RESOURCE RELATIONSHIPS ALONG THE FRASER RIVER: A STABLE ISOTOPE ANALYSIS OF ARCHAEOLOGICAL FOODWAYS AND PALEOECOLOGICAL INTERACTIONS

by

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Resource relationships along the Fraser River: a stable isotope analysis of archaeological foodways and paleoecological interactions

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Abstract

Interactions between humans, ecologies and resources within British Columbia have been sustained over millennia through the active management of terrestrial, marine, and riverine resources as well as through relationships existing between human and nonhuman environmental counterparts. Looking specifically at domestic dogs as a species so closely coupled with human action and yet still connected to the non-human environment, this dissertation examines how stable isotope analysis of dog remains and other fauna can inform us about pre-contact human-animal relationships. By examining prehistoric foodways within the Fraser River watershed, this study is the first to investigate carbon, nitrogen, and sulphur isotopic signatures of domesticated dogs and other fauna (n=244)from seven archaeological sites situated along the Fraser River as a means of determining dietary paleoecological variability that existed both spatially and temporally. In examining dietary variability and the resource relationships that shape the social and communal basis for it, I first investigate ecological communities along the Fraser River through stable isotope analysis of fauna before focusing on human-dog interactions through isotopic analysis of dogs. From a view of ecological communities as holistic in their inclusion and integrative of human and non-human counterparts, these isotopic investigations of fauna that occupied such varied niches, practiced different subsistence strategies, and played manifold roles in their resource relationships, offer an understanding of the past that brings coherence while accounting for variability in the archaeological record.

iii

Lay Summary

Interactions between humans and resources in British Columbia have occurred since time immemorial through both the active management of plant and animal resources and the relationships existing between humans and animals. This study explores differences through time and both within and between different archaeological sites along the Fraser River in British Columbia by reconstructing diet and diet changes in dogs and other fauna. This study offers some of the only multi-isotope faunal analysis, incorporating carbon, nitrogen, and sulphur isotope data. Analyses demonstrate, as hypothesized, regionalspecific differences in diet across species and that aquatic species other than salmon were contributors to dog diet, a distinction that would not be isotopically visible if limited to carbon and nitrogen isotopic analyses. The contribution of this data to the breadth of isotopic research being conducted on zooarchaeological material will hopefully be substantial and beneficial to future research projects.

Preface

This dissertation is the original, unpublished, independent work by the author, A. Diaz.

Table of Contents

Abstract	i	ii
Lay Summa	aryi	iv
Preface		v
Table of Co	ontents	vi
List of Tab	les	x
List of Figu	res	xi
Acknowled	lgementsxi	iv
Dedication	x	۲
1 Introd	uction and Overview	1
1.1 Re	lational/holistic ecologies	6
1.2 Re	source relationships and relational foodways in British Columbia	8
1.3 Or;	ganization of Dissertation1	.0
2 Stable	Isotope Analysis in Archaeology 1	.2
2.1 Pri	inciples of Stable Isotope Analysis1	.3
2.1.1	Carbon 1	.4
2.1.2	Nitrogen 1	.6
2.1.3	Sulphur1	.7
2.1.4	Bone collagen and preservation criteria1	.9
2.1.5	Correction to modern data2	3
2.2 Pro	evious isotopic work	24

	2.2.1	Isotopic analyses in the Fraser Watershed	24
	2.2.2	Isotopic work on dogs	
	2.3 Ana	alytical Methods	
3	Archae	eological Context, Sites and Samples	
	3.1 Dog	gs in Archaeological Context	33
	3.1.1	Dogs and humans in the Fraser Watershed	35
	3.2 Lat	e Period Archaeology in the Fraser Watershed	
	3.2.1	Late Period Culture History and Relevant Archaeology Sites	39
	3.3 Site	es sampled	42
	3.3.1	DgRr-1: Crescent Beach	42
	3.3.2	DgRs-2: Tsawwassen	43
	3.3.3	DgRs-30: Water Hazard	43
	3.3.4	DhRp-17: Port Hammond	44
	3.3.5	EeRI-4: Bridge River	44
	3.3.6	EeRI-7: Keatley Creek	45
	3.4 Sus	san Crockford Project	46
4	Ecolog	y along the Fraser River	47
	4.1 Res	sults	47
	4.2 Int	ra-site variability	49
	4.2.1	Crescent Beach (DgRr-1)	49

4.2.2	St. Mungo (DgRr-2) and Glenrose (DgRr-6)	51
4.2.3	Port Hammond (DhRp-17)	52
4.2.4	Bridge River (EeRl-4)	53
4.2.5	Keatley Creek HP 7 (EeRl-7)	58
4.3 Dis	scussion	60
4.3.1	Inter-site variability for terrestrial fauna	61
4.3.2	Inter-site variability for aquatic fauna	67
4.3.3	Sulphur mechanisms in soil and water	71
5 Human Isotop	n-animal (Dog) interactions in the Fraser Watershed: Insights from Sta e Analysis	able 74
5.1 Re	sults	74
5.2 Int	tra-site variability	76
5.2.1	Tsawwassen (DgRs-2)	76
5.2.2	Water Hazard (DgRs-30)	79
5.2.3	Crescent Beach (DgRr-1)	79
5.2.4	Port Hammond (DhRp-17)	80
5.2.5	Bridge River (EeRl-4)	81
5.2.6	Keatley Creek HP 7 (EeRl-7)	82
5.3 Dis	scussion	83
5.3.1	Variability and consistency in dog diet along the Fraser River	83
5.3.2	Spatial and temporal variability among dogs	91
		viii

5.:	3.3	Dogs and Human Interaction	. 95
6 Co	nclu	sions and Overview	102
6.1	Ma	jor findings and archaeological implications	103
6.3	1.1	Locally variable resource relationships	103
6.3	1.2	Dog diet variability and consistency	105
6.3	1.3	Sulphur isotope analysis in British Columbia archaeology	106
6.2	Lin	nitations	108
6.3	Fut	ure research directions and potential applications	109
6.4	Cor	ncluding Remarks	110
Refere	nces		112
Appen	dix A	: Isotopic and Elemental Information for Sampled Fauna	144

List of Tables

Table 2.1 Summary of accepted standard ranges of collagen quality criteria, as described i published literature (Ambrose 1990; DeNiro 1985; Harbeck and Grupe 2009; Nehlich and	in
Richards 2009; van Klinken 1999)	. 22
Table 3.1 Sites sampled for the current project	. 32
Table 4.1 Mean faunal values for δ^{13} C and δ^{15} N	. 48
Table 4.2 Mean faunal values for δ^{34} S, along with associated measurements and means for δ^{13} C and δ^{15} N	- 49
Table 5.1 Mean carbon and nitrogen isotopic values and elemental data for dogs	. 77
Table 5.2 Mean sulphur isotopic values and elemental data for dogs	. 77
Table 5.3 Summary of Isotope Data for Temporal Periods across all sites	. 94

List of Figures

Figure 1.1 Map of sites sampled in current study. Map created by Alejandra Diaz using ArcGIS software (2016)2
Figure 3.1 Summary of British Columbia culture history; PPT refers to Plateau Pithouse Tradition (information from Matson and Coupland 1995; Stryd and Rousseau, 1995)
Figure 4.1 Carbon (A.) and nitrogen (B.) isotopic compositions of bone collagen for fauna from the DgRr-1 (Crescent Beach). Dot plots represent individual values; box plots show summary distributions of species groups
Figure 4.2 Bivariate multiplot of carbon and nitrogen isotopic compositions for DgRr-1 fauna
Figure 4.3 Scatterplot of carbon and nitrogen isotopic compositions for DgRr-1 fauna showing terrestrial (green ellipse) and aquatic (blue ellipse) resource groupings
Figure 4.4 Bivariate multiplot (A.) and scatterplot (B.) of carbon and nitrogen isotopic compositions for DgRr-2 and DgRr-6 fauna
Figure 4.5 Bivariate multiplot (A.) and scatterplot (B.) of carbon and nitrogen isotopic compositions for DhRp-17 fauna
Figure 4.6 Scatterplots of carbon and sulphur (A.) and nitrogen and sulphur (B.) isotopic compositions for DhRp-17 fauna
Figure 4.7 Carbon (A.) and nitrogen (B.) isotopic compositions of bone collagen for fauna from EeRl-4 (Bridge River). Dot plots represent individual values; box plots show summary distributions of species groups
Figure 4.8 Bivariate multiplot (A.) and scatterplot (B.) of carbon and nitrogen isotopic compositions for EeRl-4 fauna. The bottom right scatterplot (C.) shows significant terrestrial and aquatic resource groupings
Figure 4.9 Means plot of carbon (A.) and nitrogen (B.) isotopic compositions for each species group. Error bars represent 1 standard deviation56
Figure 4.10 Sulphur isotopic compositions of bone collagen for fauna from EeRl-4 (Bridge River). Dot plots represent individual values; box plots show summary distributions of species groups
Figure 4.11 Scatterplots of carbon and sulphur isotopic compositions for fauna from EeRl-4. The right scatterplot shows significant terrestrial and aquatic resource groupings
Figure 4.12 Scatterplots of nitrogen and sulphur isotopic compositions for fauna from EeRl-4. The right scatterplot shows significant terrestrial and aquatic resource groupings

