the same population density as Europe at the beginning of the Upper Palaeolithic, which is when the suite of behaviourally modern traits appears there. They were then able to compare their population density estimates of other regions with when the 'package' of traits arrived. If population density was the driving factor in spurring the development of modern behaviour, then you would expect that the suite of traits would appear in other regions when they reached the same population density as Europe during the Upper Palaeolithic.

Powell et al. (2009) were able to find a relationship between the crossing of the population threshold and the appearance of modern behaviour in sub-Saharan Africa, North Africa, and the Levant. Yet, there were sizeable gap between the estimated time and actual time of appearance in southern, northern, and central Asia. Additionally, the temporary absence of modern traits in sub-Saharan Africa between 75-40kya was not associated with a decline in estimated population density. Despite these other findings, Powell et al. (2009) claimed that their empirical results still supported the population size hypothesis; but this conclusion has been contested.

Collard et al. (2016) argue that Powell et al.'s (2009) findings are ambiguous as a test of the population size hypothesis. They also point to a more recent multi-locus DNA study (Schiffels and Durbin 2014) that put the appearance of the 'package' of traits in Europe at a historic low in population size, and in Africa at a time when populations were shrinking. These findings cast some doubt on the conclusions of Powell et al. (2009).

Other archaeological analyses of the population size hypothesis and modern human behaviour have also cast doubt on the validity of the population size hypothesis. Klein and Steele (2013) used the size of rocky intertidal shellfish species as a proxy measurement of population density as a means of investigating the sporadic occurrence of modern behavioural traits on the South African coast during the Middle Stone Age. They found that the size of the shellfish shells did not decline until during the Late Stone Age, casting doubt over population density as the initial driver in behavioural modernity in the region.

In another archaeological study, and importantly the only explicit test of both the risk and population size hypothesis with archaeological data, Buchanan et al. (2016) found that their proxy for environmental risk (Global temperature) best predicted the number of point types through time in prehistoric Texas. Their proxy for population size, based on the number of archaeological occupation sites did not significantly correlate to technological richness.

In sum, the debate about the factors that drive toolkit structure is far from resolved. Despite the popularity of the population hypothesis there are still major theoretical and empirical issues that require further study and consideration. Experimental and archaeological analyses have been inconsistent in their support for either the risk or population hypothesis. Ethnographic research on the other hand is almost unequivocal. Among food-producing populations there is strong and robust evidence for the influence of population size over technological and cultural complexity. Yet, for those populations depending on wild food resources the evidence is overwhelmingly in support of the risk hypothesis as the best fit for the available evidence.

1.5. Previous work on toolkit complexity in the Pacific Northwest

It is in this context that Collard et al.'s (2011a) study is such a notable outlier, as an ethnographic study of food-gathering populations that did not offer support to the risk hypothesis. Considering that all previous studies have been carried out at a global or continental scale, the fact that Collard et al. (2011a) was carried out at a regional scale may be significant. Further analysis of regional-scale case study could potentially allow for a better understanding of issues of scale in the influence of environmental risk on

toolkit structure (i.e. at what geographic scale does risk start having a measurable impact on toolkit structure?). A regional scale also allows a higher resolution picture of the nature of potential environmental risk faced by groups. The potential benefits of shedding light on these questions of scale make this case study a prime candidate for further study and analysis.

A good region for a test of the risk hypothesis is one that maximizes ecological variation while minimizing geographic area. Additionally, a region must have available ethnographic and ecological data for comparison. It was with these considerations that Collard et al. (2011a) chose the Pacific Northwest as a good candidate region for such a study.

The Pacific Northwest comprises two distinct ecological and cultural areas, the Coast and the Plateau. The Coast area extends in a thin strip north to south from Yakutat Bay in Alaska to Cape Mendicino in California. It is bounded on the west by the Pacific Ocean and to the east by several mountain ranges that together make up part of the Pacific Coast Ranges. The landscape of the Coast can broadly be divided in two sections: The Northern/Central coasts, and the Southern Coast. The Northern/Central coast is defined by a complex system of steep fjords and numerous island chains. Many islands also protect several sheltered water bodies, the most significant being the Salish Sea. The Southern Coast, from the Strait of Juan de Fuca southwards is relatively straight, broken only occasionally by the estuaries of rivers, the largest of which is the Columbia.

The climate of the Coast is mild and wet. The prevailing westerly winds from the ocean cool the climate in the summers and warm them in the winter, while simultaneously bringing large quantities of rain. These climatic conditions have resulted in a rich ecology. The terrestrial ecosystem of the Coast is dominated by dense coniferous forests. The upwelling of colder water from ocean currents nourishes plankton which provides a foundation to the rich marine ecosystems of the Coast (Suttles 1990). Of these ecosystems, perhaps the most significant element are the annual runs of salmon up the rivers of the Pacific Northwest, a key resource for almost every culture in the region.

The Plateau area is dominated by high, broad open plains punctuated by troughlike river valleys and mountain peaks. Spatially it is confined by the Coast Mountains in the west, the Rocky Mountains in the east, the Subarctic in the north, and the Great Basin in the south. Together the Fraser and Columbia rivers drain 95% of the land surface of the Plateau, with both rivers supporting large seasonal salmon runs (Chatters 1998).

Climatically the Plateau has a mixture of both maritime and continental influences. Moist air moving from the North Pacific bring the area a majority of its precipitation, whereas large continental air masses from the arctic bring dry, clear weather as well as the extreme high and low temperatures in the summer and winter respectively. These conditions result in a mosaic-like vegetation distribution with steppe-grasslands dominating much of the low-elevation areas in the south; xeric and mesic montane forests in medium-elevation and northern areas; and subalpine forests and alpine meadows characteristic of high elevation areas (Chatters 1998).

To test the risk hypothesis in the Pacific Northwest Collard et al. (2011a) gathered toolkit data for 16 contact-era populations; eight from the Coast and eight from the Plateau. Data were also gathered based for nine ecological variables. The Coast and Plateau were compared based on their averages for the nine ecological variables and the four toolkit variables (Table 1 and 2). Based on the ecological variables, the Plateau was argued to be the riskier of the two areas in the Pacific Northwest, with significantly less rainfall, more extreme seasonal temperature changes, and lower ecological productivity. Based on this it was expected that Plateau cultures would have significantly higher toolkit richness and complexity. However, when Collard et al. (2011a) compared the means of the toolkit variables between the Coast and Plateau, no significant difference was detected.

Following this finding, Collard et al. (2011a) theorized that it was possible that this classification of one area as ‘lower risk’ and the other as ‘higher risk’ and then comparing their toolkit means is too reductive to properly identify the influence of environmental risk. To evaluate this possibility, Collard et al. (2011a) ran a series of correlation analyses with each toolkit structure variable compared with each ecological variable. These multivariate analyses also failed to support the risk hypothesis as none of the toolkit variables were significantly correlated with any of the ecological variables.

1.6. Aims and objectives

With the findings of Collard, et al. (2011a) in mind, there remains a real opportunity to more completely flesh out our understanding of the driving factors of toolkit structure. By determining why Collard et al.'s (2011a) results did not match the predictions of the risk hypothesis it may be possible to more accurately hone the risk hypothesis or grant credence to another potential hypothesis. Both outcomes would be beneficial to future work on toolkit structure and technological evolution more generally.

There would seem to be two possible explanations for why Collard et al.'s (2011a) results are inconsistent with the risk hypothesis. One is that environmental risk is not the main driving variable of toolkit structure in the Pacific Northwest. The other is that environmental risk drove toolkit structure but was not captured adequately by the ecological variables they employed. While these two possible explanations are not necessarily mutually exclusive, my study seeks to determine which of them is most likely to be correct through a new study of subsistence technology in the Pacific Northwest.

In the study I evaluated the risk hypothesis in two different ways. First, with Collard et al. (2011a) remaining as a noteworthy outlier in the ongoing debate around the driving factors of toolkit structure, I decided that it would be beneficial to re-do their analyses comparing populations of the Pacific Northwest with additional populations and ecological variables. This entailed comparing the averages of the Coast and Plateau, as well as carrying out multivariate analyses comparing the region as a whole. In the second part of the study, I switched from focusing on the relationship between populations' toolkits and general proxies for environmental risk to focusing on tools associated with species that differed in their riskiness. This second analysis served to better isolate components of risk, like seasonal availability, that are involved in the capture of resources which may help us understand how to better choose proxy measurements of general environmental risk. With these two separate but complementary analyses I could make a stronger argument over which of the two possible explanations of Collard et al. (2011a) is the most likely, or if both play an important role.

Chapter 2.

Testing the risk hypothesis by comparing the toolkits of groups from the Coast and Plateau

In the first set of analyses I set out to replicate the analyses of Collard et al. (2011a), but with more data. With the addition of more populations and ecological variables, t-tests were carried out comparing the Coast and Plateau for all ecological and toolkit related variables. Following this, each toolkit variable is compared to all ecological variables in stepwise regression analyses across the entirety of the Pacific Northwest.

2.1. Data Collection

I began by recreating Collard et al.'s (2011) dataset and then adding additional cultures and extra ecological variables. Using the same methodology as them (i.e. Oswalt's (1973, 1976) methodology), I recorded toolkit data for 12 cultures from the Coast (Alsea, Haida, Kwakwaka'wakw, Lower Chinook, Makah, Northern Coast Salish, Nuu-chah-nulth, Quinault, Straits Salish, Twana, Upper Stó:lō, and Yakutat Tlingit) and ten cultures from the Plateau (Bitterroot Salish [Flathead], Klamath, Modoc, N'pooh-le [Sanpoil] and Nespelem, Niimíipuu [Nez Percé], Nlaka'pamux [Thompson], Schitsu'umsh [Coeur D'Alene], Secwepemc [Shuswap], St'at'imc [Lillooet], and Sylix [Okanagon]) (Figure 1). Of these populations the Alsea, Haida, Lower Chinook, Straits Salish, Modoc, and Niimíipuu were not previously included in Collard et al.'s (2011a) study. The variables I recorded were STS, TTS, AVE, and MXT.

Data on the eight ecological variables previously included in Collard et al.'s (2011a) analysis were also collected for each group: Mean temperature during coldest month (MCM), mean temperature during warmest month (MWM), effective temperature (ET), mean annual rainfall (RMEAN), mean rainfall during wettest month (RHIGH), mean rainfall during driest month (RLOW), length of growing season (GS), and net above ground productivity (NAGP). MCM, MWM, ET, RMEAN, RHIGH, and RLOW were taken from the nearest or most central climate station to each culture. Data for GS and NAGP was obtained from Binford (2001).

I also included variables pertaining to an additional important ecological factor—salmon. The critical importance of salmon as a resource to both Coast and Plateau cultures has long been recognized (Wissler 1917). The centrality of salmon offers an opportunity to include a non-typical ecological variable in assessing environmental risk. Adapting ecological variables to the unique characteristics of the region may offer hitherto unnoticed patterns in the toolkit data. For this purpose, data was collected on the availability of the seven Pacific salmon species (*Oncorhynchus clarki*, *Oncorhynchus gorbuscha*, *Oncorhynchus keta*, *Oncorhynchus kisutch*, *Oncorhynchus mykiss*, *Oncorhynchus nerka*, *and Oncorhynchus tshawytscha*) for each culture.

Salmon stocks declined precipitously over the course of the 20th century. By 1996 pacific salmon had disappeared from 40% of their historical breeding ranges in Washington, Oregon, Idaho, and California. The picture was slightly better in British Columbia but some populations there were also in decline (National Research Council 1996). For the remaining extant salmon populations, more recent estimates of spawners range from <1% to 76% of historical abundance, which is considerably lower if constrained to natural origin fish (fish that are offspring of parents that spawned in the wild) (Good et al. 2007). Because of these factors obtaining accurate and precise data on salmon abundance is difficult, so data for multiple variables were collected to offer a variety of options.

Government agencies in Canada and the United States have been collecting data on salmon escapements in most freshwater estuaries for decades. Escapement data reflect the number of salmon that are not caught by commercial or recreational fisheries and return to spawn in freshwater bodies. Therefore, the data are not a direct reflection of total salmon abundance but do offer a potential source for comparing relative abundance between estuaries. Salmon counts were obtained from public databases and via personal communication with Fisheries and Oceans Canada, Washington Department of Fish and Wildlife, Oregon Department of Fish and Wildlife, Alaska Department of Fish and Game, California Department of Fish and Wildlife, Idaho Department of Fish and Game, and U.S. Army Corps of Engineers. The escapement data were used to create three salmon variables for the present study: 1) peak recorded number of available salmon (AVLSAL), 2) median of available salmon for a 15-year period centered at the peak recorded value (SALMED), and 3) salmon variation as a percentage average deviation from the median for the same 15 year period (SALVAR). In cultural areas with

too many potential salmon estuaries to collate, three river escapements were chosen based on ethnographic accounts of the most common fishing grounds. If no rivers were mentioned in the ethnography, I used the three largest escapements for which data are available within the range of the culture in question.

Unfortunately, high-resolution salmon escapement data were not available for all cultures. With the construction of the Chief Joseph Dam in Washington state (1950-1979), there was a complete loss of salmon in the Upper Columbia Basin. Because of this, accurate salmon estimates for cultures that fished primarily in the upper basin were impossible to attain. Instead, based on conservative estimates that 14% of the Columbia's total salmon runs ascended beyond Chief Joseph Dam (Scholz et al. 1985:86), AVLSAL for the Upper Columbia area was recorded as 14% of the peak total count for the Columbia as a whole. SALMED and SALVAR were taken from the limited historical counts available for Sockeye at Rock Island Dam (Fulton 1970:27). The cultures affected by these missing data were the Schitsu'umsh, Bitterroot Salish, Syilx, and N'pooh-le and Nespelem. Similarly, since the construction of the Iron Gate Dam in Northern California, salmon no longer migrate as far upstream as Klamath Lake (Bartholow et al. 2004). Because of this disruption, estimations for AVLSAL, SALMED, and SALVAR for the Klamath were attained through the aggregation of data for the 'Main Stem' of the Klamath with 'Misc. Klamath tributaries' and the largest escapement upstream from the Trinity River conflux (Bogus Creek).

An additional salmon related variable was included that did not depend on the veracity of the escapement data: the number of available salmon species (SALSP). This variable was simply a presence/absence variable for each of the seven pacific salmon species reflecting whether or not the species was historically present in the major estuaries of a given culture. For the historical presence of salmon, particularly in the Upper Columbia, data were taken from the National Oceanic and Atmospheric Administration.

All the ecological and toolkit variables were tested for kurtosis and skewness. Six of the ecological variables were significantly skewed. To avoid violating the assumptions of the statistical tests, ET, RLOW, and GS were $\log_e$ transformed. AVLSAL was transformed using square root transformation. It was not possible to remove the skew from SALMED and SALVAR, and therefore the results of the tests in which they are involved should be interpreted with caution.