Figure 4.13 Carbon (A.) and nitrogen (B.) isotopic compositions of bone collagen for fauna from EeRl-7 HP 7 (Keatley Creek). Dot plots represent individual values; box plots show summary distributions of species groups
Figure 4.14 Bivariate multiplot of carbon and nitrogen isotopic compositions for EeRl-7 HP 7 fauna
Figure 4.15 Sulphur isotopic compositions of bone collagen for fauna from EeRl-7 HP 7 (Keatley Creek). Dot plots represent individual values; box plots show summary distributions of species groups
Figure 4.16 Scatterplots of sulphur isotopic compositions with carbon values (left) and nitrogen values (right) for fauna from EeRl-7 HP 7
Figure 4.17 Box plots showing variability in carbon (A.) and nitrogen (B.) isotopic compositions in deer across sites sampled for the current study
Figure 4.18 Bivariate multiplot of carbon and nitrogen isotopic compositions for deer species across sites sampled for the current study
Figure 4.19 Carbon and Nitrogen values for aquatic species sampled in the current study 69
Figure 5.1 Scatterplot of carbon, nitrogen (A) and sulphur (B) isotopic compositions for dogs grouped by archaeological site
Figure 5.2 Carbon (left) and nitrogen (right) isotopic compositions of bone collagen for dogs from all sampled sites. Dot plots represent individual values; box plots show summary distributions of sites
Figure 5.3 Sulphur isotopic compositions of bone collagen for dogs from all sampled sites. Dot plots represent individual values; box plots show summary distributions of sites
Figure 5.4 Scatterplot of δ^{13} C and δ^{15} N values for dogs plotted with means and bivariate standard deviations (1SD) for other species groups
Figure 5.5 Scatterplots of δ^{34} S, δ^{13} C and δ^{15} N values for dogs plotted with means and bivariate standard deviations (1 SD) for other species groups
Figure 5.6 Graphs at left show scatterplots of carbon and nitrogen (a.), carbon and sulphur (b.) and nitrogen and sulphur (c.) isotopic compositions for domestic dogs with available temporal associations (n=133). Graphs at right show carbon (d.), nitrogen (e.), and sulphur (f.) isotopic compositions of bone collagen for domestic dogs grouped by temporal period. Dot plots represent individual values; box plots show summary distributions of temporal periods.
Figure 5.7 Bivariate scatterplot of carbon and nitrogen isotonic compositions for doas and

Figure 5.7 Bivariate scatterplot of carbon and nitrogen isotopic compositions for dogs and humans. Triangles represent humans, circles represent dogs. Green ellipse shows human

distribution, blue ellipse shows dog distribution. ^A Samples from Boston Bar were analyzed as	
part of the current study	6

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For my Dad

1 Introduction and Overview

"Pacific Coast societies were resource managers who had established long-term relationships not only with resource territories but also with the plant and animal persons with they shared their worlds."

- Moss and Cannon (2011:2)

Domestic dogs (*Canis familiaris*) were the first domesticated animals and have been found in association with human activity for at least the past 14,000 years in virtually every region of the world (Benecke 1987; Clutton-Brock 1995; Napierala and Uerpmann 2012). As the earliest animal domesticate, dogs offer unique challenges and potential insights into their relationship with humans as they occupied many different roles. In British Columbia, dogs provide a unique example of the interactions between humans and non-human species throughout prehistory and into the present. Ethnographic studies from many First Nations of British Columbia document the relationship between dogs and their masters that encompassed multiple levels of interactions, including economic, strategic, spiritual, social, and dietary exchanges. Likewise, archaeological research throughout British Columbia demonstrates that dogs have frequently been found in many contexts: in and around household remains, in association with human burials (Cybulski 1992; Digance 1986) and in intentional burials of their own (Digance 1986; Suttles 1987).

The current research focuses on the question of how the analysis of archaeological dog remains from a specific region of British Columbia—the Fraser River watershed—can inform us about long-term changes and continuities in human-animal relationships. Undeniably, interactions between humans and their environments within British Columbia have been sustained over millennia through active management of, and

interactions with, terrestrial, marine, and riverine resources. Discussions of relationships between human and non-human entities require the involvement in, and engagement with, holistic ecologies (Ingold 2000; Losey 2010; Martinez 2005; Pierotti 2011), and places archaeological investigations of diet and mobility at the forefront of understanding these complex and often overlooked relationships.

Looking specifically at prehistoric foodways within the Fraser River watershed, this study is the first to investigate carbon, nitrogen, and sulphur isotopic signatures of domesticated dogs and other fauna (n=244) from seven archaeological sites situated in two different regions of the Fraser River drainage—the Coast and the Interior—as a means of determining dietary and paleoecological variation in different environments and through time (Figure 1.1).



Figure 1.1 Map of sites sampled in current study. Map created by Alejandra Diaz using ArcGIS software (2016).

Previous studies have noted human diet variability between coastal and interior regions in British Columbia but, largely out of methodological necessity, had to focus on marine contributions to archaeological subsistence (Chisholm and Nelson 1983:85-86; Chisholm 1986; Lovell et al. 1986; Schwarcz et al. 2014). More recent ethnographic and archaeological research has consistently indicated that First Nations peoples incorporated a broad spectrum of foods in their diets, reflecting widespread movement throughout their environments, extensive trade and interaction with neighbouring peoples, and long-lasting, complex relationships with all components of their land and waterscapes (Ames and Marshall 1980:25-52; Moss 2012; Moss et al. 2006; Turner 2005). Recent work involving zooarchaeological assemblages has similarly revealed greater species diversity (Cannon 2000; McKechnie 2013), and a greater heterogeneity in the development and specialization of local subsistence economies than expected or predicted by broad regional models (Cannon and Yang 2006; Cannon et al. 2011; McMillan et al. 2008; Monks 2006; Moss 2012; Orchard 2009; Orchard and Clark 2014), underlining the necessity for a greater consideration of local subsistence variation. Complementing this body of research, isotopic analyses of archaeological remains can provide *direct* measures of food uses and mobility patterns and help us refine their spatial and temporal distribution and significance. Variation in proportions of stable isotopes in animal bones resulting from foraging practices, life histories and relationships of animals can identify patterns of local ecological variability at the level of the individual or the population within larger, more diverse species (Orchard and Szpak 2015).

In investigating resource relationships between domesticated dog and other fauna and paleoecological variability along the Fraser River, several research questions that address potential changes in resource interactions and relationships between dogs, humans, and other animals will be examined:

- 1. Previous isotopic analyses of the diets of dog remains recovered from archaeological sites in British Columbia indicate that marine-based protein, most frequently interpreted as having derived from salmon, was a major dietary contributor. These studies however, were either limited to single time periods or single sites. In contrast, this study will examine samples from seven different sites representing, in many cases, multiple time periods in order to address the question: did the contribution of marine-derived protein change either temporally or spatially?
- 2. Uncertainty persists over the extent of diversity in marine and riverine species exploited; some place singular emphasis on keystone species, while others propose a more diffuse and variable resource base (e.g., Ames and Maschner 1999; Matson and Coupland 1995; McKechnie 2013). The addition of sulphur isotope analysis to the more commonly relied upon carbon and nitrogen isotope analyses can help us to differentiate between riverine and marine resource consumption (Mowat et al. 2017; Nehlich 2015; Nehlich et al. 2014). Such a distinction is otherwise masked when analyzing only carbon and nitrogen isotope ratios. This will allow me to address the question of whether or not the contribution of freshwater aquatic resources is visible in isotopic signatures, especially in those of domestic dogs. I hypothesize that non-marine aquatic

resources were undoubtedly part of human diet and—and possibly dog diets as well—and if so, I would expect it to be identified by sulphur isotope analysis.

- 3. Viewing ecologies as holistic and integrative of human and non-human community members, the isotopic investigation of animal remains becomes a complementary and parallel examination of lived interspecies relationships and interactions. Isotopic analyses are regularly utilized in ecological studies to assess a wide variety of problems ranging from trophic dynamics to reconstructing the diet or foraging ecology of an animal. Given this, how are relationships between resources and species groups characterized isotopically and within the Fraser River watershed, is there spatial, intra- and inter-species variability that we can assess and define beyond simply providing a baseline for human isotopic data?
- 4. Finally, investigating dog diet allows indirect estimates of human diet if we can assume that dogs can serve as potential proxies for humans. This of course assumes that humans and their dogs consumed similar ranges of foods— something that needs to be estimated as part of this study. This leads directly to the following research question: is dog diet similar to human diet both temporally and spatially? I hypothesize that while low resolution comparisons may be made between dog and human diet, finer-grained dietary information may not show the same degree of similarity. One key research objective, therefore is to assess the degree of similarity between humans and dogs with respect to their diets as indicated by isotopic analyses.

The remainder of this chapter will introduce the theoretical perspectives informing my interpretations of archaeological ecologies, foodways, and human-nonhuman relationships, before discussing the chapter organization and layout of the dissertation.

1.1 Relational/holistic ecologies

The perspective of ecologies as holistic and integrative in their inclusion of all organisms provides an important framework for this study and presents a perspective that is fundamental in recognizing how all persons, both human and non-human, may have interacted in the past and how we can identify relationships through isotopic analysis. By focusing on the processes of and relations between humans and resources within their ecological communities, this dissertation discusses data derived from isotopic analysis using an ecological approach that situates practitioners in the context of an active engagement with the constituents of their surroundings. This perspective follows relatively recent anthropological and archaeological discussions of the perception of the environment and the relationships between human and non-humans in understanding ecologies holistically (Cannon 2011; Ingold 2000, 2011; Losey 2010). Considering 'subsistence strategies' that have been applied to complex hunter-gatherer groups in British Columbia, the term 'hunter-gatherer' has been problematized in recent literature as being embedded with a dualistic partitioning of the environment and human groups. More problematically, these are offered as bounded entities in their own right; environmental backdrops or constraints on the one hand and social or economic beings on the other (e.g., Moss. 2011; Moss 2014). Ingold (2000:4) notes that the physical organism and 'cultural' person, often conceived as separate components of a human being, need to be understood, rather, that persons are organisms, where "the

principles of relational thinking, far from being restricted to the domain of human sociality, must be applicable right across the continuum of organic life". Sociality and interaction, therefore, becomes a material object that is produced when persons interact.

While considering humans and non-human entities as nodes in a field of relationships isn't a new idea, this view tends be overlooked in most archaeological practice in British Columbia where materialist and evolutionary-driven explanations have prevailed and where "human" and "natural" realms are seen as relatively separate. Despite this, I think most archaeologists working in the region would agree with Ingold (1993) that just as environments shape us, they are fundamentally historical and relational to the situated action and behaviour of all their denizens.

Interactions between the environment and inhabitants have been recognized as impacting the archaeological record in British Columbia, with processes as emergent properties of behaviour resulting in variability of site size, locations, and assemblages. These processes are realized through the acquired and learned perception achieved through local interactions and relations within a community, where, as Raymond Pierotti (2011:26) notes, should be conceived of as a community "in which human beings are considered to be part of ecological communities and nonhumans are considered to be a part of social communities". For example, Moss and Cannon (2011:2) commence their volume on North Pacific fisheries from a relational and humanistic ecological perspective, identifying Pacific Coast societies as resource managers "who had established long-term relationships not only with resource territories but also with the plant and animal persons with whom they shared their worlds".

The interactions between humans and non-humans in an archaeological context, then, similarly reflect interactions between counterparts, influencing and reflective of one another and their manifold relations within their local ecology. Archaeologists can perceive this ecological interaction at a fundamental level of integration and engagement: through isotopic signatures of the human and non-human organisms recovered from archaeological sites. These provide direct evidence of this essential level of interaction between community members, where ecologically derived signatures become an elemental, vital, and structural component of the individual. Arising from this ecological approach, two fundamental components contribute to the theoretical perspective of the present study; a relational model of foodways and resources and second, a model of resource relationships between humans and nonhumans.

1.2 Resource relationships and relational foodways in British Columbia

A relational model of foodways and mobility extends the application of a holistic ecology through considerations of how members of a local community interconnect and are involved in one another's subsistence and being. Drawing from Traditional Ecological Knowledge (TEK) and ethnographically documented indigenous land management practices (Anderson 2005; Deur and Turner 2005; Martinez 1998; Moss 2011; Pierotti 2011; Senos et al. 2006; Turner et al. 2000; Turner 2005), change is examined via a dwelling perspective, where the ecological counterparts are constituted through relations and involvement with one another.

Pierotti and colleagues (Pierotti 2011; Pierotti and Wildcat 2000) see the fundamental characterization of TEK as being based on close observation of nature and

natural phenomena. While it converges on Western scientific approaches, it also encompasses a concept of community membership that differs from that of "Western and political thought" (Pierotti 2011: 1333). Closely aligned with the holistic ecological community outlined previously, TEK is "strongly tied to specific physical localities...therefore all aspects of the physical space can be considered part of the community, including animals, plants, and landforms" (Pierotti 2011: 1334). TEK also emphasizes the idea that individual plants and animals exist on their own terms but relatedly, which leads to two basic TEK concepts: (1) all things are connected, which is conceptually related to Western community ecology, and (2) all things are related, which changes the emphasis from the human to the ecological community as the focus of theories concerning this involvedness.

Building on the perspective of ecologies that are wholly inclusive of all organisms then, relationships between human and non-human beings figure explicitly into recognizing and understanding these interactions in archaeological contexts. Ethnographic narratives detail indigenous worldviews, ways of negotiating within human-plant-animal relations (Hanna 1995), ways of recognizing "the point of vital connection between human beings and the Earth and all it represents" (Laforet 1998:62), and ways of understanding the relationships existing and having to be maintained, as noted by Richard Atleo (2005:ix): "since the salmon and human have common origins they are brothers and sisters of creation...If the salmon are not properly respected and recognized they cannot properly respect and recognize their human counterparts of creation". Recalling the often discussed notion of complexity,

changes and processes do not go from simple to complex, but from complex to complex, from equal to equal, from one-life form to another (Atleo 2005).

Losey demonstrates this perspective in his thoughtful assessment of fishing weir histories on the Northwest Coast. Noting that human-animal relationships are overwhelmingly defined by ecological parameters, which have in turn limited the questions researchers can ask or have tended to ask as well as restricted traditional definitions of what constitutes valid archaeological material, he turns to animistic understandings of the past and how people viewed their relations to animals and the technologies used to capture them. Losey (2010:18) stresses "...rather than dismissing animistic understandings as mistaken or mere metaphors, these approaches, and my own, take such perspectives as valid and highly revealing ways of understanding one's relationships in the world". Beyond animate relations, Bjarnar Olsen and colleagues (Olsen 2010; Olsen et al. 2012), have marked archaeology as fundamentally the science and study of old things, but things that involve the tangible mediation of past and present, and recognition that things are constitutive of our very being. The role of the archaeologist, then, is to make these networks of humans and non-humans visible, unburdened by "any central hero subjects - human, worldview, mind - we should envisage a brigade of actors... acting together" (Olsen 2010:145).

1.3 Organization of Dissertation

This dissertation is organized into four substantive chapters, excluding the introductory and concluding chapters. Chapter 2 discusses stable isotope analysis as a methodology, establishing the considerations necessary in assessing isotopic material, outlining the analytical methods and preservation criteria used in the current project,

and discussing previous isotopic work conducted in British Columbia. Chapter 3 presents the archaeological context of the samples studied with a focus on time periods and regions relevant to the current research project as well as discussing previous archaeological research on dogs conducted in the study area. Chapter 4 reports the carbon, nitrogen, and sulphur isotopic compositions of faunal and wild canids, and examines both intra- and inter-site patterns of diet and mobility in understanding the prehistoric ecology of the region under study. Building on Chapter 4, Chapter 5 presents and discusses carbon, nitrogen, and sulphur isotopic data of domestic dogs, investigating intra- and inter-site patterning as well as comparing dogs to other fauna and published human data for British Columbia late period sites in order to address the previously discussed research questions.

2 Stable Isotope Analysis in Archaeology

Stable isotope analysis has been used widely to reconstruct ancient diet (e.g., Van der Merwe and Vogel 1978; Ubelaker and Katzenberg 1995; Lee-Thorp et al. 1989; O'Connell and Hedges 1999; Privat et al. 2002) and more recently, to investigate potential mobility patterns of past populations (e.g., Craig et al. 2006; Nehlich et al. 2010; Richards et al. 2001). The archaeological reconstruction of diet using stable isotopes is predicated on the fact that there is a quantitative and systematic relationship between isotopic compositions of bodily tissues of an organism and that of its diet (Ambrose 1993; Ambrose and Norr 1993; Bocherens and Drucker 2003; DeNiro and Epstein 1978, 1981). Both carbon and nitrogen have been used in palaeodietary studies since the development of the methodology, from studies investigating the presence of maize (Katzenberg et al. 1995; Schoeninger 2009; van der Merwe 1982) to levels of Neanderthal carnivory (Richards et al. 2000).

Sulphur isotopes are now being more commonly employed in the suite of isotopic analyses, thanks in large part to technical advances in mass spectrometry. They can help differentiate between freshwater and terrestrial ecosystems and distinguish between the consumption of foods from different geographical regions (Krouse and Herbert 1988; Peterson and Fry 1987; Richards et al. 2001). This chapter will examine carbon, nitrogen, and sulphur analysis further, as well as discuss issues and concerns most relevant to the chronological, geographic, and climatic contexts of material deriving from British Columbia.