2.2. Implementation of Collard et al.'s (2011a) t-test analytical protocol

Following Collard et al. (2011a) I began by assessing whether the climatic variation between the Coast and Plateau was apparent in the data for the ecological variables. T-tests were performed for each ecological variable to determine if the means for the Coast and Plateau were significantly different. Additionally, I used Benjamini-Hochberg's (1995) correction to adjust the significance level to account for multiple comparisons. In most cases, the Coast and Plateau proved to be significantly different. MCM, RMEAN, RHIGH, RLOW, and NAGP were all found to be significantly lower in the Plateau, and MWM was found to be significantly higher (Table 3). If one conceptualizes environmental risk as positively correlated with higher degrees of seasonality and lower resource abundance, as it is framed in the risk hypothesis, then the more extreme seasons, lower rainfall, and lower available vegetal mass of the Plateau distinguishes it as being, in theory, a higher risk environment than the Coast.

This distinction between Coast and Plateau is less stark when considering the ecological variables relating to salmon. Likely due to the large salmon runs into the Plateau via the Columbia and Fraser rivers, there was no significant difference in AVLSAL, SALMED, or SALVAR between the Coast and Plateau (See Table 3., also Appendix A). However, there was a significant difference in SALSP between the two areas, with an average of 6.08 salmon species available on the Coast and 3.68 in the Plateau.

Under the risk hypothesis, if the ecological variables reflect an accurate assessment of environmental risk then one would expect the Plateau to have a higher number of subsistants and technounits on average. To test this prediction, I again used t-tests to detect if there were any statistical differences in toolkit structure between the Coast and Plateau. As before, Benjamini-Hochberg's (1995) correction was applied to account for multiple comparisons.

As in Collard et al (2011a), none of the four main toolkit variables was found to differ significantly between the Coast and Plateau (Table 4). Additionally, none of the four variables' averages was in the predicted direction: the Coast had a higher average than the Plateau for all of the toolkit variables. Thus, the predictions of the risk hypothesis were not supported again.

2.3. Implementation of Collard et al.'s (2011a) multivariate analytical protocol

It is possible that comparing just the averages of the toolkit variables of the Coast and Plateau is too crude of a measure to capture the influence of risk at a regional level. So, in the other component of the recreation of Collard et al.'s (2011a) analyses the toolkit averages of the Coast and Plateau are not compared as areas, but instead all populations are compared across the entire Pacific Northwest region. To achieve this, I carried out stepwise regression analyses of the four major toolkit variables (STS, TTS, AVE, MXT), with all of the ecological variables, for the entirety of the Pacific Northwest.

The results of the stepwise regression analyses bolster an understanding of toolkit structure in the Pacific Northwest tied to the availability of salmon. Of the four general toolkit variables, only STS failed to produce a significant model (Table 5). The analyses of TTS (Table 6), AVE (Table 7), and MXT (Table 8) all produced models in which the toolkit variable was significantly positively correlated with the number of salmon species (SALSP). However, when the Benjamini-Hochberg correction was carried out the correlation with TTS was no longer significant (p value=0.053). The analyses of AVE and MXT on the other hand remained significant and also included the median of available salmon (SALMED) in their secondary models, increasing their effect size. Notably, in each of these secondary models there was a slightly negatively correlation with SALMED, not positive, while the relationship with SALSP remained positive.

2.4. Discussion

Despite the inclusion of data pertaining to additional cultures and further ecological variables, the initial results of my analyses were similar results to those obtained by Collard et al. (2011a). Many of the ecological variables demonstrated a significant difference between the Coast and Plateau. Based on these ecological differences the Plateau again appeared to be significantly higher in environmental risk than the Coast. Yet, the t-tests of the general toolkit variables for the cultures of the Coast and Plateau were not found to be significantly different. Additionally, in the multivariate analyses none of the ecological variables that have previously been found to correlate with toolkit richness and complexity produced a significant relationship with any of the toolkit variables. Similar to the previous effort (Collard et al. 2011a) these findings indicated two

possibilities: that environmental risk is not the major determining factor for toolkit structure in the Pacific Northwest, or that environmental risk is not being measured accurately. It should be noted again that these possibilities are not necessarily mutually exclusive.

Of the two possibilities the former—that environmental risk is not the major determining factor for toolkit structure in the Pacific Northwest—has been bolstered by the inclusion of salmon related variables in the regression analyses. While the intricacies of the relationship between SALSP, SALMED, and toolkit structure require further investigation, one conclusion is certain: these data do not support the predictions of the risk hypothesis. An increase in the number of available salmon species correlating with an increase in toolkit complexity (as measured by TTS, AVE, and MXT) cannot be viewed as an increase in environmental risk.

The relationship between SALSP and SALMED present in the multivariate analyses indicates that the relationship between salmon availability and toolkit structure is not one dimensional. The second models for both AVE and MXT were positively correlated with SALSP while being slightly negatively correlated with SALMED. This discrepancy deserves attention. One possible explanation is that it is simply a result of poor data. SALSP is the coarsest of the salmon variables, but since it is simply a historical presence/absence variable for the seven species of Pacific salmon, it is not affected by the catastrophic decline in Pacific Salmon stocks across the Pacific Northwest that has occurred during the 20th century (Nehlsen et al. 1991; Roos 1991). These declines likely would have a considerable influence on the accuracy of the raw salmon population data used in variables like SALMED. This is particularly true in the case of the Upper Columbia, where due to severely limited data SALMED was limited to only a few data points reflecting historical sockeye counts, missing data for the other salmon species completely. This lack of high quality SALMED data for a major portion of the Plateau must inform any interpretation of the correlations found in the stepwise regression analyses. With these considerations in mind, it is still worthwhile to explore the possibility that these correlations do in fact reflect a real relationship with toolkit structure.

Considering that each of the salmon species' runs occur at different time times of the year (Suttles 1990:24-25), it is logical that SALSP reflects to a degree the longevity of the window of opportunity when salmon are readily available. Conversely, SALMED is

simply a measure of the median number of salmon theoretically available in a given year. Considering the immense size of salmon runs in the Pacific Northwest, particularly in the Fraser and Columbia, the key variable may not be the gross number of salmon. It is possible that the duration of the period that salmon harvesting can occur is the critical factor for toolkit structure.

Millions of salmon passing through an area over a limited time period does not mean that all those salmon were available to those living in the area. A large segment of the technology associated with catching salmon are associated not with the main channels of large rivers like the Fraser or Columbia. Instead, weirs and dip-nets are typically associated with use in smaller tributaries where weirs could feasibly be built across the entire width of the river. This is not always the case, as platforms for dip-nets were built in some places along major rivers, and sometimes drag-nets were also used at the mouths of large rivers. However, even under these conditions the millions of salmon travelling upstream in the Fraser and Columbia would not have been entirely available to groups situated at the estuary of the rivers. In areas with such a high number of individual salmon travelling by, the critical variable may have been the length of time during which fishing could have been practiced as opposed to the total number of available salmon. The relationship to toolkit structure appears to support this conclusion, more salmon does not simply result in larger toolkits. Instead the influence on the toolkits appear to relate to salmon's (quite limited) seasonal availability.

While this relationship between SALSP and toolkit structure supports the explanation that risk was not the main driving factor of toolkit structure in the Pacific Northwest, it is still possible that environmental risk is not being sufficiently measured with the ecological variables that were chosen for these analyses. The failure to find any correlation with ecological variables that have been used in past studies as risk proxies made a new approach valuable, particularly with comparing inland and coastal areas directly. The types of risk on the Coast may be different from those in the Plateau, which would not be reflected in the ecological variables we had chosen. The variables used in these analyses mostly reflect climate, certainly an important aspect of environmental risk, but it does not take into account the risk involved in the capturing of marine prey. I judged it beneficial to change perspectives from comparing populations to comparing subsistants based on the species that they were made to acquire. This proposed analysis makes up the third chapter of this study.

Chapter 3.

Testing the risk hypothesis by comparing tools used to capture different prey species

To more completely evaluate whether risk was being sufficiently accounted for in my assessment of Pacific Northwest toolkit structure, an alternative approach was devised. Comparing the toolkits of populations across a region is a relatively coarse form of analysis, particularly when risk is being represented by general climatic proxy measurements (e.g. Rainfall, temperature). Many elements can influence stochastic variation and so risk should be understood as a multifaceted variable with many possibly interacting contributing factors. To achieve this, I decided to focus our second set of analyses on the number and complexity of tools associated with individual species, rather than on populations' toolkits.

This focus on individual species was done in hopes that it would offer a more detailed breakdown of what sort of risk the toolkits of the Pacific Northwest were responding to. In the previous analysis the ecological variables used largely indicated that the Coast was an area of relatively low risk; but, the increased difficulty in the acquisition of aquatic prey has previously played a major role in the proposed models of toolkit structure for both Oswalt (1976) and Osborn (1999). This is due to the added dimension of maneuverability available to marine prey (depth), as well as the difficulty inherent in accessing marine prey, with watercraft and other associated equipment often a requirement. Without the difficulty of capturing marine prey being reflected in the previous analyses, it is possible that the riskiness of the Coast was underestimated.

By using data on what prey species subsistants were associated with I was then able to determine the average complexity of tools used to acquire species across the Pacific Northwest. Due to the available ecological data on species in the Pacific Northwest I was then capable of investigating whether marine prey, or highly seasonal prey, are associated with more complex subsistants on average. These data could then be used to evaluate whether I am sufficiently accounting for risk in the Pacific Northwest. Additionally, it may have been the case that at the regional level coarse climatic variables are incapable of sufficiently capturing environmental risk and that future

environmental risk assessments may be better served by using ‘sets’ of important species as reflections of general environmental risk.

3.1. Data collection

To begin with, the species to be included in the analyses were chosen. The selection was based on the species included in Joseph Jorgensen’s (1980) study of Western North America’s Indigenous peoples. Jorgensen’s list of 76 species was reduced to only reflect species naturally present in the territory of the 22 groups included in the present study. This number was further reduced by excluding marine mammals that were not regularly hunted. The final list of 51 species included 20 land mammal species, 13 marine mammal species, nine species of anadromous fish, seven species of saltwater fish, and three species of freshwater fish.

Next, the previously collected toolkit data were divided based on their intended prey species. For each culture the number of subsistants and technounits associated with each of the 51 species that was present in that culture’s geographical area was determined. When the ethnographic accounts of subsistants were not specific to species (e.g., bow and arrow described as being used for ‘Large land mammals’), it was assumed that the subsistant was used for all species that fit that general category and were present in the group’s territory. The one exception to this rule was the case of large bodied predator species (i.e. cougars and wolves). Since the hunting and/or trapping of large bodied predator species is relatively rare most ethnographies make specific mention of either a taboo against hunting these species or mentioned specifically that they were hunted. Due to this I assumed that they were not being hunted in all cases unless specific mention was made in an ethnographic account.

Thereafter, I calculated an average of the subsistants and technounits associated with each of the 51 species. If a species was present within the territory of a given culture but they had no subsistants associated with its acquisition, they were simply not included in the calculated average rather than treated as a zero value. For example, along the Coast whales are present in most areas but were only hunted by a few cultures. The average number of subsistants and technounits for these whale species only reflect the cultures who did hunt them, and not those who had no whale hunting subsistants present in their toolkit. This ensured that the final value for associated subsistants only

reflected the technology of groups that actually hunted the species without being outweighed by zero values. I was interested in the associated tools of species, not whether or not cultures hunted the species in question, so the exclusion of zero values was justified.

To illustrate how I derived the species-specific tool averages from the original toolkit data, I will walk through an example of a single species, the mule deer (*Odocoileus hemionus*), also known as black-tailed deer. The first step was to establish its presence or absence in the territories of the 22 groups. This is achieved with the aid of a range of ecological sources. When there was doubt about the exact border of a species' range, I erred on the side of caution and included the species in the group's territory. Typically it was only in the case of certainty that a species was ruled as absent from a culture's range. Special attention was paid to cases of modern introduction of a species into an area not originally in the species' range. For instance, the Sitka deer (*Odocoileus hemionus sitkensis*) is a subspecies of the mule deer and is currently present on the islands of Haida Gwaii. But, the Sitka deer was introduced to the islands in the 1890s as a game animal (Vancouver Sun, 11 April 2018), and so was not part of the islands' ecosystem at the time of contact. Thus, in the example table for the mule deer (Table 9) the column for the Haida is marked with "N/A" to reflect the fact that the species was absent from the islands prior to contact with Europeans.

Following the establishment of each species' presence or absence in the territories of all the groups, the next step was to count the associated subsistants and technounits. This was accomplished by returning to the original toolkit data for each group, where the use of each subsistant had been noted during the original data collection (Original toolkit data available in Appendix III). For example, for the Kwakwaka'wakw there were seven subsistants associated with the capturing of deer, with a total of 23 technounits contributing to those subsistants. These subsistants consisted of the bow and arrow[1], club, brush blind, spring trap, tossing-pole snare trap, and brush driving fence. Together, these subsistants reflect the diverse methods that were utilized by the Kwakwaka'wakw people to capture black-tailed deer, and by dividing the number of technounits by the number of subsistants we get the average complexity of the subsistants used for black-

[1] in Oswalt's methods, arrows are counted as a separate subsistant to the bow to reflect that most cultures have multiple types of arrows for different prey

tailed deer (3.29 technounits per subsistant).Once these data have been compiled for each culture and each species, I was then able to compare the average complexity of subsistants associated with species, rather than cultures, across the entire Pacific Northwest.

Next, in order to be able to determine if high risk species were associated with more complex subsistants, I needed to a method of assigning each species a “risk ranking”. In the interest of simplicity and due to a lack of specific data in some cases, the risk involved in the capture of a species was estimated on the basis of two ordinal variables: ease of access and seasonality. The ease of access variable sought to encompass the difficulty of capturing the different species given their physiological and ecological characteristics, whereas the seasonality variable captured how frequently a species would have been available for capture. Each species was assigned a value for the two variables, and these were then summed to generate an overall risk ranking for that species (Table 10).