2.1 Principles of Stable Isotope Analysis

Isotopes, which are varieties of elements differing in the number of neutrons in their nuclei, occur naturally in the atmosphere in varying abundances. While the chemical properties attributed to isotopes of the same element are not dissimilar. additional neutrons add mass to atoms and molecules, which in turn, slows their rate of reaction relative to "lighter" isotopes. As differences in rates of movement and chemical reactions cause discrimination or fractionation, usually against the heavier isotopes of an element, it is possible to measure the selection for or against one of these isotopic elements having occurred during food uptake in an organism (Ambrose 1993; Chisholm 1989; Katzenberg 1992). The processes by which bone collagen, the material most often used for stable isotope analysis, forms and is remodeled are closely related to recorded isotopic dietary signatures. Bone remodels slowly over the life of an individual with the material making up the collagen portion of bone gradually exchanging with new materials derived from an individual's diet. Isotopic dietary signatures recorded in bone collagen then, provides a long-term averaged incorporation of diet, representing approximately 20 years for humans (Hedges et al. 2007; Ubelaker et al. 2006) and anywhere from six months to three years for dogs (Fisher et al. 2007; Martin et al. 1998; Noe-Nygaard et al. 1988).

Given heavy stable isotopes comprise a small portion of the distribution of an element and differences in the natural abundance of stable isotopes are usually very small (a few thousandths of a percent), the ratio of the heavier to the lighter isotope is measured relative to a standard as follows (after McKinney et al. 1950:730):

 δ_{sample} (%0) = (R_{sample}/R_{standard} - 1) x 1000,

where R is the ratio of the heavier to the lighter isotope (¹³C/¹²C, ¹⁵N/¹⁴N or ³⁴S/³²S for the current study). Carbon isotopic compositions are standardized relative to Vienna PeeDee Belemnite (VPDB) (Coplen 2011). Nitrogen is standardized relative to AIR (Mariotti 1983). Sulphur is standardized relative to Vienna Canyon Diablo Troilite (VCDT) (Faure 1986).

2.1.1 Carbon

Stable isotope analyses involving carbon have generally been used to study the relationship between the consumer and its diet in terrestrial environments, foraging behaviour (browsing vs. grazing), the incorporation of maize and other C4 plants in diets (e.g. van der Merwe and Vogel 1978) and in C3 exclusive biomes, comparing the contribution of isotopically enriched marine versus terrestrial protein, which reflects differences in the predominant source of carbon taken in by plants (i.e., dissolved bicarbonates vs. atmospheric carbon dioxide; see below) at the base of the food web (Chisholm et al. 1982; 1983), which is discussed below. δ^{13} C values represent the relative depletion of a body tissue in ¹³C to the standard Vienna PeeDee Belemnite (VPDB) (Coplen 2011) as the latter contains more ¹³C than nearly all dietary resources and most human tissues. Plant and animal values are thus displayed in negative figures, with C3 eating herbivores and their consumers averaging in around –22‰ and lower and C4 eating herbivores and their consumers averaging nearer to -10% (Kohn 2010; Schoeninger and DeNiro 1984). British Columbia, a region almost exclusively habituated by C3 plants but with marine, freshwater, and brackish aquatic watersheds dominating the landscape, has a complex aquatic isoscape that can be differentiated by δ^{13} C analyses to compare terrestrial versus marine protein inputs.

Biochemical fractions

Perhaps the most significant variation of plant δ^{13} C values is related to the biochemical fractions of a consumer's diet being incorporated into consumer tissue. Although all tissue in the body reflects diet, isotopic values between tissues differ, mainly attributed to differences in tissue composition and turnover time and synthesis from different constituents of the diet (Bocherens and Drucker 2003; DeNiro and Epstein 1978a, b; Hedges et al. 2006; Lee-Thorp et al. 1989). For example, plants are not chemically homogenous; rather, they are comprised of carbohydrates, lipids, and proteins that each differ in δ^{13} C values, are distributed differently among various plant tissues, and may be selectively chosen by herbivores (Ambrose 1993; Hedges et al. 2006). Along with these biochemicals differing isotopically themselves, carbon routing from the plant or animal to the consumer's various bodily tissues varies according to the overall diet and the tissue itself. Molecules from dietary protein, for example, particularly amino acids, are preferentially used in the construction of collagen and so bone collagen stable isotope values generally reflect the protein component of diet more than dietary lipid and carbohydrate intake (Ambrose and Norr 1993; Tieszen and Fagre 1993; see below). Further consideration will be given to bone collagen in the following section regarding carbon fractionation in each substrate as well as reasons for variation in δ^{13} C values.

Marine and Aquatic δ^{13} C variation

While the principles lying behind photosynthetic differentiation of stable isotope values in plants is fairly well understood, isotopic compositions in marine and aquatic ecosystems are more complex. δ^{13} C values in marine organisms are generally less

depleted than terrestrial fauna as dissolved CO₂ enriches oceanic carbon relative to atmospheric CO₂ (Schwarcz and Schoeninger 1991; Sealy 2005). In the Pacific Ocean bordering British Columbia, aquatic foodwebs are based on either pelagic phytoplankton, characterized by relatively low δ^{13} C values, or kelp and other benthic macroalgae, characterized by relatively high δ^{13} C values (Orchard and Szpak 2015). In addition to any differences in δ^{13} C that occur between these two groups of primary producers, environmental factors such as light intensity, growth rate, water temperature, water velocity, and salinity can all influence the extent to which δ^{13} C values are influenced in these aquatic plants (Raven et al. 2002). Carbon isotopic compositions on freshwater ecosystems can be similarly highly variable as the range of δ^{13} C values is affected by geology, sediments, and animal activity, among other factors. Plants in freshwater ecosystems similarly display variable δ^{13} C values that fall anywhere within the range of marine and terrestrial plants. (Hecky and Hesslein 1995; Zambrano et al. 2010).

2.1.2 Nitrogen

 δ^{15} N values reflect the amount of animal protein ingested by a consumer relative to the standard (AIR) (Ambrose 1993; DeNiro and Epstein 1981). Differences in δ^{15} N values can be used to distinguish marine from terrestrial foods (Schoeninger and DeNiro 1984; Sealy et al. 1987) and investigate levels of carnivory and piscivory (Bocherens et al. 1999; Richards et al. 2000, 2001). The nitrogen isotope composition of animal collagen reflects the source of nitrogen at the base of the food web which will vary by their environmental context, such as soil conditions and climate, and how nitrogen is incorporated into plant tissues. For example, legumes, which fix

atmospheric nitrogen, tend to have very low δ^{15} N values (DeNiro and Epstein 1981; Szpak 2014; Szpak et al. 2014).

The trophic level effect reflects the enrichment in δ^{15} N values between an individual's diet and their own body tissue (Schoeninger and DeNiro 1984; Ambrose 1993; Hedges and Reynard 2007). Trophic level enrichment from diet to consumer tissue ranges from +3% to +5% depending on species (Bocherens and Drucker 2003; DeNiro and Epstein 1981; Szpak et al. 2014). Additionally, while enrichment values have largely been based on global surveys from temperate environments, studies have shown significant variation between trophic levels within and between habitats, especially tropical ecosystems (Ambrose 1993; Heaton et al. 1986; Sealy et al. 1987; Sponheimer et al. 2003; Szpak 2014). Diet and the digestive physiology of animals (e.g., Ambrose 1991; Pearson et al. 2007; Sealy et al. 1987), starvation, including pregnancy and lactation effects (e.g., Fuller et al. 2006; Minagawa and Wada 1984), and the effects of climate and aridity, mainly reflecting water stress (e.g., Dupras and Schwarcz 2001; Handley et al. 1999; Hobson et al. 1993) have all been demonstrated to affect δ^{15} N values of an organism.

2.1.3 Sulphur

There have been comparatively few studies applying sulphur-based stable isotope analysis to archaeological material, with early studies focused mainly on assessing the amount of sulphur in bone collagen as an indicator of the preservation quality of the analyzed material (Richards et al. 2001; Craig et al. 2006; Privat et al. 2007). However, largely due to technical advances in mass spectrometry, especially online continuous flow (Giesemann et al. 1994) that allows the use of relatively small

amounts of collagen, sulphur isotope analysis of human bone collagen is more commonly being used to address questions of archaeological importance. Stable sulphur isotope values in bone collagen reflect dietary methionine sources, which is an essential amino acid with δ^{34} S values primarily obtained from the soluble sulphur (in soil, bedrock, and local water) taken up by plants at the base of a food web (Brady and Weil 1996). Applications utilizing sulphur isotope studies can also distinguish between freshwater and terrestrial ecosystems, especially when measured together with carbon and nitrogen isotope ratios. Isotopic differences between sulphur sources in marine and non-marine aquatic environments has allowed researchers to distinguish between marine and non-marine consumers by their δ^{34} S values (Krouse and Herbert, 1988; Weber et al., 2002).