Because ease of access is composed of multiple contributing factors, each species was assigned a risk score based on generalized rankings in three categories: Group size, speed, and location on landscape. Each category was scored based on a simple 1, 2, or 3 value based on perceived risk. Group size was ranked from species that congregate in large herds/schools averaging larger than 50 individuals (1); to small groups of less than 50 (2); to those who remain mostly solitary (3). Particular importance was placed on the group size at times of year when the species in question was usually hunted. A larger group size reduces risk because there is a higher likelihood of capture due to there being a larger number of available prey present at any one point in time and space. Speed was ranked based on recorded top speeds of each species and was binned in three categories: slow (1-20 km/h), medium (21-40 km/h), or fast (>40 km/h). In the case of fish species, top speed data was largely lacking. In the case of salmon and other anadromous fish species estimated average speed was used. Since while spawning they are swimming upstream and the average speeds are well within the ‘slow’ speed bin (Quinn 1988; Webber et al. 2007), average speed was judged an acceptable compromise. Other fish species’ speeds are largely educated guesses based on the available data for anadromous fish. Lastly, the location on landscape was based on a generalized judgement of where the prey was being primarily accessed. The three categories were: Shore/Lowlands/Rivers (1), Coastal Waters/Mountains (2), and Open

Ocean (3). These rankings were made to reflect an increased risk taken when travelling outside of easily accessible areas to acquire prey. For example, relative to hunting on the land, hunting in coastal waters requires increased investment in watercraft as well as carrying an increased risk of bodily harm when compared to spearing fish from the shores of a stream or river. These risks are then compounded when travelling outside of protected coastal waters and into more open bodies of water. This principal also applies for hunting in some areas on the mainland, considering the increased risk that results from travelling to mountainous regions beyond more navigable lowland areas. Each species was scored for these three criteria and summed for a final 'Ease of Access' score.

Seasonal availability of resources is a key component to annual subsistence cycles for societies in temperate environments, particularly those in the Pacific Northwest (Suttles 1968). For this reason, seasonality was deemed to be an important enough component of the risk assessment to weigh more heavily than any of the single components making up the 'Ease of Access' score. Unfortunately, data for the duration of seasonal availability of species fluctuates in their precision and also vary between areas of the Pacific Northwest. Due to this constraint in the data, seasonality rankings were still constrained to three ranked categories, so the "value" of each category was increased from a '1, 2, 3' ranking to a '1, 4, 6' ranking. This was done so that the seasonality score would not be outweighed completely by the nine available points composing the "Ease of Access" score. Seasonality rankings were therefore: year-round availability (1), some changes in seasonal availability but still available for six or more months in a year (4), and highly seasonal resources available for five or less months in a year (6). With these values, seasonality is more equally weighed with ease of access and, when summed, offer an overall "Risk of Capture" score.

In order to outline the entire process of compiling "Risk of Capture" scores, I return to the example of the mule deer as well as an additional example species, the California Gray Whale (*Eschrichtius robustus*). Mule deer are typically found in small herds, which results in a group size score of two. Speed-wise mule deer are capable of short bursts that exceed 40km/h, which is reflected in a speed score of three. Additionally, mule deer are found across a broad range of habitat, which qualifies them for a location score of one (Shore, Lowlands, and Rivers). Together, these give an "Ease of Access" score of six. This is then combined with a seasonality score of one because they are available

year-round in most habitats without any significant fluctuations in seasonal availability. Thus, the “Risk of Capture” score for the mule deer is seven.

Turning now to the gray whale, this species’ “Ease of Access” score of six was again compiled from the scores for group size, speed, and location on landscape. Outside of calving lagoons (which are not in the Pacific Northwest) gray whales do not gather in large groups, rarely if ever exceeding seven whales total, and usually individuals scatter to feed on their own area of the sea bottom. This is reflected in a group size score of three as they are relatively solitary. During their migrations their swimming speed is relatively slow, averaging only 1.3-2.2 kilometres per hour, resulting in a speed score of one. As for where they are found, gray whales typically do not venture far offshore, typically keeping to coastal waters, reflected in a location score of two.

The gray whale’s “Ease of Access” score is combined with a seasonality score of six. This seasonality score is based on the highly migratory behaviour of gray whales, whereby they travel from their rich feeding grounds in subarctic waters to calving grounds in Southern California and Baja waters. This migration takes place every year, meaning that they are only ever available in a single location for a limited amount of time. This high seasonality score when combined with the ‘Ease of Access’ score results in the total ‘Risk of Capture’ score of 12.

Thus, the mule deer is less risky to capture than the gray whale. This means that, if the risk hypothesis is correct, the mule deer should be associated with less complex subsistants than the gray whale.

3.2. Analyses

The risk of capture score of species were compared to three toolkit variables: the number of associated subsistants, the number of associated technounits, and the average complexity of associated subsistants. The relationships between the variables were depicted in scatter-plots and then tested for significance.

The number of associated subsistants and technounits did not have a straightforward relationship with the risk of capture rankings (Figures 2 and 3). Rather, the relationship was inverted-U-shaped: the number of subsistants and technounits increased up until a risk score of nine, but then declined sharply. In order to test the relationship’s

significance, I used curvilinear regression to account for the non-linear nature of the data. In both cases these analyses result in a significant relationship between risk of a species and the number of associated subsistants (p=.006) and technounits (p=.029). Species with a risk ranking of higher than nine have fewer associated subsistants and technounits than those species of medium/low risk.

In contrast to associated subsistants and technounits, when the average complexity of tools by species is compared to the risk of capture score a simple linear relationship is clearly visible (Figure 4). This was confirmed through linear regression analysis which found a significant positive linear relationship between a species' risk ranking and the complexity of associated subsistants (p=.000) This indicates that while the total number of subsistants and technounits associated with a high risk species were low, those few associated subsistants were very complex.

3.3. Discussion

The results of these analyses shed some light on the question of whether or not risk was sufficiently accounted for in the analyses of Collard et al (2011a) and the analyses I reported in Chapter 2. The results of both the initial risk rankings as well as the associated subsistant complexities indicate that the acquisition of marine prey, particularly marine mammals, is highly risky. What makes my data unique is that in the case of the Pacific Northwest there appear to be counteracting factors that are influencing the overall environmental risk.

Past studies have mostly had both a larger diversity and sharper contrast in environments due to their global or continental scale. Due to this factor the different component factors influencing environmental risk likely were not obviously visible within the coarse variables that were used as risk proxy measurements. Variables such as latitude, used as a proxy for time stress and environmental risk in Torrence (1983, 1989), may not always closely align with risk in all circumstances. At a global scale latitude may correlate well with environmental risk in general, but in Torrence's sample latitude also positively correlates with a higher likelihood of a coastal population. Of the 20 populations in Torrence's sample (the same sample that was used in Collard et al. 2005 and Read 2008), 11 are primarily located along a coastal environment and nine are interior populations, relatively evenly split. However, this split becomes lopsided in

higher latitude environments. Of the 12 populations that are located in temperate, subarctic, or arctic environments, eight of them are located along a coast. Of the 11 coastal populations, eight are from temperate, subarctic, or arctic environments. Coastal populations making up a larger proportion of the populations at higher latitudes may have been highly significant to Torrence's findings.

If, all other factors being equal, a coastal population experiences higher levels of risk than interior populations because of the nature of marine resources, it would have different effects for Torrence's sample and my sample of the Pacific Northwest (and the sample of Collard et al. [2011a]). In Torrence's global sample, with more coastal populations at high latitude, the influence of marine resource acquisition on toolkit structure would be aligning with the proxy measurement used for environmental risk; whereas in the case of the Pacific Northwest it would be counter to the risk proxies used.

In terms of climate the Coast is certainly "low risk" relative to the Plateau, but the high risk involved in the capture of marine resources may be counteracting this influence. Simultaneously, the Plateau should also be considered relatively high risk, reflected in the climatic variables used in Chapter 2. The relative strength in influence on toolkit structure of climatic variables on the one hand and marine resources on the other is difficult to parse, but the prey-species analysis suggests that they each have significant but counteracting influence with the prevalence of marine prey increasing the relative risk of the Coast while the hotter, drier, and less productive environment of the Plateau is also relatively high in environmental risk.

These potential counteracting influences on environmental risk raises important questions about how we choose environmental risk proxy measurements when trying to test the risk hypothesis. They also reinforce past research that explicitly drew attention to the distinction between dependency on marine and territorial resources and its effect on toolkit structure (Oswalt 1973, 1976; Osborn 1999). At a global level coarse risk proxies like latitude, ET, or GS appear to be capable of capturing the impact of risk on toolkit structure. However, at a regional level correlation between these coarse climatic variables and toolkit structure have proven illusive. With the species level analysis showing that marine prey species are often higher risk than terrestrial prey and therefore typically have more complex subsistants associated with them, it is worth considering

whether in regional studies we need to redesign how we are quantifying environmental risk as a variable.

Of course, the species level analysis supports these conclusions mostly from data that reflect average complexity of associated subsistants by species. It is worth stressing that these data do not necessary reflect the overall size/composition of toolkits at the population level. In order to carry out more accurate toolkit analyses studying populations' toolkits a great deal of thought will need to be put into devising composite variables of environmental risk that are capable of reflecting the increased risk of marine resources. This is particularly challenging since the presence of a marine species does not necessarily mean that the local populations would possess technology to pursue it. For example, whale species are present all along the Coast, are ranked as very high risk, and are associated with highly complex subsistants. Yet, they are only actively hunted by a select few cultures. So, the mere presence of a whale species does not de facto make an area higher risk. There is likely another contributing factor that makes the immense technological investment required for whaling "worth it" under particular circumstances. Determining these other contributing factors and including them in future regional analyses of environmental risk should be a priority.

Aside from these considerations of the risk reflected in marine resources, other significant conclusions can also be drawn from the analyses of total associated subsistants and technounits (Figure 2 and 3). Explaining the relationship between risk and the number of associated subsistants and technounits seems relatively straightforward. High risk prey are typically associated with few but complex subsistants. This is likely due to high risk prey not being worth significant technological investment for their capture. Lower risk prey that are relatively abundant year-round and easy to access would probably result in many different methods of capture, resulting in a higher number of associated subsistants.

Another immediately striking feature of the associated subsistants and technounits are the clear "clumps" of species at a risk ranking of nine that occur in both the number of associated subsistants and technounits. These clumps represent the five major species of anadromous Pacific salmon: *Oncorhynchus tshawytscha* (Chinook), *Oncorhynchus keta* (Chum), *Oncorhynchus kisutch* (Coho), *Oncorhynchus gorbuscha* (Pink), and *Oncorhynchus nerka* (Sockeye). Together the five salmon species average 10.08

subsistants and 64.18 technounits, well above all other species included in the analyses. The highest associated subsistant count for a terrestrial mammal is the white-tailed deer (*Odocoileus virginiana*) with 7.00 subsistants, and the highest marine mammal is the sea otter (*Enhydra lutris*) with only 3.80.

These findings appear consistent with the positive correlations found in Chapter 2 between TTS, AVE, and MXT on one hand and SALSP on the other. The considerable investment in technology relating to the capture of salmon throughout the Pacific Northwest clearly signals a strong relationship between the presence of salmon and toolkit structure generally. Interestingly, the averages of the number of subsistants associated with salmon species is actually slightly higher in the Plateau (where there are fewer salmon species) than in the Coast (viewable in Appendix C). Consequently, the relationship between TTS and SALSP cannot solely be explained as the salmon-related subsistants boosting the overall total number of technounits. However, I do not have enough data to understand the exact nature of the relationship at this time.

Chapter 4.

General Discussion

4.1. Is risk driving toolkit structure in the Pacific Northwest?

The study reported here investigated why Collard et al (2011a) did not find an association between hunter-gatherer toolkit structure and environmental risk in the Pacific Northwest, when most other work on the topic has found such an association. There were two plausible explanations for Collard et al.'s (2011a) results. One was that Collard et al.'s (2011a) variables did not account for environmental risk adequately. The other was that environmental risk was not the primary factor influencing toolkit structure in the Pacific Northwest. To evaluate these possibilities I devised two separate sets of analyses. First, I revisited Collard et al.'s (2011a) analyses with data for additional populations and more ecological variables. Second, a new perspective was gained through focusing on tools associated with prey species rather than populations.

The results of the two sets of analyses illuminate different aspects of the factors influencing toolkit structure in the Pacific Northwest. At face value both of the possible explanations of Collard et al.'s (2011a) results appear to be supported by the two sets of analyses. The prey-species analyses support the hypothesis that we are undervaluing the risk of important elements of coastal subsistence when we use coarse climatic variables as environmental risk proxy measurements alone. On the other hand, the significant positive correlation found between the number of salmon species present (SALSP) and multiple toolkit variables (AVE and MXT) supports the idea that risk is not the only driver of toolkit structure in at least significant parts of the Pacific Northwest and that other variables need to be considered.

It should be stressed that while these findings may appear contradictory, the two possibilities explored here are not necessarily mutually exclusive. That is, it is entirely possible that environmental risk in the Pacific Northwest has not been accounted for accurately while also not being the only driving factor in toolkit structure for the Pacific Northwest. What this could possibly mean for future evaluations of toolkit structure in the Pacific Northwest and across the world warrants further discussion.

First, I will consider the issue of environmental risk quantification, focusing primarily on the results of the prey species analyses. In the global and continental studies of toolkit structure that have been published to date, latitude, effective temperature, rainfall, species richness, and net above ground productivity have been used as proxies for environmental risk (Torrence 1989; Collard et al. 2005, 2013b). In each of these cases there was a large range of climatic extremes represented in the sample. It seems likely that the high degree of contrast in the environmental variables made patterns in the data clearer than is possible in smaller regional studies. By constraining the scope to the Pacific Northwest, the range of variation represented in climatic variables is limited. The Plateau is significantly different from the Coast according to most ecological variables, but the contrast in environments is not as sharp as between an equatorial rainforest and the high arctic. Without as much of a contrast in climate, other variables' contributions to subsistence related risk appear to have a stronger influence over toolkit structure and make it more difficult to parse all of the contributing factors.

Risk is a composite variable consisting of many contributing factors. Risk is defined as the effects of stochastic variation in the outcome of capturing food resources, which can be influenced by everything from temperature, rainfall, seasonality, or the maneuverability of prey species. In the case of the Pacific Northwest my data indicate counteracting influences from climatic variables and marine prey, respectively. The Coast is considerably less risky in terms of climatic variables: it has more rainfall, higher effective temperature, greater net above ground productivity, and a longer growing season. Yet the prey species-specific data demonstrate how higher proportions of marine resources, particularly marine mammals, in an environment can be expected to increase overall risk. Marine mammals consistently were ranked as high risk, and often had the most complex associated subsistants. Marine prey are more difficult to access directly, often requiring the use of watercraft, and have an extra dimension of movement (depth) available in evasive maneuvers, when compared to land mammals. These factors serve to decrease reliability in capture and thereby increase risk. It is not hard to imagine that this increased risk would have a corresponding effect on toolkit structure; increasing the complexity of tools associated with marine prey would help explain why in the original toolkit variable t-tests the Coast and Plateau had the same average for STS (39) but the Coast had a higher average for TTS (212 compared to 178 for the Plateau).

Marine mammals typically did not have many associated subsistants, but those few subsistants were highly complex, so would have less of an influence on STS than TTS.

This complexity in the many components that contribute to risk and subsistence is not readily apparent when comparing the general toolkit variables (i.e. STS, TTS, AVE) alongside simple climatic variables. If nothing else, the prey species-specific analyses demonstrate that simple climatic and ecological variables are not sufficient to capture environmental risk in the Pacific Northwest. The Coast and Plateau are not significantly different in their overall toolkit structure, but this appears to at least partially be due to differences in the sources of risk involved. These differences in how risk influences toolkit structure can be expected to become increasingly important in regional studies, especially when comparing interior and coastal populations. In these cases, coarse climatic variables such as temperature and rainfall have failed to capture the nuances of environmental risk in coastal environments. Unfortunately, how best to capture the risk of capturing aquatic prey at a population level remains unknown at this time. Significant further research is necessary to investigate the relationships between the contributing variables of risk and developing best practices in parsing their influences across varying ecological contexts.

With the difficulties of current environmental risk quantification in the Pacific Northwest established, I will now turn my attention to the possibility that environmental risk may not be the only contributing factor to toolkit structure in the Pacific Northwest. This perspective derives primarily from the results of the stepwise regression analyses and focuses on the importance of salmon in those analyses. To reiterate, of the 12 ecological variables included in the stepwise regression analyses, only those variables concerning salmon availability were significantly associated with any of the toolkit structure variables. SALSP produced statistically significant models, positively correlating with AVE and MXT. The other toolkit variables (STS, TTS) were also positively correlated with SALSP. Further, TTS produced a viable model with SALSP, but was not significant following correction for multiple comparisons. These positive correlations between SALSP and the general toolkit variables is intriguing. This correlation is opposite to what is predicted by the risk hypothesis, which suggests that as environmental risk increases so does toolkit richness and complexity. It is difficult to imagine that having more salmon species available would increase risk, so this pattern runs in direct opposition to the risk hypothesis. Other explanatory hypotheses should therefore be considered.

As I mentioned in the Introduction, several recent papers on toolkit structure have highlighted a difference in the results of studies of the toolkits of hunter-gatherers and small-scale agricultural groups. Collard et al. (2011b) and Fogarty and Creanza (2017) have both highlighted this pattern in the empirical data. In the case of food-gatherers, the ethnographic evidence strongly supports the risk hypothesis, whereas among food-producers population size is more strongly positively correlated with toolkit richness and complexity.

Rather than being a case of either risk of resource failure or population size, Collard et al. (2011b) proposed niche construction as a single explanatory theory that fits all cases, a proposal further supported by Fogarty and Creanza (2017). Niche construction is a process through which organisms alter their environments and by doing so also alter or change the selective pressures that they are subject to. This process could offer a better explanatory theory to the observed pattern between food-gatherers and food-producers. Through niche construction in the form of agricultural development and intensification, food-producers insulate themselves, at least partially, from environmental risk. In contrast, food-gatherers are significantly more exposed to environmental effects on technological fitness. Niche construction offers a holistic explanation for the difference between the results of analyses focused on the toolkits of food-gatherers and those focused on the toolkits of food-producers. As niche construction related behaviour becomes more extensive and/or intensive, the impact of environmental risk declines while population size becomes increasingly important in influencing toolkit structure.

Niche construction theory perhaps offers the best available explanation for the observed toolkit structure patterns in the Pacific Northwest. Importantly, it adds nuance to the line drawn between food-producers and food-gatherers. There exists significant variation among food-gatherers, typically framed as immediate- and delayed-return systems (Woodburn 1980). In immediate-return system food-gatherers no surplus is created and resources are consumed on a daily basis. In contrast, delayed-return food-gatherers “reap the benefits of their labor sometime after investing it” (Kelly 1995:31), for example via long-term food storage. It is possible that in some delayed-return systems niche construction behaviour is providing a buffer to environmental risk and thereby changing toolkit structure.

The Pacific Northwest has long stood out as a unique region for those interested in cross-cultural studies of food gatherers. A solution employed in some attempts to create universal, generalized models of hunter-gatherer societies was to exclude the Pacific Northwest as an outlier (Service 1979; Leacock and Lee 1982). As a practice this was part of a pursuit of an “essential core” of hunter-gatherers, which could then be extrapolated into a model of hunter-gatherer behaviour and projected into the prehistoric record (Kelly 1995). In this pursuit, “outliers” were typically explained away based on either extraordinary natural environments or unique historical contexts. In the case of the Pacific Northwest culture area, its outlier status has consistently been attributed to a “naturally abundant environment” (Suttles 1968; Service 1979). This abundance, it was argued, explained the development of atypical societal attributes for non-agricultural societies such as seasonal or full sedentism, labour specialisation, resource ownership, social hierarchy, slavery, ritual feasting, and food storage (Service 1979).

Archaeological research in the Pacific Northwest has led to more nuanced analyses of the role of resource abundance and distribution in the history of the region. Importantly for our purposes, these more nuanced studies stressed the temporal and spatial variation of resource abundance, as well as the importance of storage technology for the preservation of food surpluses. Suttles (1968) offered one of the earliest contributions, criticizing earlier works for their emphasis on the overall abundance of resources without consideration for spatial-temporal variation.

Archaeological explanatory models for Pacific Northwest cultural complexity have typically focused on the Marpole phase (2400-1200 cal. BP.), paying particular attention to the Gulf of Georgia and mouth of the Fraser River. At this time and place the various elements of complex social and economic organization typical of the area seem to have fully developed (Mitchell 1971; Burley 1980; Matson and Coupland 1995; Grier 2003). These changes were accompanied by an increase in the size of houses and villages, and an increase in the total number of dated sites, which possibly indicates a significantly increase in population size as well as changes in the organization of labour, control of resources, and the intensification of salmon fisheries (Ames 1994, 1995; Grier 2003; Lepofsky et al. 2005).

Attempts to explain these changes frequently stress the importance of access to and control of salmon (Suttles 1968; Mitchell 1971; Fladmark 1975; Schalk 1977; Burley

1980; Matson 1983, 1992; Croes and Hackenberger 1988; Grier 2003). Matson's (1983, 1992) model posits that salmon intensification, residential sedentism, and ownership of resource patches evolved along the Pacific Northwest Coast when resources were sufficiently abundant, reliable, predictable, and limited geographically and temporally. The drawing of causal linkages remains difficult, however, with mixed support from archaeological data (Lepofsky et al. 2005). The development of storage technology is also central to several models as a means of bridging the gap between seasonal abundance and stored surplus, allowing for delayed consumption during winter months (Schalk 1977; Burley 1980).

More recent analyses combining archaeology, ecology, and ethnography have further deepened our understanding of ecological management by the cultures of the Pacific Northwest. It is now clear that while Pacific Northwest groups did not engage in agricultural practices in the strictest sense, they engaged in a considerable amount of habitat manipulation and management. These practices included tending estuarine "root plots" (Deur 2002) as well as the selective burning of the landscape to produce favourable conditions for economically important plants (Turner 1999, Armstrong 2018). Additionally, considerable evidence of "clam gardens" has been found. These were artificially walled beach terraces that increased the productive capacity for shellfish. Such structures have been found along the Coast from Alaska to Washington state (Augustine and Dearden 2014, Groesbeck et al. 2014, Lepofsky et al. 2015, Deur et al. 2015). Together, these practices signify a considerable degree of niche construction whereby environmental risk is at least partially mitigated. Perhaps not to the same extent as more formally recognized food producers, but the exact point at which environmental risk is not the primary factor in toolkit structure is still not clear. Current findings only suggest that environmental risk is the primary factor for food-gatherers whereas food producers' toolkits appear to be more driven by population. However, under what precise circumstances environmental risk is overtaken by population size as the primary driver, either under a threshold mechanism where the change-over is relatively sharp or under a more gradual incremental increase of influence, remains unknown at this time.

These perspectives from Pacific Northwest archaeology provide a context within which to situate my own findings concerning toolkit richness and complexity in the region. The archaeological evidence, at least in the case of the Coast, offers some support for the niche construction hypothesis. Storage technology in tandem with increased salmon

intensification evolved alongside increased social and economic complexity. Additionally, practices of ecological stewardship increased the economic yield of other important species. Together these factors may have increased the carrying capacity of areas rich in salmon resources, leading to increased populations. The niche construction hypothesis predicts that as the influence of environmental risk is blunted through niche construction, population size increases in its proportional impact on toolkit richness and complexity. While the intensification of salmon fisheries certainly qualifies as risk mitigation when combined with storage and preservation technologies, to fully evaluate the niche construction hypothesis future studies should focus on testing whether population size correlates with toolkit complexity. However, due to the problematic history of population estimates and censuses in the Pacific Northwest (Boyd 1999; Belshaw 2009), this task fell outside of the scope of this study.

4.2. Potential limitations of this study

With any study extensively reliant on primary ethnographic sources, the reliability of these accounts can be questioned. Especially so when dealing with a small sample size of 22 cultures. Ethnographers are not capable of seeing everything, nor do they record every detail. Importantly for the Pacific Northwest, travelers and those lacking in professional training may be more likely to omit things they do not understand or make errors in documentation. Fortunately for my purposes, subsistence practices and technology were often a popular area of interest in many ethnographies, and the description of subsistence related technology is typically quite straightforward, although the quality of descriptions does vary. There is little reason to think that any systematic errors from ethnographers would have affected my sample disproportionately: both the Coast and Plateau should be relatively equally affected by poor ethnographic accounts. The potential influence of one or two particularly poor ethnographies is mitigated when comparing the averages of the Coast and Plateau through t-tests, as in Chapter 2. However, the multivariate analyses would be more susceptible of influence from a single culture's toolkits being poorly recorded by an ethnographer as we are comparing each culture as its own datapoint. For this reason, the results of the multivariate analyses should perhaps be viewed with additional skepticism.

Similarly, the specificity that was possible in the prey species-focused analyses was highly dependent on the detail recorded by the ethnographers. In some cases, the

intended prey species were detailed extensively, but in others authors only gave broad categories of prey (ex, fish or large mammals). This lack of specificity in some cases would have limited the ability to compare subsistence technology between specific species if sufficient detail was not given. Despite this, the influence on the final analyses should be minimal, as the figures compared are the averages of associated subsistants across the Pacific Northwest as a region, which should again alleviate some of the influence of particularly non-specific ethnographic accounts.

Another concern with the ethnographic record in the Pacific Northwest is that a select few individuals are responsible for a large proportion of the primary ethnographic record. This is particularly noteworthy in the case of James Teit (1864-1922) who is the primary source for much of the ethnographic record in the Plateau, having written major ethnographies on the Bitterroot Salish, Nlaka'pamux, Schitsu'umsh, Secwepemc, St'at'imc, and Sylix. Any potential methodological blind spots for Teit would have large effect on the reliability of much of the data from the Plateau. However, Teit's extensive knowledge on the Plateau peoples resulting from the considerable amount of time spent in the Plateau could also be seen as a valuable asset. Teit's ethnographies often have direct comparisons of subsistence technology to other Plateau cultures, making them valuable in pinpointing small differences between similar subsistants. Such detail would likely be missing from an ethnographic account from an author only familiar with a single population or culture.

A related issue to that of the reliability of ethnographic accounts is the tumultuous shift that occurred in cultures of the Pacific Northwest post-contact. Following contact from Europeans during the late-18th century there began a long period of catastrophic depopulation for indigenous peoples in the Pacific Northwest. In the first century of contact a population decline of 80% has been seen as a minimum (Boyd 1999:262) and many cultures reached their population nadir in the late 19th or early 20th century (Belshaw 2009:88). This depopulation was largely the result of introduced diseases, although the introduction of new economic incentives, like the fur trade, is also thought to have potentially increased conflict between cultures (Belshaw 2009:85). It is certainly not out of the question to think that this decline in population had an impact on subsistence practices and technology with the potential loss of considerable cultural knowledge, particularly with the introduction of European weapons and other technology. Additionally, the introduction of the fur trade likely made pelts of certain species much

more valuable, which would have shifted subsistence behaviour and technology. These changes cannot be overstated, and while ethnographers tried their best to document pre-contact technology, it is likely that some ethnographic accounts came too late.

Outside of issues with the ethnographic record there are other important limitations to this study that should be considered. My attempts to rank the risk of individual prey species of the Pacific Northwest relied heavily on the quality of ecological data. Due to some ecological sources lacking a great deal of specificity, the scales that species were ranked along had to be reduced to simple three-category ranked systems. Looking beyond the simplicity of the ranking systems used, there are many elements of prey species that would contribute to risk that are not included in this study. For example, both deer species in the sample have risk scores of seven, while the risk score for Grizzly bears is only one more, eight. There is no additional variable in my system that would account for the increased risk of aggressive behaviour or more dangerous physiological characteristics (claws, teeth, etc…). This lack of more detailed and exhaustive data for the species used is certainly a fair criticism.

Additionally, it should be noted that the sample of 51 species is not exhaustive in including all species that were important to the people of the Pacific Northwest. Notably, subsistants associated with plants and shellfish were not included in the prey species-focused analyses. While there were plant and shellfish species that were highly significant in their contributions to the diets of cultures in the Pacific Northwest, neither is capable of significant evasive movement so there are typically few associated subsistants. The few subsistants that are associated with plants and shellfish are also typically very simple. Based on this it was judged reasonable to not include these species in the analyses, but their absence should be noted when drawing conclusions on the findings. All things considered, despite the above noted complications with the species analyses, since this was the first toolkit analysis of its kind a conscious decision was made to keep it relatively simple and manageable with the intention of further improving the methods in future studies.

4.3. Future research directions

Several remarks have been made with future research in mind, but it is worth here collecting them for further emphasis. For future evaluations of the risk hypothesis there

are several important considerations to keep in mind. If more regional tests are to be carried out, particularly those comparing inland to coastal populations, it is clear that simple ecological variables (ex. rainfall, effective temperature, etc…) are not capable to capturing the nuances of environmental risk at such a scale. Instead, attention needs to be paid to developing methods of including the increased risk of marine prey in the overarching analysis. Simple presence/absence of high risk species does not appear to be adequate enough, as some populations do not develop the technology to acquire all the high risk species that they have theoretical access to. How to overcome this issue is particularly challenging but is critical to modifying the risk hypothesis to a regional scale.

Risk's composite nature should be a clear focus in future studies, and investigations should be taken into other potential proxy risk measurements that could be added to future studies. To further develop the explanatory power of the risk hypothesis we cannot depend on studies at the global scale using simple climatic variables. Instead more regional studies should be attempted to further develop our understanding of how variables contribute to environmental risk. Perhaps comparing two independent regions of either coastal or interior populations can aid in controlling for the major distinction that was found in the Pacific Northwest. By comparing the Plateau to another interior region for example, but one that still provides an ecological contrast, the issue of marine prey could be mitigated.