Local soluble inorganic sulphur is a mixture of rainwater (5 to 10‰), groundwater (-5 to 10‰) and stream water (-20 to 10‰) (Nriagu et al., 1991). Accordingly, the δ^{34} S value in the available food for humans depends on the δ^{34} S values of the ecosystem. Ocean water sulphate (SO4) has a fairly uniform value of about +21‰ while continental geological formations exhibit a wide range of δ^{34} S values that vary over different areas of bedrock between -19‰ and +30‰ (Krouse et al., 1987; Peterson and Fry, 1987). The biological cycle of sulphur is in part characterized by the activity of sulphur oxidizing and reducing bacteria which together comprise the majority of contemporary turnover rates in the biosphere (Alexander, 1971; Baas-Becking, 1925; Postgate, 1959). Terrestrial plants have reported values averaging around -7‰ to +8‰ (Nriagu and Coker, 1978), with the exception of plants in coastal areas, which can exhibit δ^{34} S values close to that of seawater, due to the effect of sea

spray or precipitation high in marine sulphur (Kusakabe et al., 1976; Nehlich and Richards 2009; Richards et al. 2001).

There is also a broad distinction between sulphur which has and sulphur which has not become incorporated in the sedimentary cycle. Sulphur in meteorites, ultrabasic and basic sills, granitic intrusions, and igneous rocks of primary origin have δ^{34} S values narrowly distributed around zero while volcanic gases and rocks tend to have a wider range of δ^{34} S values distributed symmetrically around δ^{34} S = 0, with the range of values being due to a variety of inorganic chemical reactions and equilibria which tend to enrich oxidized forms of sulphur and deplete reduced forms of sulphur in ³⁴S (Grinenko and Thode, 1970; Hoefs, 1973; Puchelt et al., 1971; Rafter et al., 1960; Sakai, 1957).

2.1.4 Bone collagen and preservation criteria

Bone collagen

Collagen is the main component in the organic phase of bone, comprising approximately 20% of bone by weight, and does not vary significantly in its structure and amino acid composition among vertebrates (Ambrose 1993). Though the isotopic values of amino acids in collagen vary greatly and systematically, it is generally measured as a whole unless there are concerns of contamination or diagenesis. Diet to collagen spacing (Δ diet-col) is typically approximated at an average of -5±1.5‰ for mammals in natural ecosystems, though diet manipulation will certainly influence this fractionation (e.g., Bocherens and Drucker 2003; DeNiro and Epstein 1981; Schwarcz 1991; Tieszen and Boutton 1988). More recent attention has been given to the mechanisms involved in protein routing from the diet to consumer tissues. Krueger and Sullivan's (1984) model states, most generally, that the δ^{13} C value of collagen is a function of the growth substrate (protein), thus isotopically representing only the protein portion of the consumer's diet. Experiments feeding animals low-protein diets have shown the carbon from non-protein sources (carbohydrates and lipids) is most likely utilized during amino acid synthesis (Ambrose and Norr 1993), though in levels for collagen synthesis, carbohydrates and lipids may be severely underrepresented. Hedges (2003) cites a combination of factors that may be associated with carbon sourcing for collagen, including animal species (herbivore or carnivore particularly), digestive system, and quality of the diet, all of which are most likely involved to varying degrees.

Bone collagen preservation and quality

Bone collagen retains reliable biogenic isotopic signatures and is resistant to diagenetic factors up to a point, after which deterioration of the organic material results in forms of contamination and degradation (Collins et al. 2002; Hedges 2002; Hedges et al. 1995; Nielsen-Marsh and Hedges 2000; Smith et al. 2003; van Klinken 1999). Contamination of bone collagen is generally indicated by the inclusion of lipids, carbonates, humic acids or other carbon rich substances in the substrate (Ambrose 1993) and generally occurs in more temperate zones while collagen degradation is observed in regions with higher overall temperature and lower precipitation (van Klinken 1999). Factors affecting preservation are therefore dependent on regional climatic factors that render them relevant for a given area.

"Collagen" yield (in quotations as the actual material is a proteinaceous fraction that may or may not be wholly collagenous, see Ambrose 1990; DeNiro and Weiner

1988) is expressed as the weight percentage or as a weight ratio (mg/g) and while modern bone is comprised of approximately 22% collagen, the percentage decreases steadily during burial, which is dependent mainly on climatic conditions (van Klinken 1999). While researchers have found collagen preserved in material with a 3.5% "collagen" yield (Ambrose 1990), samples containing 2% to 0.5% "collagen" should be tested further to determine collagenous degradation.

The nitrogen and carbon content of extracted "collagen" are similar elemental quality indicators. Expressed as a percentage (wt.%) of combusted "collagen" both elemental values should be constant when extraction involves well preserved or modern bone (van Klinken 1999). Carbon weights diverging from wt.% 35 indicate the addition of organic carbon (higher values) or the presence of inorganic substances in the extract (lower values). Nitrogen values diverging from wt.% 11-16 show similar changes, and especially for low "collagen" bone.

Derived from the nitrogen and carbon content of extracted "collagen", the atomic C:N ratio of collagen is a common parameter set to determine the viability of collagenous material, with modern collagen having a value of 3.21 and material falling within the range of 2.9 to 3.6 considered to be representative of diagenetically unaltered collagen (DeNiro 1985). However, as the C:N ratio of collagen is an average of its 18 isotopically dissimilar constituent amino acids, gradual deterioration of collagen α -chains can alter the protein such that higher amounts of non-collagenous proteins (NCP's) and the loss of amino acids specific to collagen, such as glycine and aspartic acid would result in skewed C:N ratio and isotope values (Ambrose 1993; Schoeninger et al. 1989; Tuross et al. 1988; van Klinken 1999).
This study uses a variety of criteria to determine well preserved collagen samples from poorly preserved samples (%collagen, %C, %N, %S, and elemental ratios, following recommendations of Ambrose 1990; DeNiro 1985; Harbeck and Grupe 2009; Szpak 2011; van Klinken 1999, see Table 2.1 where collagen yield > 1%, %C \geq 13%, %N \geq 4.8%, %S \geq .15% for mammals and .40% for fish, C:N ratio > 2.9 and < 3.6, C:S ratio >300 and < 900 for mammals and >125 and <225 for fish and N:S ratio > 100 and <300 for mammals and >40 and <80 for fish).

Collagen Quality Criteria		Range
%collagen		1% – 22%
%C		13% – 47%
%N		4.8% - 18%
%S	Mammalian	0.15% - 0.35%
C:N	FISH	2.9 – 3.6
C:S	Mammalian Fish	600 ± 300 175 ± 50
N:S	Mammalian Fish	200 ± 100 60 ± 20

Table 2.1 Summary of accepted standard ranges of collagen quality criteria, as described in published literature (Ambrose 1990; DeNiro 1985; Harbeck and Grupe 2009; Nehlich and Richards 2009; van Klinken 1999)

C:N, C:S, and N:S ratios were calculated using Equations 1, 2 and 3, respectively:

(1) C:N ratio =
$$\frac{\%C}{\%N} \times \frac{14.007}{12.011}$$

(2) C:S ratio =
$$\frac{\%C}{\%S} \times \frac{32.064}{12.011}$$

(3) N:S ratio =
$$\frac{\%N}{\%S} \times \frac{32.064}{14.007}$$

2.1.5 Correction to modern data

Due to the unavailability of regionally analogous isotopic data from archaeological samples, it was necessary to compare results of the current study with some published modern faunal data. The direct comparison of modern and archaeological isotope data is somewhat problematic due to past environmental changes that may have affected elemental compositions. The relative proportion of ¹³C in our atmosphere is steadily decreasing over time and before the industrial revolution, δ^{13} C of our atmosphere was approximately -6.5‰ with the value now around -8‰, termed the Suess effect (Keeling et al. 2010; Long et al. 2005). An ocean-specific adjustment has been described by Misarti et al. (2008) of 1‰ for modern tissue δ^{13} C values to be comparable with preindustrial values and Halfmann et al. (2015) note the magnitude of the freshwater Suess effect may be slightly larger and closer to the atmospheric Suess effect of approximately 1.5‰.

Similarly important in comparing archaeological isotope values with modern data are differences in isotopic discrimination in different bodily tissues. Modern data is often obtained from biological material more readily available from an animal, such as hair and blood, which both differ in their diet-tissue discrimination (e.g., Bocherens et al. 2014; Raghavan et al. 2010). Average differences in terrestrial animals of +2‰ between hair and collagen and muscle and collagen for δ^{13} C values have been observed (Crowley et al. 2010; Drucker et al. 2008; Raghavan et al. 2010; Sare et al. 2005; Tieszen and Fagre 1993; Tieszen et al. 1983), while average differences of +1.5‰ between hair and collagen and everage differences and solve the both hair and muscle being enriched in ¹⁵N relative to bone, have been observed (Finucane 2007; Hedges et

al. 2009; O'Connell et al. 2001). The δ^{13} C and δ^{15} N offsets between muscle and bone collagen for fish, initially calculated for salmon, but likely attributable to other species, have been reported as +2.5‰ for δ^{13} C muscle to collagen offsets and -1‰ for δ^{15} N muscle to fish bone collagen offsets (Halfmann et al. 2015; Misarti et al. 2009). Accordingly, this study uses the following corrections when discussing sampled material in relation to previously published modern fauna values:

- a) δ^{13} C archaeological fauna = δ^{13} C modern fauna (aquatic and terrestrial) + 1‰
- b) δ^{13} C terrestrial collagen = δ^{13} C terrestrial hair and muscle + 2.0‰
- c) δ^{15} N terrestrial collagen = δ^{15} N terrestrial hair -1.5‰.
- d) δ^{15} N terrestrial collagen = δ^{15} N terrestrial muscle -2%.
- e) δ^{13} C fish collagen = δ^{13} C fish muscle + 2.5‰
- f) δ^{15} N fish collagen = δ^{15} N fish muscle 1‰.

2.2 Previous isotopic work

Fairly limited isotopic analyses have been conducted on human and faunal remains from archaeological sites in the Fraser watershed, with some analyzed from sites sampled for the current study. Previous isotopic analyses utilizing dog remains have primarily assessed the use of dogs as an analog for human dietary practices. The following section details previous archaeological work conducted for both these foci.

2.2.1 Isotopic analyses in the Fraser Watershed

Isotopic work conducted in British Columbia in the 1980's was at the forefront of establishing δ^{13} C values as indicators of marine-oriented diets in C3 dominant environments (Chisholm 1986; Chisholm and Nelson 1983; Chisholm et al. 1982, 1983; Lovell et al. 1986). While these isotopic analyses were instrumental in establishing

isotopic differences between terrestrial and marine derived protein, they were all essentially derived from the same material and were limited in their study of only carbon values, thereby constraining the resolution of understanding archaeological foodways in British Columbia. More recently, Schwarcz et al. (2014) re-examined Chisholm's original data as well as offering a revised and expanded dataset, including a sample of previously unpublished δ^{15} N values. Hepburn (2016) has also recently summarized and subsequently re-analyzed isotopic values determined by Chisholm and colleagues including the addition of several human sets of values from forensic specimens of archaeological origin. Within the Fraser River watershed, Chisholm's original results from Fraser Delta (n=34), including individuals from sites DgRr-1, DgRs-1, DhRr-6, and DgRr-2 all dated to the Late Period (3000 – 150 years ago), saw the average δ^{13} C value at -13.6 ±0.1‰, while 2 children, both from DgRs-1, had values of -14.0‰ and -14.2‰, respectively. Three Fraser Delta 'outliers' had δ^{13} C values less than -16‰: DfRs-3 (-20.8‰), DgRs-1 (-19.5‰), and White Rock (-15.9‰), which Chisholm (1986:105) argues cannot be taken as a reliable indicator of diet change. This is isotopically comparable to other coastal dwelling individuals analyzed by Chisholm and colleagues, with the conclusion that inhabitants of the Fraser Delta possibly obtained more of their protein from terrestrial species than other 'Gulf of Georgia' individuals. Chisholm (1986) also suggested that shellfish, which is isotopically lighter due to the presence of terrestrial biogenic carbon in river outwash, was eaten in sufficient quantity to be reflected in the Fraser Delta individuals' isotopic signature.

Samples tested from the Interior Plateau within the current study area include nine adult individuals from the Lillooet area dated to 1600 BP and later with a mean

 δ^{13} C value of -15.5‰ ± 0.1 and one child from the Lillooet area with a δ^{13} C value of -16.1‰. A single Lillooet individual had a value nearer to the terrestrial end of spectrum at 19.3‰ (Chisholm 1986). On average, groups with easy access to salmon bearing streams and rivers obtained about 40 to 60 (±10) % of their protein from salmon, with little significant proportional change for the last 5000 years.

Lovell et al. (1986) utilized stable isotope analysis to investigate salmon consumption in the BC interior. The study evaluated 44 archaeological human burials from 21 sites along the Fraser, Thompson, and Columbia rivers with a primary goal of examining differential access to salmon. Individuals sampled from the current study area include 8 adults from the Lillooet area with a mean δ^{13} C value of -15.5‰ ± 0.1. Their conclusions parallel Chisholm's results that groups "with easy access to salmon obtained about one-half to two-thirds of their protein from salmon, and have done so throughout the last 2,000 years" (Lovell et al. 1986:104). Schwarcz et al.'s (2014) recent analysis of samples obtained by Chisholm and colleagues in the 1970s and 1980s includes previously unpublished δ^{15} N values and additional δ^{13} C values from previously unpublished analyses of collagen from several individuals. Sites within the current study area that were sampled include Coastal sites DfRs-3, DgRr-1, DgRr-2, DgRs-1, DjRi-3, DjRi-5, and Interior sites EeRl-167, EeRl-169, EeRl-18, and EeRl-80, all in the Lillooet area. Schwarcz et al. (2014:467) conclude that the diet of coastal BC peoples in the Late Period "was dominated by marine foods and largely excluded terrestrial protein sources". The inclusions of δ^{15} N data in the study demonstrate that most of the marine resources consisted of high trophic level marine organisms, which the authors cite as a mixture of fish, mostly salmon and herring, and marine mammals. They also

identify a low trophic level marine resource, presumably marine mollusks, making up a notable fraction (approximately 30%) of the diet of some individuals, mainly among individuals from the Fraser Delta and Gulf Islands. Schwarcz et al. (2014) note their observations of the importance of marine foods are consistent with other recent studies using faunal analyses (e.g. Coupland et al., 1993; Cannon, 2000; Orchard and Clark, 2005; Stewart et al., 2009; Coupland et al., 2010). Finally, Hepburn's (2016) analysis of existing isotopic data, compiled from previously discussed publications as well as archaeological reports available in the Provincial Archaeological Report Library of British Columbia (e.g. Arcas 1994a, 1994b, 1999) from British Columbia, saw more variable Interior diets, with values representing a range between purely terrestrial to mixed marine (anadromous fish) and terrestrial. He notes, along salmon-bearing rivers, the apparent marine component of diet is positively correlated with downstream proximity to the ocean.

While these studies signify that coastal dwellers obtained the majority of their protein from marine species, measured at about 90 ± 10% and Interior people obtained upwards of 60%, the fact that the research was limited to the use of carbon isotopic analysis precluded any discussion beyond the amount of terrestrial versus marine protein that was ingested. This limitation was largely due to methodological constraints, but nearly 40 years later and with the development of more accurate isotopic analysis with smaller sample sizes, a higher resolution stable isotope study, such as the one conducted here, greatly increases our understanding of the complexity and finer distinctions observable in archaeological foodways as well as offering data related to mobility and spatial movement.

2.2.2 Isotopic work on dogs

Burleigh and Brothwell (1978) were the first to use isotopic analyses of domesticated dog remains as proxies for human diet. They noted an unexpected enrichment in δ^{13} C in 3000-year-old Peruvian dog hair and inferred the dogs had consumed large quantities of maize, positing that dogs, humans and other fauna could be used as supportive evidence of maize cultivation in the past. Since 1978, stable isotopic analyses of dogs have successfully provided evidence of production of maize and other plant domesticates (Allitt et al. 2008; Bentley et al. 2005; Hogue 2003), trends in marine subsistence economy (Cannon et al. 1999; Clutton-Brock and Noe-Nygaard 1990; Fischer et al. 2007; Guiry and Graves 2013; Rick et al. 2011; Schulting and Richards 2002) and canid-human relations, (Booth et al. 2011; Losey et al. 2011; White 2004; White et al. 2001, 2004). Guiry (2012:352) recently coined the term, "canine surrogacy approach (CSA)," by which he asserts that isotopic analyses of dogs can provide an analog for human subsistence practices that is either direct (e.g. dogs are "source" information regarding human diet) or indirect (e.g., dogs provide evidence of specific food procurement behaviour, such as maize cultivation). The assumptions underlying the idea that dogs can serve as proxies for human diet are: (1) dogs and humans are metabolically similar and incorporate isotopes in a similar manner, and (2) dogs would have accessed the same foods as their human companions either as scavengers of food waste or human faeces (coprophagy), or through purposeful feeding by humans (Allitt et al. 2008; Cannon et al. 1999; Guiry 2012; 2013; Katzenberg 1989: Tankerslay and Koster 2009). Intentional feeding of dogs could imply the care and affection of a companion "pet", guardian and/or hunting partner, fattening for use as

food or, preparation for specific ritual or ceremonial contexts, whether or not the dog was to be eaten (Olsen 2000; White et al. 2001). The canine surrogacy approach in relation to the current project is discussed further in Section 5.33. Similarities between human and dog dietary practices have been observed for pre-colonial Antilles (Laffoon et al. 2017), Alaska (McManus-Fry et al. 2018), though both studies note isotopic differences, likely due to the relative importance of different dietary inputs into human versus dog diet. These studies, while oriented in dietary interpretation of isotopic signatures, underline the intimate and enduring relationship between humans and dog counterparts. Human-canid relationships are similarly evidenced by studies investigating the earliest evidence of live-traded dogs at Ceibal (Sharpe et al. 2018), where the possible ceremonial contexts of these captive-reared animals suggest human-dog relationships played an important role in the symbolic development of political power in the Maya region.