As for the Pacific Northwest itself, the relationship between toolkit structure and the abundance of salmon warrants further analysis. Niche construction as a potential explanatory model is promising but requires more rigorous testing. As noted above, future studies should strive to test the niche construction hypothesis by comparing toolkit structure to reconstructions of population size. This was previously attempted in Collard et al. (2013b), and no correlation with population was found. However, the population data was sourced from Binford's (2001) Constructing Frames of Reference. After conducting my own research to verify the population figures recorded therein, I think the accuracy of the population estimates should be considered questionable. Any pre-contact population estimate is typically highly contested and politicized, coming alongside huge error bars. Any future attempts to test the niche construction hypothesis in this region should tread carefully and take multiple population estimating methods into consideration.

Beyond issues with population number estimates, there are also issues in how populations are divided in the analysis. Areas of the Pacific Northwest were highly interconnected and exchange was common, this will be a particularly difficult issue with the many Coast Salish populations of the central Coast. Future analyses should pay close attention to linguistic families and patterns of exchange. Also, the use of ethnographies in this study limited us to a small temporal frame, it may be possible in future studies to begin incorporating archaeological data. Archaeological data has the added challenge of not having the recorded use of artifacts, which makes counting subsistants extremely difficult. Issues of preservation add further complications. Conducting ethnographic interviews with contemporaneous living descendants of communities may also offer an avenue for the addition of more data and verifying the data from ethnographic accounts.

Chapter 5.

Conclusions

How technology is adapted and changes through both time and space is an important aspect of understanding changes of material culture in the archaeological record. The factors that drive these changes have been subject to considerable debate over the last 40 years, with the risk and population size hypotheses being the most prominent. For hunter-gatherer populations the risk hypothesis has consistently been the most successful hypothesis in explaining existing patterns in toolkit structure. However, in a regional test of the risk hypothesis, Collard et al. (2011a) found no significant relationship between their proxies for environmental risk and toolkit structure in the Pacific Northwest. I set out to test whether these previous findings were due to not measuring environmental risk sufficiently, and/or if another important factor was at play.

Through two independent sets of analyses I found that it was likely that both the possible explanations for the previous findings were at least partially correct. Analyses of the subsistants associated with specific species across the Pacific Northwest demonstrated that marine prey and prey whose availability was highly seasonally constrained were more likely to be associated with more complex tools. This runs contrary to the risk assessments used previously which based their understanding of environmental risk almost entirely on coarse climatic variables. These variables underestimated the risk of coastal environments because of their milder climates, not recognizing the increased risk seemingly intrinsic to the capture of marine prey.

On the other hand, my multivariate analyses of the toolkit variables associated with the populations of the Pacific Northwest resulted in an interesting finding: several toolkit variables were positively correlated with the number of salmon species available. The risk hypothesis would suggest that as an environment becomes more risky toolkit variables should increase. It is difficult to imagine that the number of salmon species increasing would represent a riskier environment, so the relevance of the risk hypothesis to the Pacific Northwest remains unclear. Niche construction theory provides a possible explanation of these data, reconciling the population and risk hypotheses, but requires considerably more work before any such explanation can be asserted with confidence.

The results presented here offer ample ground for further research. The risk hypothesis remains the best supported toolkit structure hypothesis in the case of hunter-gatherers but could be strengthened by more time spent parsing all the composite variables that contribute to an environment's risk. Coarse climatic variables do not seem sufficient at a scale smaller than a continent, especially when comparing populations from both inland and coastal environments. Determining how to fold these potentially conflicting contributing variables into our assessments of environmental risk will be a substantial task but it is a promising path to better understanding the important relationship between our technology and the world around us.

Tables and Figures

Table 1. t-test results from Collard et al. (2011a) for toolkit structure variables

Variable	Northwest Coast mean	Plateau mean	*p* value
STS	39	39	.984
TTS	212	178	.350
AVE	5	5	.038
MXT	37	31	.097

Table 2. t-test results from Collard et al. (2011a) for ecological variables

Variable	Northwest Coast mean	Plateau mean	*p* value
MCM	3	-5	.000
MWM	16	19	.002
ET	12	12	.727
RMEAN	1652	458	.001
RHIGH	263	68	.001
RLOW	4	2	.001
GS	7	6	.375
NAGP	740	324	.000
RICH	50	28	.000

Table 3. t-test results for ecological variables

Variable	Northwest Coast mean	Plateau mean	*p* value
MCM	3.69	-2.16	.00
MWM	15.7	20.04	.00
ET	12.28	12.64	.12
RMEAN	2077.83	434.66	.00
RHIGH	312.79	66.8	.00
RLOW	53.33	16.35	.00
GS	6.67	6.2	.16
NAGP	733.87	328.91	.00
AVLSAL	1,484,266.83	447,468.06	.13
SALMED	487,843.58	37,763.4	.06
SALVAR	65.18	120.77	.47
SALSP	6.08	3.68	.00

Table 4. t-test results for toolkit structure variables

Variable	Northwest Coast mean	Plateau mean	*p* value
STS	32.33	28.6	.56
TTS	166.67	137.1	.48
AVE	5.08	4.85	.54
MXT	39.17	33.1	.30

Table 5. Stepwise regression analysis results – STS

Excluded Variables

	Pearson Correlation	*p* value
MCM	.056	.401
MWM	-.119	.299
ET	-.096	.335
RMEAN	.023	.459
RHIGH	.077	.366
RLOW	-.053	.407
GS	-.149	.253
NAGP	.064	.389
AVLSAL	.151	.251
SALMED	.189	.200
SALVAR	.020	.465
SALSP	.283	.101

Table 6. Stepwise regression analysis results – TTS

	R	R Square	Adjusted R Square	Std. Error	Included Variables	*p* value	Corrected *p* value
Model 1							
	.442	.195	.155	55.15	SALSP (+)	.040	.053

Excluded Variables

	Pearson Correlation	*p* value
MCM	.074	.371
MWM	-.151	.251
ET	-.131	.280
RMEAN	.137	.271
RHIGH	.200	.186
RLOW	.036	.437
GS	.034	.440
NAGP	.128	.286
AVLSAL	.133	.278
SALMED	.104	.322
SALVAR	.082	.359

Table 7. Stepwise regression analysis results – AVE

	R	R Square	Adjusted R Square	Std. Error	Included Variables	*p* value	Corrected *p* value
Model 1							
	.440	.193	.153	.787	SALSP (+)	.041	
Model 2							
	.590	.348	.279	.726	SALSP (+); SALMED (-)	.017	.034

Excluded Variables

	Pearson Correlation	*p* value
MCM	-.055	.404
MWM	-.092	.341
ET	-.144	.261
RMEAN	.208	.177
RHIGH	.245	.136
RLOW	.163	.234
GS	.357	.051
NAGP	.078	.365
AVLSAL	.015	.473
SALVAR	.175	.218

Table 8. Stepwise regression analysis results – MXT

	R	R Square	Adjusted R Square	Std. Error	Included Variables	*p* value	Corrected *p* value
Model 1							
	.502	.252	.215	7.07	SALSP (+)	.017	
Model 2							
	.647	.419	.357	6.40	SALSP (+); SALMED (-)	.006	.024

Excluded Variables

	Pearson Correlation	*p* value
MCM	.179	.213
MWM	-.227	.155
ET	-.176	.217
RMEAN	.404	.031
RHIGH	.464	.015
RLOW	.252	.129
GS	.266	.116
NAGP	.353	.053
AVLSAL	-.025	.456
SALVAR	.009	.484

Table 9. Example table for subsistants associated with the mule deer

	Alsea		Haida		Kwakwaka'wakw		…	Sylix		Overall Average	
Species	**Subsistants**	**Technounits**	**Subsistants**	**Technounits**	**Subsistants**	**Technounits**		**Subsistants**	**Technounits**	**Subsistants**	**Technounits**
Mule Deer (Odocoileus hemionus)	2	9	N/A	N/A	7	23	…	8	36	6.90	24.95

Table 10. Prey species risk and associated technology data

Common Name		Group Size	Speed	Location	Seasonality	Risk Total	STS	TTS	AVE	Source(s)
Small Mammals										
Cottontail rabbit	*Sylvilagus sp.*	2	3	1	1	**7**	4.22	13.33	3.24	1
Jackrabbit	*Lepus sp.*	2	3	1	1	**7**	4.10	14.20	3.59	1
Porcupine	*Erethizon dorsatum*	3	1	1	1	**6**	3.75	13.05	3.35	1
Bobcat	*Lynx rufus*	3	3	1	1	**8**	3.56	14.06	3.94	1
Lynx	*Lynx canadensis*	3	3	1	1	**8**	4.10	16.00	3.47	1
Coyote	*Canis latrans*	3	3	1	1	**8**	4.67	21.67	3.39	1
Beaver	*Castor canadensis*	2	1	1	1	**5**	3.95	14.71	3.71	1
Medium Sized Mammals										
Gray wolves	*Canis lupis*	2	3	1	1	**7**	5.00	24.00	4.80	1
Antelope or pronghorn	*Antilocapra americana*	2	3	1	1	**7**	4.67	15.50	3.38	1
Mountain goat	*Oreamnos americanus*	2	2	2	1	**7**	4.42	15.00	3.36	1
Cougar	*Felis concolor*	3	3	1	1	**8**	4.00	26.00	6.50	1
White-tailed deer	*Odocoileus virginiana*	2	3	1	1	**7**	7.00	24.60	3.57	1
Mule deer or black-tailed deer	*Odocoileus hemionus*	2	3	1	1	**7**	6.90	24.95	3.69	1
Large Mammals										
Caribou	*Rangifer sp.*	1	3	1	4	**9**	5.50	18.67	3.50	1
Bighorn Sheep	*Ovis canadensis*	2	2	2	1	**7**	4.33	13.78	3.24	1
Black bear	*Ursus americanus*	3	3	1	1	**8**	5.43	24.81	4.57	1
Elk	*Cervus sp.*	2	3	1	1	**7**	5.90	20.30	3.45	1
Grizzly bear	*Ursus arctos*	3	3	1	1	**8**	5.47	24.74	4.50	1
Moose	*Alces alces*	3	3	1	1	**8**	4.20	13.80	3.34	1
Bison	*Bison bison*	1	3	1	1	**6**	4.60	12.40	2.71	1

Common Name		Group Size	Speed	Location	Seasonality	Risk Total	STS	TTS	AVE	Source(s)
Anadromous Fish										
Char, Dolly Varden	*Salvelinus malma*	1	1	1	6	**9**	5.00	26.58	4.65	2, 3
Salmon, Chinook	*Onchorhynchus tshawytscha*	1	1	1	6	**9**	10.38	63.90	6.04	2, 3
Salmon, Chum	*Onchorhynchus keta*	1	1	1	6	**9**	9.15	59.38	6.16	2, 3
Salmon, Coho	*Onchorhynchus kisutch*	1	1	1	6	**9**	10.17	64.78	6.17	2, 3
Salmon, Pink	*Onchorhynchus gorbuscha*	1	1	1	6	**9**	10.46	67.69	6.37	2, 3
Salmon, Sockeye	*Onchorhynchus nerka*	1	1	1	6	**9**	10.26	65.16	6.15	2, 3
Sea-lamprey, western	*Entosphenus tridentatus*	1	1	1	6	**9**	6.50	33.36	4.67	2, 3
Trout, cutthroat	*Onchorhynchus clarki sp.*	1	1	1	6	**9**	5.41	28.41	4.80	2, 3
Trout, steelhead	*Onchorhynchus mykiss sp.*	1	1	1	4	**7**	6.86	36.14	4.92	2, 3
White sturgeon	*Acipenser transmontanus*	3	1	1	4	**9**	5.15	29.69	5.58	2, 4
Saltwater fish										
Eulachon	*Thaleichthys pacificus*	1	1	2	6	**10**	3.50	18.17	5.42	2
Pacific cod	*Gadus macrocephalus*	1	1	2	1	**5**	3.45	15.55	4.44	2
Pacific halibut	*Hippoglossus stenolepis*	1	1	2	1	**5**	3.00	15.64	5.44	2
Pacific herring	*Clupea pallasii*	1	1	2	6	**10**	3.45	17.27	4.36	2
Sardine or California pilchard	*Sardinops sagax caerulea*	1	1	2	6	**10**	3.09	15.91	4.77	2
Surf smelt	*Hypomesus pretiosus*	1	1	2	6	**10**	3.18	16.45	4.82	2
Freshwater fish										
Sucker	Fam. *Catostomidae,* genera *Catostomus*	3	1	2	1	**7**	6.42	33.16	4.80	2
Whitefish, lake	*Coregonus sp.*	3	1	2	1	**7**	7.33	38.67	5.07	2
Whitefish, Mountain	*Prosopium sp.*	3	1	2	1	**7**	7.80	46.00	5.65	2
Sea Mammals										

Common Name		Group Size	Speed	Location	Seasonality	Risk Total	STS	TTS	AVE	Source(s)
Northern Elephant Seal	*Mirounga angustirostris*	1	1	1	4	**7**	2.82	13.55	4.14	5
Northern Fur-Seal	*Callorhinus ursinus*	1	2	1	4	**8**	2.82	13.55	4.14	5
Orca	*Orcinus orca*	2	2	2	1	**7**	2.33	22.67	9.83	5
Dall's Porpoise	*Phocoenoides dalli*	2	3	2	4	**11**	2.13	14.00	6.63	5
Harbour porpoise	*Phocoena phocoena*	2	2	2	1	**7**	2.13	14.00	6.63	5
North Pacific Right Whale	*Eubalaena japonica*	3	1	2	4	**10**	2.50	24.00	9.75	5
Harbour Seal	*Phoca vitulina*	2	1	1	1	**5**	2.82	13.55	4.14	5
California Sea-lion	*Zalophus californianus*	1	2	1	4	**8**	3.22	15.89	4.57	5
Stellar Sea-lion	*Eumetopias jubatus*	1	2	1	1	**5**	3.10	14.90	4.41	5
Sea-otter	*Enhydra lutris*	2	1	1	1	**5**	3.80	17.20	4.43	5
California gray Whale	*Eschrichtius robustus*	3	1	2	6	**12**	2.33	22.67	9.83	5
Fin Whale	*Balaenoptera physalus*	3	1	2	4	**10**	2.33	22.67	9.83	5
Humpback Whale	*Megaptera novaeangliae*	2	2	2	4	**10**	2.33	22.67	9.83	5