2.3 Analytical Methods

All samples for the current study were prepared at the Archaeology Isotope Laboratory at the University of British Columbia following standard procedures for bone collagen extraction as outlined in Richards and Hedges (1999). Bones were demineralized in a 0.5M HCl solution, followed by a gelatinization step in pH3 water at 75°C for 48 hours. Gelatinized solutions were then filtered with Ezee-filters (manufactured by Elkay Laboratory Products, UK) and then with 30kA ultrafilters (manufactured by PALL Corporation, USA) to remove low molecular weight contaminants. The remaining solution was lyophilized in a freeze dryer for 48 hours. All isotopic composition measurements are calibrated to international references distributed by the U.S.

Geological Survey (USGS), the National Institute of Standards and Technology (NIST, earlier as the National Bureau of Standards – NBS), and the International Atomic Energy Agency (IAEA).

For carbon and nitrogen isotope measurements, samples were analyzed in duplicate, when collagen material permitted, with an Elementar vario MICRO cube elemental analyzer coupled to an Isoprime[™] mass spectrometer in continuous-flow mode. All reported carbon and nitrogen isotope values based on duplicate analyses are averages and are reported in 'permil' (‰).

Stable carbon and nitrogen isotopes values were calibrated to Vienna Pee Dee Belemnite (VPDB) and atmospheric air (AIR) using USGS40 and USGS41, respectively (Coplen 2011). USGS40 (δ^{13} C: -26.39‰ and δ^{15} N: -4.52‰) and USGS41 (δ^{13} C: +37.63‰ and δ^{15} N: +47.6‰) are isotopically homogenous L-glutamic acids that are chemically similar to many natural biological materials, and therefore commonly used as organic reference materials for C and N isotopic measurements (Qi et al. 2003). In addition to USGS40 and USGS41, internal standards methionine (purchased from Sigma-Aldrich) and an in-house seal collagen standard were used to check measurement accuracy. The average observed δ^{13} C values for methionine and seal collagen are -28.6 ‰ (n=63) and -13.8 ‰ (n=35), respectively, which compare well with expected values of -28.6 ‰ and -13.7 ‰. The average observed δ^{15} N values for methionine and seal collagen are -5.0‰ (n=63) and +17.4‰ (n=35), respectively, which compare well with expected values of -5.0‰ and +17.4 ‰.

For the measurement and analysis of sulfur isotopic compositions, samples were analyzed in duplicate, when collagen material permitted, with an Elementar vario

MICRO cube elemental analyzer, coupled to an Isoprime^M 100 mass spectrometer in continuous flow mode. Sulphur isotope values were calibrated to Vienna Canyon Diablo Troilite (VCDT) using IAEA-S-1 and NBS-127 (Coplen and Krouse 1998; Krouse and Coplen 1997). IAEA-S-1 is a silver sulfide with a homogenized δ^{34} S value of -0.30‰ and NBS-127 is a barium sulfate with a homogenized δ^{34} S value of +20.3‰ (Coplen and Krouse 1998; Halas and Szaran 2001). In addition, IAEA-S-3 (silver sulfide), NIST 1577c (bovine liver) and casein protein (purchased from Sigma-Aldrich) were used to check measurement accuracy. The average observed δ^{34} S for IAEA-S-3, NIST 1577c, and casein protein were -32.3‰ (n=4), +1.7‰ (n=22), and +6.3‰ (n=30), respectively, which compare well with the expected values of -32.3‰, +1.7‰, and +6.3‰.

Statistical Analysis

Statistical analyses of results were conducted using IBM SPSS statistic software package (Version 20) and Systat software package (Version 12). Data are expressed as means ± standard deviation (SD). Differences between group means for δ^{13} C, δ^{15} N, and δ^{34} S values were determined by one-way ANOVA, or one-way MANOVA, when assumptions for parametric testing were met. Non-parametric Kruskall-Wallis tests were conducted to test for significant differences between groups when assumptions were not met. For ANOVA and MANOVAs, when differences were detected, post-hoc comparisons are conducted using the Tukey HSD test. A value of P < 0.05 was considered statistically significant. Analyzing isotopic data with the Bayesian mixing model, Food Reconstruction Using Isotopic Transferred Signals (FRUITS), was attempted, however limited faunal input resulted in low-resolution food web reconstruction. This is discussed further in Chapter 5.

3 Archaeological Context, Sites and Samples

The materials for this study were sampled from eight previously excavated archaeological sites situated within the environs of the Fraser River in British Columbia (Table 3.1; Appendix A). Samples ranged temporally from Locarno Beach Phase (3500-2350 BP) through to Gulf of Georgia Phase/Kamloops Horizon (1200 – 200 BP) which comprises the Late Period in British Columbia culture history (Matson and Coupland 1995; Stryd and Rousseau, 1995; see Figure 3.1). The majority of samples date between 2000 and 1400 BP. The following chapter discusses the study area and samples within the context of Fraser River and British Columbia archaeology.

	Borden			
Site Name	Number	n	Temporal Components	Date Ranges (BP)
Crescent Beach	DgRr-1	60	Locarno Beach Phase Marpole Phase Gulf of Georgia Phase	3500 - 2350 2400 - 1500 1500 - 200
Tsawwassen	DgRs-2	9	Gulf of Georgia Phase	1500 – 200
Glenrose	DgRr-2	3		
St. Mungo	DgRr-6	1		
Water Hazard	DgRs-30	49	Marpole Phase	2400 - 1500
Port Hammond	DhRp-17	15	Locarno Beach Phase Marpole Phase Gulf of Georgia Phase	3500 - 2350 2400 - 1500 1500 - 200
Bridge River	EeRl-4	66	Plateau Horizon	1400 – 1000 cal BP
Keatley Creek	EeRl-7	41	Plateau Horizon Kamloops Horizon	2400 - 1200 1200 - 200
	TOTAL	244		

Table 3.1 Sites sampled for the current project.



Figure 3.1 Summary of British Columbia culture history; PPT refers to Plateau Pithouse Tradition (information from Matson and Coupland 1995; Stryd and Rousseau, 1995).

3.1 Dogs in Archaeological Context

While dogs as the first animal domesticate has a general consensus, the timing of *Canis familiaris* domestication varies, with the oldest faunal remains undeniably attributed to domestic dogs dating to approximately 15,000 years ago (Larson et al. 2012; Pionnier-Capitan et al. 2011; Napierala & Uerpmann 2012) and some genetic evidence suggesting it extends to 100,000 years ago (Freedman et al. 2014; Vilà et al. 1997). Recent genetic data support a more recent domestication date, occurring at a single geographic origin between 20,000 and 40,000 years ago (Botigué et al. 2017).

Regardless of the when dogs were initially domesticated, as humans began occupying the New World, they were accompanied by domesticated dogs (Fiedel 2005;

Wang and Tedford 2008). Looking at dogs as an example of the interactions between human and nonhuman counterparts, the species is unique in its relationship to humans throughout prehistory and into the present day. Canids were the only domesticated animal in pre-contact Canada and had an integral and important part to play in indigenous societies, not only as a food resource in some cases, but also in hunting, transport, protection, and especially myth and ritual (Crellin 1994). The earliest remains of domestic dogs in North America and earliest individual dog burials anywhere in the world are found at the Koster site in Illinois and date to approximately 9900 years ago (Perri et al. 2018). Debate exists over the origin of New World dogs with some researchers suggesting a common origin of Old World grey wolves for American and Eurasian dogs (Leonard et al. 2002; vonHoldt et al. 2010) and others arguing for the presence of independent domestication events occurring after the arrival of human populations in the Americas (Koop et al. 2000; Witt et al. 2015). Recent genetic research indicates that North American dogs were not derived from North American wolves and instead form a monophyletic lineage that likely originated in Siberia and dispersed into the Americas alongside people (Leathlobhair et al. 2018). An initial population of dogs likely arrived in North America and dispersed across the continent, then remained isolated for 9,000 years. Subsequent to this, multiple reintroductions and dispersals of dogs occurred, from Western Eurasia, through to dogs brought by Europeans and finally during the Alaskan gold rush (Derr 2005; Leathlobhair et al. 2018).