Sources

1. Jorgensen 1980, Joseph G. 1980
2. Froese and Pauly 2019
3. Quinn 1988
4. Webber et al. 2007
5. Allen et al. 2011

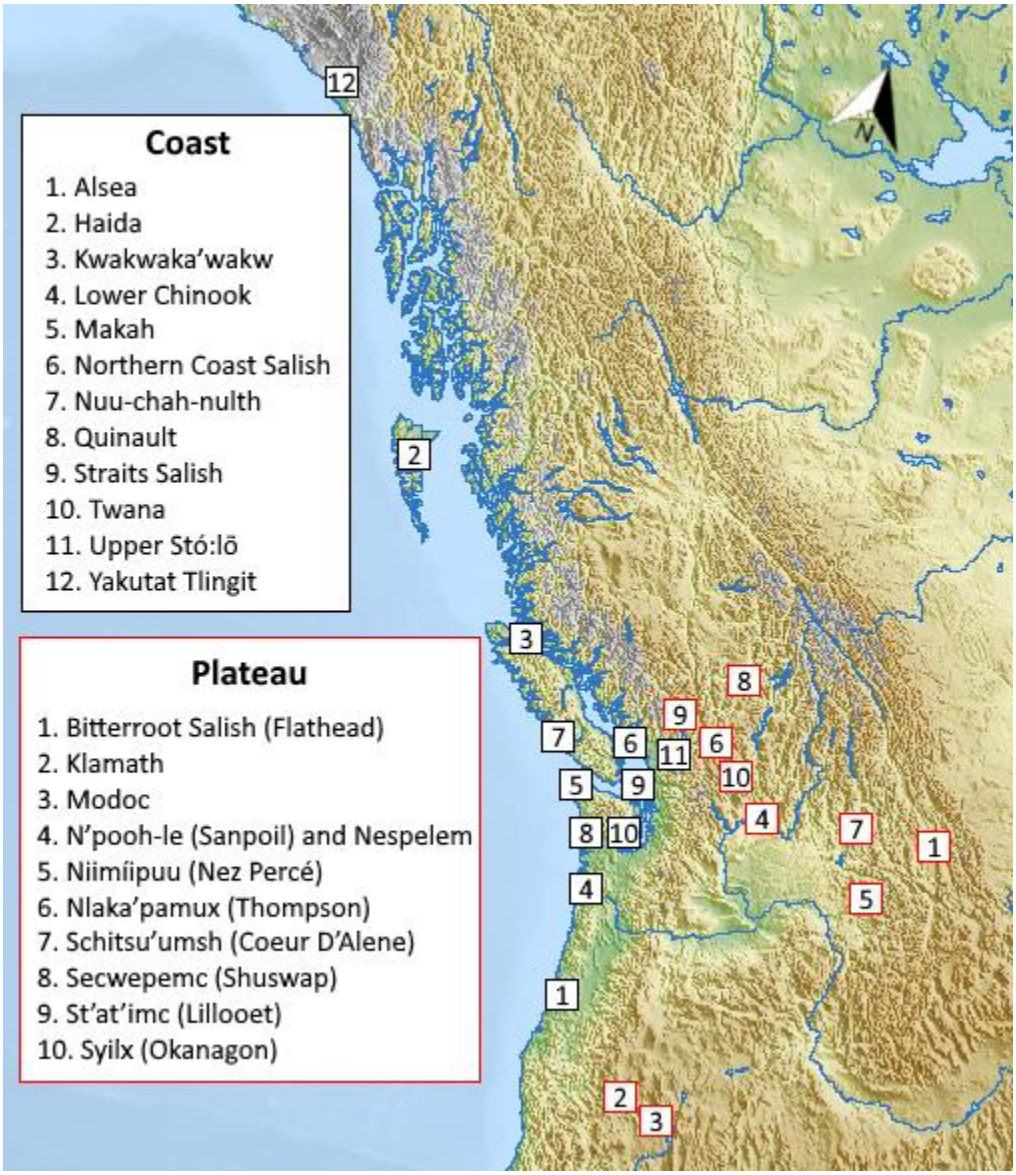
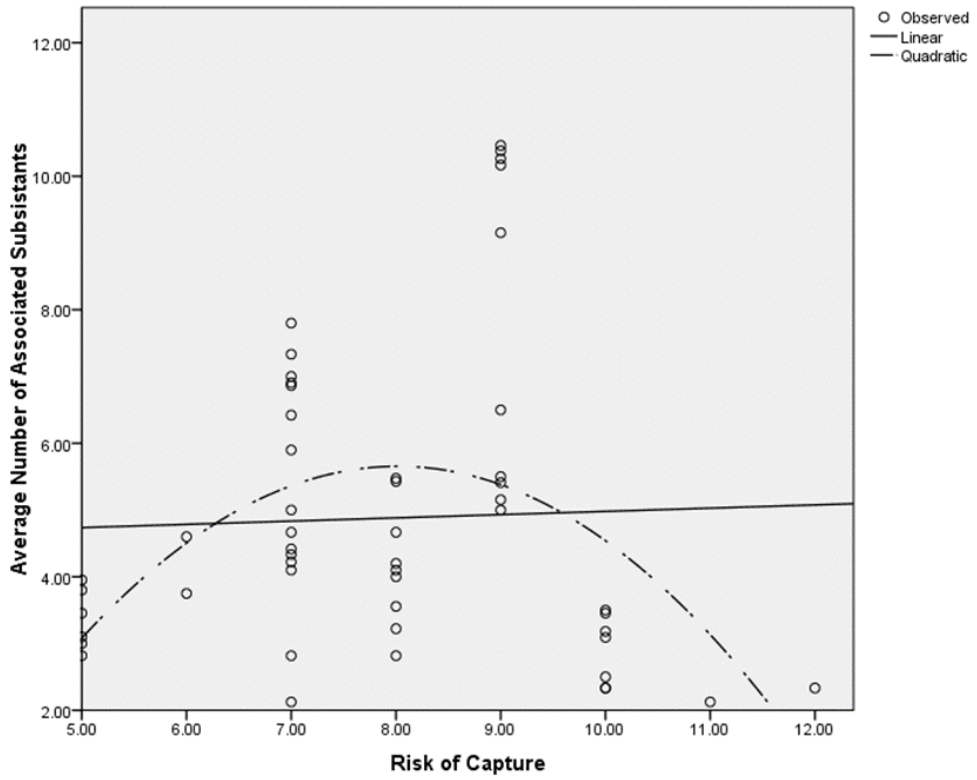


Figure 1. Map of Pacific Northwest, with cultures included in this study
Base map from mapswire.com (Licensed under a Creative Commons Attribution 4.0 International License.)



Curvilinear Regression

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.036[a]	.001	-.019	2.27677	.001	.063	1	49	.802
2	.438[b]	.192	.158	2.06918	.191	11.325	1	48	.002

a. Predictors: (Constant), Risk

b. Predictors: (Constant), Risk, Risk_squared

ANOVA[a]

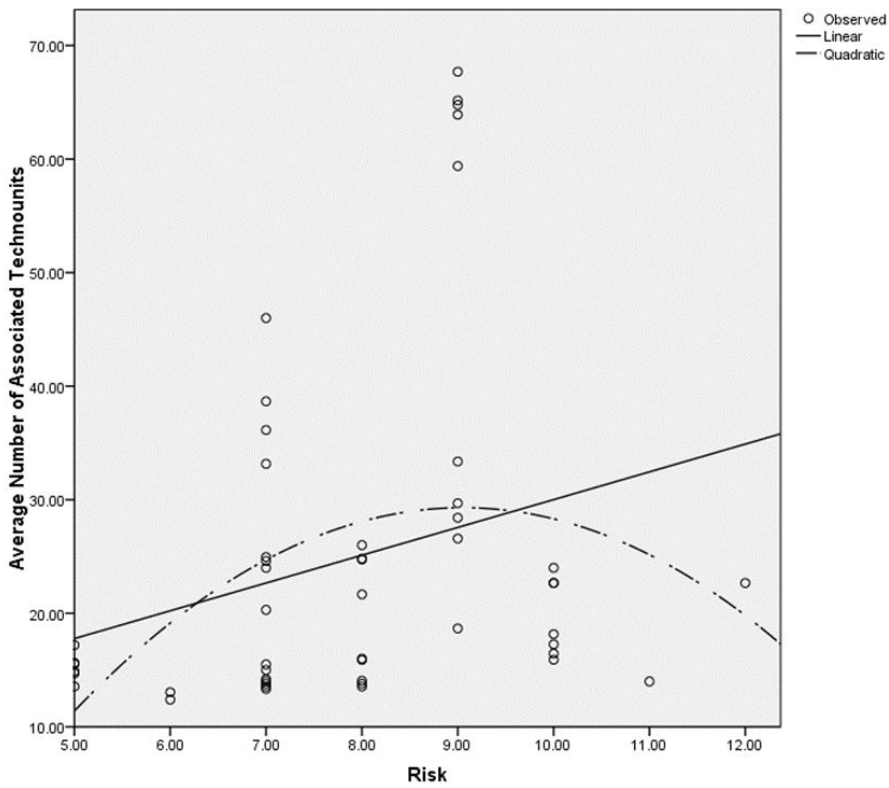
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.329	1	.329	.063	.802[b]
	Residual	254.001	49	5.184		
	Total	254.330	50			
2	Regression	48.818	2	24.409	5.701	.006[c]
	Residual	205.512	48	4.281		
	Total	254.330	50			

a. Dependent Variable: AVGSUB

b. Predictors: (Constant), Risk

c. Predictors: (Constant), Risk, Risk_squared

Figure 2. Average number of subsistants associated with species, by Risk of Capture



Curvilinear Regression

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.271[a]	.073	.055	14.65135	.073	3.885	1	49	.054
2	.370[b]	.137	.101	14.28735	.063	3.529	1	48	.066

a. Predictors: (Constant), Risk

b. Predictors: (Constant), Risk, Risk_squared

ANOVA[a]

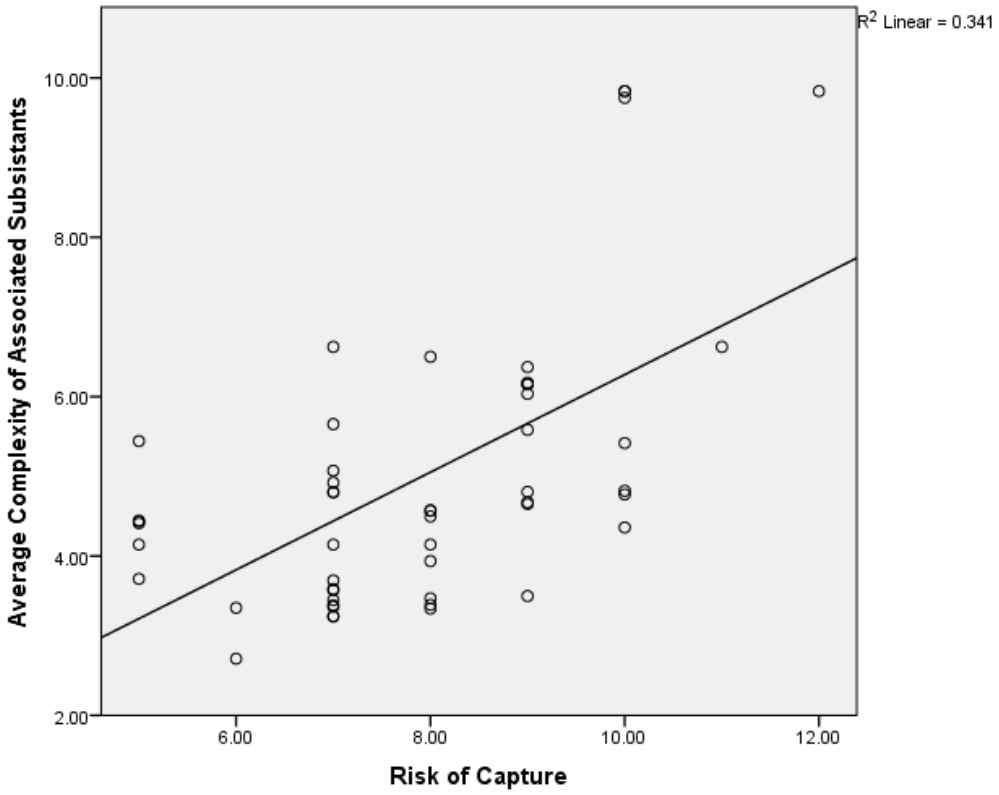
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	833.971	1	833.971	3.885	.054[b]
	Residual	10518.438	49	214.662		
	Total	11352.409	50			
2	Regression	1554.248	2	777.124	3.807	.029[c]
	Residual	9798.161	48	204.128		
	Total	11352.409	50			

a. Dependent Variable: AVGTEC

b. Predictors: (Constant), Risk

c. Predictors: (Constant), Risk, Risk_squared

Figure 3. Average number of technounits associated with species, by Risk of Capture



Correlations

		Risk	AVGAVE
Risk	Pearson Correlation	1	.584**
	Sig. (2-tailed)		.000
	N	51	51
AVGAVE	Pearson Correlation	.584**	1
	Sig. (2-tailed)	.000	
	N	51	51

**. Correlation is significant at the 0.01 level (2-tailed).

Figure 4. Average complexity of subsistants associated with species, by Risk of Capture

References Cited

Acerbi, Alberto, Jeremy Kendal, and Jamshid J Tehrani
2017 Evolution and Human Behavior Cultural complexity and demography: The case of folktales. Evolution and Human Behavior 38(4):474–480.

Allen, Sarah G., Joe Mortenson, and Sophie Webb
2011 *Marine Mammals of the Pacific Coast*. University of California Press, Berkeley, CA.

Ames, Kenneth M.
1994 The Northwest Coast: Complex Hunter-Gatherers, Ecology, and Social Evolution. *Annual Review of Anthropology* 23:209–229.
1995 Chiefly Power and Household Production on the Northwest Coast. In *Foundations of Inequality*, edited by Douglas Price and Gary M. Feinman, pp. 155–187. Plenum Press, New York.

Armstrong, Chelsey G., Wal'ceckʷu Marion Dixon, Nancy J. Turner
2018 Management and traditional production of Beaked Hazelnut (k'áp'xw-az', *Corylus cornuta*; Betulaceae) in British Columbia. *Human Ecology* 46:547-559.

Augustine, Skye and Philip Dearden
2014 Changing paradigms in marine and coastal conservation: A case study of clam gardens in the Southern Gulf Islands, Canada. *The Canadian Geographer* 58(3):1-10.

Aunger, Robert
2000 The Life History of Culture Learning in a Face-to-Face Society. *Ethos* 28(3):445–481.

Bar-Yosef, Ofer
2002 The Upper Paleolithic Revolution. *Annual Review of Anthropology* 31:363–393.

Bartholow, John M., Sharon G. Campbell, and Marshall Flug
2004 Predicting the thermal effects of dam removal on the Klamath river. *Environmental Management* 34(6):856–874.

Belshaw, John Douglas
2009 The West We Have Lost: First Nations Depopulation. In *Becoming British Columbia: A Population History*, pp. 72–90. UBC Press, Vancouver.

Benjamini, Y., and Y. Hochberg
1995 Controlling the false discovery rate: a practical and powerful approach to multiple testing. *Journal of the Royal Statistical Society B* 57:289-300.

Bettencourt, Luis M A, José Lobo, and Deborah Strumsky
2007 Invention in the city: Increasing returns to patenting as a scaling function of metropolitan size. *Research Policy* 36:107–120.

Binford, Lewis R.
2001 Constructing frames of reference: an analytical method for theory building using ethnographic and environmental data sets. University of California Press, Berkeley, CA.

Boyd, Robert
1999 The Coming of the Spirit of Pestilence: Introduced infectious diseases and population decline among Northwest Coast Indians, 1774-1874. UBC Press, Vancouver.

Boyette, Adam Howell
2013 Social learning during middle childhood among Aka foragers and Ngandu farmers of the Central African Republic. PhD dissertation. Department of Anthropology, Washington State University, Pullman, WA.

Brumm, Adam, and Mark W Moore
2005 Symbolic Revolutions and the Australian Archaeological Record. *Cambridge Archaeological Journal* 15(2):157–175

Buchanan, Briggs, Michael J. O'Brien, and Mark Collard
2016 Drivers of technological richness in prehistoric Texas: an archaeological test of the population size and environmental risk hypotheses. *Archaeological and Anthropological Sciences* 8(3):625–634.

Burley, David
1980 Marpole: Anthropological Reconstructions of a Prehistoric Northwest Coast Culture Type. Simon Fraser University, Burnaby, BC.

Caldwell, Christine A, and Ailsa E. Millen
2010 Human cumulative culture in the laboratory: Effects of (micro) population size. *Learning & Behavior* 38(3):310–318.

Carlino, Gerald A, Satyajit Chatterjee, and Robert M Hunt
2007 Urban density and the rate of invention. *Journal of Urban Economics* 61:389–419.

Chatters, James C.
1998 Environment. In *Handbook of North American Indians: Plateau*, edited by Deward E. Walker, pp. 29–48. Smithsonian Institution, Washington, DC.

Collard, M., M. Kemery, and S. Banks
2005 Causes of toolkit variation among hunter-gatherers: a test of four competing hypotheses. *Canadian Journal of Archaeology* 29(1):1–19.

Collard, Mark, Briggs Buchanan, Michael J O Brien, Mark Collard, Briggs Buchanan, and Michael J O Brien
2013 Population Size as an Explanation for Patterns in the Paleolithic Archaeological Record: More Caution Is Needed. *Current Anthropology* 54(S8):S388–S396.

Collard, Mark, Briggs Buchanan, Jesse Morin, and Andre Costopoulos
2011 What drives the evolution of hunter-gatherer subsistence technology? A reanalysis of the risk hypothesis with data from the Pacific northwest. *Philosophical Transactions of the Royal Society B: Biological Sciences* 366(1567):1129–1138.

Collard, Mark, Briggs Buchanan, Michael J. O'Brien, and Jonathan Scholnick
2013 Risk, mobility or population size? Drivers of technological richness among contact-period western North American hunter-gatherers. *Philosophical Transactions of the Royal Society B: Biological Sciences* 368(1630).

Collard, Mark, Briggs Buchanan, April Ruttle, and Michael J. O'Brien
2011 Niche Construction and the Toolkits of Hunter–Gatherers and Food Producers. *Biological Theory* 6(3):251–259.

Collard, Mark, Krist Vaesen, Richard Cosgrove, Wil Roebroeks, and Mark Collard
2016 The empirical case against the 'demographic turn' in Palaeolithic archaeology. *Philosophical Transactions of the Royal Society B: Biological Sciences* 371(1698).

Croes, Dale R., and Steven Hackenberger
1988 Hoko River Archaeological Complex: Modeling Prehistoric Northwest Coast Economic Evolution. In *Prehistoric Economies of the Pacific Northwest Coast, Research in Economic Anthropology*, edited by Barry Issac, pp. 19–85. JAI Press, Greenwich, CT.

Demps, Kathryn, Francisco Zorondo-rodríguez, Claude García, and Victoria Reyes-García
2012 Social learning across the life cycle: cultural knowledge acquisition for honey collection among the Jenu Kuruba , India. *Evolution and Human Behavior* 33(5):460–470.

Derex, Maxime, Marie-pauline Beugin, Bernard Godelle, and Michel Raymond
2013 Experimental evidence for the influence of group size on cultural complexity. *Nature* 503(7476):389–391.

Deur, Douglas
2002 Rethinking precolonial plant cultivation on the Northwest Coast of North America. *The Professional Geographer* 54(2):140-157.

Deur, Douglas, Adam Dick (Kwaxsistalla), Kim Recalma-Clutesi (Ogwi'low'qwa), and Nancy J. Turner
2015 Kwakwaka'wakw "Clam Gardens": Motive and agency in traditional Northwest Coast mariculture. *Human Ecology* 43(2):201-212.

Dev, S, and F Riede
2012 Quantitative functional analysis of Late Glacial projectile points from northern Europe. *Lithics* 33:40–55.

Ericsson, K Anders, and Neil Chamess
1994 Expert Performance: Its Structure and Acquisition. *American Psychologist* 49(8):725–747.

Fay, Nicolas, Naomi De Kleine, Bradley Walker, and Christine A Caldwell
2019 Increasing population size can inhibit cumulative cultural evolution. *Proceedings of the National Academy of Sciences* 116(14):6726–6731.

Fladmark, Knut R
1975 A paleoecological model for northwest coast prehistory. National Museums of Canada, Ottawa.

Fogarty, Laurel, and Nicole Creanza
2017 The niche construction of cultural complexity: Interactions between innovations, population size and the environment. *Philosophical Transactions of the Royal Society B: Biological Sciences* 372(1735).

Fulton, Leonard A
1970 Spawning Areas and Abundance of Steelhead Trout and Coho, Sockeye, and Chum Salmon in the Columbia River Basin: Past and Present. *U S Fish Wildl Serv Spec Sci Rep Fish* 618:1–37.

Froese, R., and D. Pauly
2019 FishBase. www.fishbase.org, accessed May 15, 2019.

Good, Thomas P., Timothy J. Beechie, Paul McElhany, Michelle M. McClure, and Mary H. Ruckelshaus
2007 Recovery Planning for Endangered Species Act-listed Pacific Salmon: Using Science to Inform Goals and Strategies. *Fisheries* 32(9):426–440.

Grier, Colin
2003 Dimensions of Regional Interaction in the Prehistoric Gulf of Georgia. *Emerging from the Mist: Studies in Northwest Coast Culture History*:170–187.

Groesbeck, Amy S., Kirsten Rowell, Dana Lepofsky, and Amy K. Salomon
2014 Ancient clam gardens increased shellfish production: Adaptive strategies from the past can inform food security today. *PLoS One* 9(3):e91235.

Grove, Matt
2016 Population density, mobility, and cultural transmission. *Journal of Archaeological Science* 74:75–84.

Hattori, Shiho
2007 Variability of Plant Knowledge concerning Vernacular Names of Plants and Their Uses among Adult Baka Hunter-gatherers in Cameroonian Rainforests. *Journal of African Studies* 2007(71):21–40.

Henrich, Joseph
2004 Demography and Cultural Evolution: How Adaptive Cultural Processes can Produce Maladaptive Losses: The Tasmanian Case. *American Antiquity* 69(2):197–214.
2006 Understanding Cultural Evolutionary Models: A Reply to Read's Critique. *American Antiquity* 71(4):771–782.

Henshilwood, Christopher S, Christopher S Henshilwood, Francesco Errico, Royden Yates, Zenobia Jacobs, Chantal Tribolo, Geoff A T Duller, Norbert Mercier, Judith C Sealy, Helene Valladas, Ian Watts, and Ann G. Wintle
2002 Emergence of Modern Human Behavior: Middle Stone Age Engravings from South Africa. *Science* 1278(2002):1278–1280.

Hewlett, Barry S., and L. L. Cavalli-Sforza
1986 Cultural Transmission among Aka Pygmies Author. *American Anthropologist* 88(4):922–934.

Hopkinson, Terry, April Nowell, and Mark White
2013 Life Histories, Metapopulation Ecology, and Innovation in the Acheulian. *PaleoAnthropology* 2013:61–76.

James, Hannah V.A, and Michael D. Petraglia
2005 Modern Human Origins and the Evolution of Behavior in the Later Pleistocene Record of South Asia. *Current Anthropology* 46(S5):S3–S27.

Jorgensen, Joseph G.
1980 *Western Indians*. W.H. Freeman and Company, San Francisco.

Kelly, Robert L.
1995 The Foraging Spectrum: Diversity in Hunter-Gatherer Lifeways. Smithsonian Institution, Washington, DC.

Kempe, Marius, and Alex Mesoudi
2014 An experimental demonstration of the effect of group size on cultural accumulation. *Evolution and Human Behavior* 35(4):285–290.

Klein, Richard G, and Teresa E Steele
2013 Archaeological shell fi sh size and later human evolution in Africa. *Proceedings of the National Academy of Sciences* 110(27):10910–10915.

Kline, Michelle A, and Robert Boyd
2010 Population size predicts technological complexity in Oceania. *Proceedings of the Royal Society B-Biological Sciences* 277(1693):2559–2564.

Kline, Michelle Ann, Robert Boyd, and Joseph Henrich
2013 Teaching and the life history of cultural transmission in Fijian villages. *Human Nature* 24(4):351-374.

Kobayashi, Yutaka, and Kenichi Aoki
2012 Innovativeness , population size and cumulative cultural evolution. *Theoretical Population Biology* 82(1):38–47.

Langley, Michelle C, Christopher Clarkson, and Sean Ulm
2011 From small holes to grand narratives: The impact of taphonomy and sample size on the modernity debate in Australia and New Guinea. *Journal of Human Evolution* 61(2):197–208.

Leacock, Eleanor Burke, and Richard B Lee
1982 Introduction. In *Politics and history in band societies*, edited by Eleanor Burke Leacock and Richard B Lee, pp. 1–19. Cambridge University Press, Cambridge.

Lepofsky, Dana, Ken Lertzman, Douglas Hallett, and Rolf Mathewes
2005 Climate Change and Culture Change on the Southern Coast of British Columbia 2400-1200 Cal. B.P.: An Hypothesis. *American Antiquity* 70(2):267–293.

Lepofsky, Dana, Nicole F. Smith, Nathan Cardinal, John Harper, Mary Morris, Gitla (Elroy White), Randy Bouchard, Dorothy I.D. Kennedy, Anne K. Salomon, Michelle Puckett, Kirsten Rowell, and Eric McLay
2015 Ancient shellfish mariculture on the Northwest Coast of North America. *American Antiquity* 80(2):236-259.

Macdonald, Katharine
2007 Cross-cultural Comparison of Learning in Human Hunting: Implications for Life History Evolution. *Human Nature* 18:386–402.

Matson, Richard Ghia
1983 Intensification and the Development of Cultural Complexity: The Northwest Versus the Northeast. In *The Ecolution of Maritime Cultures on the Northeast and the Northwest of America*, edited by Ronald J Nash, pp. 125–148. Simon Fraser University, Burnaby, BC.
1992 The Evolution of Northwest Coast Subsistence. In *Long-Term Subsistence Change in Prehistoric North America*, edited by Dale R. Croes, R. Hawkins, and B. L. Issac, pp. 367–428. JAI Press, Greenwich, CT.

Matson, Richard Ghia, and Gary Graham Coupland
1995 The prehistory of the Northwest Coast. Academic Press, San Diego.

McBrearty, Sally, and Alison S Brooks
2000 The Revolution That Wasn't: A New Interpretation of the Origin of Modern Human Behavior. *Journal of Human Evolution* 39:453–563.

Mellars, Paul
1991 Cognitive Changes and the Emergence of Modern Humans in Europe. *Cambridge Archaeological Journal* 1(1):63–76.
2005 The Impossible Coincidence. A Single-Species Model for the Origins of Modern Human Behavior in Europe. *Evolutionary Anthropology* 14:12–27.

Mesoudi, Alex
2011 Variable Cultural Acquisition Costs Constrain Cumulative Cultural Evolution. *PLoS ONE* 6(3):15-17.

Mitchell, Donald Hector
1971 Archaeology of the Gulf of Georgia area, a natural region and its culture types. British Columbia Provincial Museum, Victoria, BC.

Mithen, S.
2005 The singing Neanderthals: the origins of music, language, mind and body. Weidenfeld and Nicholson, London.

Muthukrishna, Michael, Ben W Shulman, Vlad Vasilescu, and Joseph Henrich
2014 Sociality influences cultural complexity. *Proceedings of the Royal Society B-Biological Sciences* 281(1774).

Nakahashi, Wataru
2014 The effect of cultural interaction on cumulative cultural evolution. *Journal of Theoretical Biology* 352:6–15.

National Research Council
1996 Upstream: Salmon and Society in the Pacific Northwest. The National Academies Press, Washington, DC.

Nehlsen, W., J.E. Williams, and J.A. Lichatowich
1991 Pacific salmon at the crossroads: Stocks at risk from California, Oregon, Idaho, and Washington. *Fisheries* 16(4–21).

Nelson, Margaret C, Michelle Hegmon, Stephanie R Kulow, Matthew A Peeples, Keith W Kintigh, and Ann P Kinzig
2011 Resisting Diversity: a Long-Term Archaeological Study. *Ecology and Society* 16(1):25.

O'Connell, James F, and Jim Allen
2007 Pre-LGM Sahul (Pleistocene Australia-New Guinea) and the Archaeology of Early Modern Humans. In *Rethinking the human revolution: new behavioural and biological perspectives on the origin and dispersal of modern humans*, pp. 395–410. McDonald Institute for Archaeological Research, Cambridge, UK.

Ohmagari, Kayo, and Fikret Berkes
1997 Transmission of Indigenous Knowledge and Bush Skills Among the Western James Bay Cree Women of Subarctic Canada. *Human Ecology* 25(2):6–25.

Osborn, Alan J.
1999 From global models to regional patterns: possible determinants of Folsom hunting weapon design diversity and complexity. In *Folsom lithic technology, explorations in structure and variation*, edited by Daniel S. Amick, pp. 188–213. International Monographs in Prehistory, Ann Arbor, MI.

Oswalt, Wendell H.
1973 *Habitat and Technology*. Rinehart & Winston, New York.
1976 *An Anthropological Analysis of Food-Getting Technology*. Wiley-Interscience, New York.

Powell, Adam, Stephen Shennan, and Mark G. Thomas
2009 Late Pleistocene demography and the appeareance of modern human behavior. *Science* 324(5932):1298–1301.

Premo, L S, and Steven L Kuhn
2010 Modeling Effects of Local Extinctions on Culture Change and Diversity in the Paleolithic. *PLoS ONE* 5(12).

Pynn, Larry
2018 Ottawa spends $5.7 million on deer eradication in Haida Gwaii featuring New Zealand sharpshooters. *Vancouver Sun* 11 April. Vancouver

Quinn, Thomas P.
1988 Estimated swimming speeds of migrating adult sockeye salmon. *Canadian Journal of Zoology* 66(10):2160–2163.

Read, Dwight
2006 Tasmanian Knowledge and Skill: Maladaptive Imitation or Adequate Technology? *American Antiquity* 71(1):164–184.
2008 An Interaction Model for Resource Implement Complexity Based on Risk and Number of Annual Moves. *American Antiquity* 73(4):599–625.

Riede, Felix
2008 The Laacher See-eruption (12 , 920 BP) and material culture change at the end of the Allerød in Northern Europe. *Journal of Archaeological Science* 35:591–599.

Roos, John F.
1991 Restoring Fraser River salmon : a history of the International Pacific Salmon Fisheries Commission, 1937-1985 / by John F. Roos. Edited by Pacific Salmon Commission. Vancouver : Pacific Salmon Commission.

Schalk, R.L.
1977 The Structure of an Anadromous Fish Resource. In *For Theory Building in Archaeology*, edited by Lewis R. Binford, pp. 207–249. Academic Press, Orlando, FL.

Schiffels, Stephan, and Richard Durbin
2014 Inferring human population size and separation history from multiple genome sequences. *Nature Genetics* 46(8):919–925.

Scholz, Allan, Kate O'Laughlin, David Geist, Jim Ueharra, Dee Peone, Luanna Fields, Todd Kleist, Ines Zozaya, Tim Peone, and Kim Teesatuskie
1985 Compilation of information on salmon and steelhead total run size, catch and hydropower related losses in the upper Columbia river basin, above Grand Coulee Dam. Eastern Washington University. Cheney, Washington.

Service, Elman R
1979 *The hunters.* 2d ed. Prentice-Hall. Englewood Cliffs, NJ.

Shennan, SJ Stephen
2001 Demography and Cultural Innovation: a Model and its Implications for the Emergence of Modern Human Culture. *Cambridge Archaeological Journal* 11(01):5–16.

Shott, M. J.
1986 Technological and Settlement Mobility : Examination. *Journal of Anthropological Research* 42(1):15–51.

Stiner, Mary C., and Steven L. Kuhn
2006 Changes in the "Connectedness" and Resilience of Paleolithic Societies in Mediterranean Ecosystems. *Human Ecology* 34(5):693–712.

Suttles, Wayne
1968 Coping with Abundance: Subsistence on the Northwest Coast. In *Man The Hunter*, edited by Richard B. Lee and Irven DeVore. Aldine Publishing Company, Chicago.
1990 Environment. In *Handbook of North American Indians: Northwest Coast*, edited by Wayne Suttles, pp. 16–29. Smithsonian Institution, Washington, DC.

Tehrani, Jamshid J, and Mark Collard
2009 On the relationship between interindividual cultural transmission and population-level cultural diversity: a case study of weaving in Iranian tribal populations. *Evolution and Human Behavior* 30(4):286–300.

Torrence, Robin
1983 Time budgeting and hunter-gatherer technology. In *Hunter-gatherer economy in prehistory*, edited by Geoff Bailey, pp. 11–22. Cambridge University Press, Cambridge, UK.

1989 Retooling: Towards a behavioral theory of stone tools. In *Time, Energy and Stone Tools*, edited by Robin Torrence, pp. 57–66. Cambridge University Press, Cambridge.

2000 Hunter-gatherer technology: macro- and microscale approaches. In *Hunter-gatherers: an interdisciplinary perspective*, edited by Catherine Panter-Brick, Robert H. Layton, and Peter Rowley-Conwy, pp. 99–143. Cambridge University Press, Cambridge, UK.

Turner, Nancy J.

1999 "Time to Burn": Traditional use of fire to enhance resource production by Aboriginal Peoples in British Columbia. In *Indians, fire and the land in the Pacific Northwest*, edited by R. Boyd, pp. 185-218. Oregon State University Press, Corvallis, OR.

Vaesen, Krist

2012 Cumulative Cultural Evolution and Demography. *PLoS ONE* 7(7): e40989.

Vaesen, Krist, Mark Collard, Richard Cosgrove, and Wil Roebroeks

2016 Population size does not explain past changes in cultural complexity. *Proceedings of the National Academy of Sciences* 113(16):E2241–E2247.

Webber, Jason D., Stephanie N. Chun, Teresa R. MacColl, Leslie T. Mirise, Ayako Kawabata, Emily K. Anderson, Tae Sung Cheong, Lev Kavvas, Maureen Gee McRotondo, Karen L. Hochgraf, Roger Churchwell, and Joseph J. Cech

2007 Upstream Swimming Performance of Adult White Sturgeon: Effects of Partial Baffles and a Ramp. *Transactions of the American Fisheries Society* 136(2):402–408.

Wissler, Clark

1917 The American Indian: an introduction to the anthropology of the New World. Douglas C. McMurtrie, New York.

Woodburn, James

1980 Hunters and Gatherers Today and Reconstruction of the Past. In *Soviet and Western Anthropology*, edited by A. Gellner, pp. 95–117. Duckworth, London.

Appendix A.
Technological and Ecological Data for Cultures

Cultures	Technological Variables				Ecological Variables											
	STS	TTS	AVE	MXT	MCM (°C)	MWM (°C)	ET (°C)	RMEAN (mm)	RHIGH (mm)	RLOW (mm)	GS	NAGP	AVLSAL	SALMED	SALVAR (%)	SALSP
Coast																
Alsea	21	98	4.67	30	7.4	14.7	12.46	1707.6	274.8	20.8	7	633.54	89427	46468	32.11	4.3
Haida	22	106	4.82	34	3.1	15	12.01	1440.3	223.8	61.4	6	850.97	3291750	122500	243.51	5.3
Kwakwaka'wakw	49	277	5.65	47	3.3	14.1	11.74	1808.2	283.7	54.4	6	836.90	807450	154600	60.54	6.3
Lower Chinook	24	90	3.75	21	5.9	16.1	12.67	1708.4	283.2	26.2	7	846.96	2829960	1838196	19.05	6.0
Makah	18	85	4.72	41	4.7	15.3	12.28	2528.3	394.2	50.3	7	922.43	9770	2649	43.84	6.0
Northern Coast Salish	42	227	5.40	40	3	17.6	12.69	1100.3	194.2	29.7	7	569.30	3605578	1375763	42.29	6.7
Nuu chah nulth	35	228	6.51	49	4.5	14.8	12.10	3257.4	471.2	76.8	7	643.11	201223	55167	64.64	7.0
Quinault	29	172	5.93	50	4.1	15.9	12.38	2766.3	427.5	55.6	7	921.38	72466	34388	45.65	4.3
Straits Salish	50	230	4.60	43	4.5	16.1	12.48	715.3	122.4	20.3	7	544.17	3465891	1273989	47.25	7.0
Tlingit	29	127	4.38	34	-2.2	12.4	10.85	3940.0	413.5	162.3	5	756.34	145416	82393	29.32	7.0
Twana	46	237	5.15	44	3.7	17.9	12.85	2281.9	407.7	27.9	7	701.91	234658	33739	89.93	6.3
Upper Stó:lō	23	123	5.35	37	2.3	18.5	12.81	1680.0	257.3	54.3	7	579.45	3057613	834271	64.00	6.7
Coast Average	**32.33**	**166.67**	**5.08**	**39.17**	**3.7**	**15.7**	**12.28**	**2077.8**	**312.8**	**53.3**	**6.7**	**733.87**	**1484267**	**487843.6**	**65.18**	**6.1**
Plateau																
Bitterroot Salish (Flathead)	19	109	5.74	35	-2.9	20.4	12.66	394.5	61.0	18.3	6	362.06	392290.9*	12859**	9.06	4.0
Klamath	43	150	3.49	30	-1.8	17.4	12.19	527.8	113.3	10.7	5	286.73	58070[†]	13386[†]	93.23	2.0
Modoc	19	62	3.26	19	-0.4	19.1	12.64	307.1	37.1	8.1	6	195.11	0	0	0	1.0
Niimíipuu (Nez Percé)	22	88	4.00	28	0.9	23.6	13.54	213.7	40.9	16.8	6	503.35	48618	44317	13.43	3.5
Nlaka'pamux (Thompson)	31	169	5.45	35	-2.4	21.4	12.87	338.7	49.1	14.4	6	243.94	1743401	50528	843.48	5.0
N'pooh-le (Sanpoil) and Nespelem	31	163	5.26	41	-2.2	23.4	13.19	275.3	47.2	6.6	7	232.06	390366.9*	12859**	9.06	3.3
Schitsu'umsh (Coeur D'Alene)	33	144	4.36	34	-1.2	20.6	12.84	652.3	94.5	22.1	7	415.74	390366.9*	12859**	9.06	4.0
Secwepemc (Shuswap)	43	221	5.14	39	-4.6	19.3	12.33	390.1	46.2	11.2	5	488.99	108476	36267	43.23	4.5

Cultures	Technological Variables				Ecological Variables											
	STS	TTS	AVE	MXT	MCM (°C)	MWM (°C)	ET (°C)	RMEAN (mm)	RHIGH (mm)	RLOW (mm)	GS	NAGP	AVLSAL	SALMED	SALVAR (%)	SALSP
St'at'imc (Lillooet)	22	132	6.00	35	-3.2	16.1	11.79	850.1	138.0	47.5	7	305.53	449952	108806	64.35	6.5
Syilx (Okanagon)	23	133	5.78	35	-3.8	19.1	12.36	298.0	40.7	7.8	7	255.58	893138.9*	85753	122.79	3.0
Plateau Average	**28.60**	**137.10**	**4.85**	**33.10**	**-2.2**	**20.0**	**12.64**	**434.7**	**66.8**	**16.4**	**6.2**	**328.91**	**447468.1**	**37763.4**	**134.19**	**3.7**

*** AVLSAL from 14% of Total Columbia data, with the inclusion of limited data from non-dammed watersheds**
**** SALMED from historical Sockeye counts in the Upper Columbia from 1935-37**
[1] Data from several combined Lower Klamath tributaries

Appendix B.
Ethnographic Sources for Toolkit Data

Barnett, H.G.
1937 *Culture Element Distributions: VII, Oregon Coast*. University of California Press, Berkeley.
1975 *The Coast Salish of British Columbia*. Greenwood Press, Westport, CT.

Barrett, Samuel A.
1910 The material culture of the Klamath Lake and Modoc Indians of northeastern California and southern Oregon. University of California Press, Berkeley.

Boas, Franz
1909 The Kwakiutl of Vancouver Island. AMS Press, New York.

Dawson, George M.
1880 On the Haida Indians of the Queen Charlotte Islands. Dawson Brothers, Montreal.

de Laguna, Frederica
1972 Under Mount Saint Elias: The history and culture of the Yakutat Tlingit. Smithsonian Institution Press, Washington.

Drucker, Philip
1939 *Contributions to Alsea Ethnography*. University of California Press, Berkeley.
1951 *The northern and central Nootkan tribes*. United States Government Printing Office, Washington.

Duff, Wilson
1952 The Upper Stalo Indians of the Fraser Valley, British Columbia. British Columbia Provincial Museum, Victoria, BC.

Elmendorf, William W.
1974 Structure of Twana Culture. Garland, New York.

Maud, Ralph (editor)
1978 [1899] The Salish People: The local contribution of Charles Hill-Tout, Volume I: The Thompson and the Okanagan. Talonbooks, Vancouver, BC.

Morice, A.G.
1893 Notes archaeological, industrial and sociological, on the Western Dénés with an ethnographical sketch of the same. Transactions of The Canadian Institute Session 1892-93.

Murdock, George P.
1934 The Haidas of British Columbia. In *Our Primitive Contemporaries*. The MacMillan Company, New York.

Olson, Ronald L.
1936 *The Quinault Indians*. University of Washington Press, Seattle.

Ray, Verne F.
1933 The Sanpoil and Nespelem Salishan Peoples of Northeastern Washington. University of Washington Press, Seattle.
1938 Lower Chinook Ethnographic Notes. University of Washington Press, Seattle.
1963 Primitive Pragmatists: The Modoc Indians of Northern California. University of Washington Press, Seattle.

Smith, Marian W.
1940 *The Puyallup-Nisqually*. AMS Press, New York.

Spier, Leslie
1930 *Klamath ethnography*. University of California Press, Berkeley.

Spinden, Herbert J.
1908 *The Nez Perce Indians*. Kraus Reprint Corporation, New York.

Suttles, Wayne P.
1974 The economic life of the Coast Salish of Haro and Rosario Straits. Garland, New York.

Swan, James G.
1857 Northwest Coast; Or, Three Years' Residence in Washington Territory. Ye Galleon Press, Fairfield, WA.
1870 The Indians of Cape Flattery, At the Entrance to the Strait of Fuca, Washington Territory. Collins, Philadelphia, PA.

Teit, James A.
1900 The Thompson Indians of British Columbia. AMS Press, New York.
1906 The Lillooet Indians. AMS Press, New York.
1909 The Shuswap. AMS Press, New York.
1930 The Salishan tribes of the Western Plateaus. United States Government Printing Office, Washington.

Voegelin, Ermine W.
1942 *Culture Element Distributions: XX, Northeast California*. Anthropological Records, Vol. 7, No. 2. University of California Press, Berkeley.

Waterman, Thomas T.
1920 *The whaling equipment of the Makah Indians*. University of Washington Press, Seattle.

Whelchel, David L.
1991 *Ozette Archaeological Project Research Reports, Volume III, Ethnobotany and Wood Technology.* Reports of Investigations 68. Department of Anthropology, Washington State University, Pullman, and National Park Service,Pacific Northwest Regional Office, Seattle.

Appendix C
Supplementary Data File

Description:

The accompanying Excel spreadsheet contains the compiled raw toolkit data for all cultures, as well as the data for subsistants associated with individual species. Each culture's data is contained in a separate tab, with the all the subsistants listed and the page number of the relevant ethnography. The associated prey of each subsistant is also noted.

The tab titled 'Associated Species Data' contains the data for tools associated with species. These data show how many subsistants/technounits were associated for each species for each culture, as well as overall averages for the Coast, Plateau, and Pacific Northwest as a whole. Boxes filled with red indicate that the species was absent from the given geographic area.

Filename:

Appendix Tables for All Cultures.xlsx