3.1.1 Dogs and humans in the Fraser Watershed

Dogs are incredibly unique in the roles they have played in human history and prehistory and stand as a special case in comparison to other domesticates; they have been pets, hunting aids, sources of traction, status symbols, spirit guides, sources of fur or wool, objects of worship, pariahs and they have often played many of these roles simultaneously within a single society (Crellin 1994; Russell 2012). Their complex relationships with humans have frequently placed dogs in a liminal or ambiguous position, like us and of the human world but animals or non-human counterparts within this sphere. Dog remains are components of faunal assemblages in a large number of sites within the Fraser watershed, have been found in association with human burials (Cybulski 1992; Digance 1986), in deliberate burials of their own (Digance 1986; Suttles 1987) and are common finds in housepit villages such as Keatley Creek and Bridge River (see below) with some remains dating back to 4000 BP (Barsh et al. 2006; Marino 2015), demonstrating their far-reaching bond with human groups in British Columbia.

Coast and Interior Salish groups viewed their worlds as positional and relational with relationships between dogs and humans embodying an animistic engagement of the two beings. The relationships between a dog or dogs and their masters then, as evidenced in the archaeological record, serve as a means to establish the variety of engagements that lead to the construction of a person, human or non-human. Ethnographic writing and legends involving dogs record interactions that surpass conventional economic uses of them as labour, hunting companions, food, or sources of textile material and even surpass common social bonds between dogs and humans that

remain in contemporary society. Many Salish narratives describe a time before the transformer had set the world in order for humans, "when animals were people (and people were animals)" (Thompson and Egesdal 2008:xxx). Contrasting non-indigenous literature, all these stories are characterized by the fact that "they really happened" (Thom 1997:12).

Many Salish narratives emphasize dogs that are often involved in transformations but also engaged in social and intimate relationships with humans. "The Boy who Turned into a Dog", describes a boy who is transformed into a dog until he is found bathing in human form after removing his dog skin. The legend recounts "for some time after that, the boy ate garbage about the village, but soon he became quite normal again" (Indian Children 1975:78). The legend of "Dog Husband" or "The Dog Children" is widespread in ethnographic literature and has been recorded for Nlaka'pamux (Teit et al. 1917:62-63), Sto:lo (Teit et al. 1917: 130-131), and Lillooet (Teit et al. 1917: 463), among others.

Ethnographic accounts detail dogs occupying roles normally reserved for humans. Teit documents the thoughtful care and treatment of dogs, writing that owners would purge them with medicine and give them "lukewarm drinks prepared from the Hudson Bay plant" (1906, 2(7)). McIlwraith (1948) records an instance of a dog inheriting the ancestral names and wealth of a childless couple that results in the dog's position as a chief in the community. The Cowlitz narrative of Dog, Wolf, and Coyote emphases the liminality of the human-dog relationships. Wolf and Coyote carelessly put out a fire, so they send their brother Dog to beg for fire from humans. The humans nearby welcomed Dog into their house and fed him. Dog decided to stay with the humans, so

Wolf and Coyote remain without fire (Adamson 1934:307). The dog is thus aligned with animals in nature, but with humans in culture

3.2 Late Period Archaeology in the Fraser Watershed

The study area for this dissertation includes the immediate environs surrounding the Fraser River, from its end in the Pacific to the Interior Plateau region north of what is now Lillooet, British Columbia The Fraser River watershed is a vital economic, physical, transportation, dietary, ceremonial, and environmental component that, through itself and its related activities, has shaped preand post-contact lifeways in the province. It originates in the western slopes of the Rocky Mountains near Mount Robson and flows southwest into the Pacific Ocean, 1375 km away, draining a large basin, 250,000 km², comprising approximately 25% of British Columbia (Evenden 2004). In its course, the river passes through several different ecological regions shaped by varying moisture and temperature: evergreen forests of pine, spruce, and fir on the western slopes of the Rockies, dry plateau and sagebrush country in some sections of the Interior, and dense rain forests on the coast. The Fraser River basin's diverse ecologies and historical and archaeological importance make it a unique location for studies on the foodways and resource relationships occurring archaeologically.

Previous archaeological investigations have generally concentrated on specific sites and culture types within British Columbia. While this is often a necessary component of focusing archaeological research, identifying and investigating only certain environs of the Fraser River tend to close off and isolate these culture groups or regional areas from each other. In his discussion of the Northwest Coast as a study

area, Donald (2003:113) notes for example, especially considering their linguistic relationship, the differences between Plateau and Northwest Coast in the archaeological past may have been far less. Thinking of the entire Fraser River as a locus of travel, inhabitation, movement and interaction in its own right, these regions should be thought of less as discrete units confined to type-based boundaries, and more, while generally patterned in archaeological traits, fluid in the borders that have been applied to them. As Grier (2006) notes, the connection between large occupations, village sites, stored salmon and other aquatic resources, and the positioning of large sites in excellent fishing locales points to the Fraser River as having acted as a central economic and political focus of the interactive networks that developed in the region (see also Burley 1980; Grier 2003; Mitchell 1971a; 1971b).

As the current study examines temporal as well as spatial trends in resource relationships, foodways, and mobility within the Fraser River watershed, this necessitates an understanding of the published culture histories while keeping cognizant of the room to move between them. The Central Northwest Coast and lower Fraser River regions encompass the Fraser River Delta and are often grouped into the Gulf of Georgia region and culture type, which extends south into what is currently Washington State, and what researchers generally consider distinct in its natural, ethnographic, and archaeological character (e.g., Grier 2003; Suttles 1987). From the Fraser River upstream near Hope, the culture types and chronology have been more closely aligned to those of the Interior Plateau. This larger region encompasses areas east and south of the Fraser River, extending into present-day United States, where it is called the Columbia Plateau. The Fraser Canyon exists between the Coast and the

Plateau, and indeed, ethnographically and presently, is a heavily used route and connection between Coast and Interior Salish communities. Brief chronologies ca. 3000 BP to the proto-historic period will be outlined below with a focus on archaeological units sampled for the current research project. A composite chronology for both Central Northwest Coast and Interior Plateau culture histories is presented in Figure 3.1

3.2.1 Late Period Culture History and Relevant Archaeology Sites

Locarno Beach Phase (3500-2350 BP)

Locarno Beach Phase sites sampled in the current project include Crescent Beach (DgRr-1) and Port Hammond (DhRp-17). Faunal assemblages dated to the Locarno Beach Phase indicate broadly based subsistence patterns with a shift towards intensification of fish, predominantly salmon, though intensification and the assumption upon which theories of complexity have been questioned (see Butler and Campbell 2004). Other resources include flat fish (flounder and sole), and herring; shellfish (bay mussel); sea mammals, land mammals and birds, particularly wapiti and coast deer for the former and waterfowl for the latter. River fish such as eulachon have also been recovered in large numbers (Matson and Coupland 1995).

Marpole Phase (2400 - 1500 BP)

Crescent Beach (DgRr-1), Water Hazard (DgRs-30) and Port Hammond (DhRp-17) have samples dated to the Marpole Phase. This phase is considered to have developed from the preceding Locarno Beach Phase (Fladmark 1982, Mitchell 1990) and was originally defined from excavations around the Lower Mainland. Sites exhibit a greater emphasis on storage of food resources, larger and more elaborate village architecture, and distinctive changes in the material culture. These large sites are indicative of the

Marpole pattern of multi-family 'winter nucleated' settlements comprised of large post and beam houses, processing and storage features, and midden deposits. While artifact assemblages are similar to those in the Locarno Beach Phase, Marpole Phase assemblages are marked by indicators of complex hierarchical groups with higher levels of social stratification, including three levels of society; elites, commoners, and rarely, slaves (Burley 1980, Fladmark 1982, Mitchell 1990). Evidence indicates a wide range of resources were utilized at a time when large and generally predictable annual runs of salmon predominated, though other resources, including root crops, sea and land mammals, birds and shellfish, were used.

Plateau Horizon (2400 – 1200 BP)

The Plateau Horizon is characterized by the greatest pre-contact population density on the Canadian Interior Plateau. Large villages indicate continuous reoccupation over long periods of time. Diet inferred from faunal remains includes large amounts of and a heavy reliance on salmonid species, but mid-elevation roasting pits indicate the use and importance of root foods in the region (Lepofsky 2000; Lepofsky and Peacock 2004). Terrestrial fauna and riverine species were also utilized. Canids also appear in the archaeological record on both the Plateau and Northwest Coast (Crellin 1994; Crockford 1997). Sites having Plateau Horizon components sampled for the current project include Keatley Creek (EeRl-7) and Bridge River (EeRl-4) (Hayden 2000a, 200b, 2005; Prentiss 2014; Prentiss et al. 2018).

Developed Coast Salish or Gulf of Georgia Phase (1500 - 200 BP)

Previously listed sites with components of this phase include the permanent winter village Port Hammond (DhRp-17), as well as Crescent Beach (DgRr-1) and

Tsawwassen (DgRs-2). The distribution of sites with 'Developed Coast Salish' or 'Gulf of Georgia' components is more extensive than in the post-contact era and includes a range of seasonally utilized settlement types such as villages, late winter camps for herring and shellfish procurement, spring camps for eulachon and sturgeon fishing, summer camps for salmon fishing and berry collecting, autumn fish weir and plant harvesting sites, among other site types. Differential access to resources is thought to be the primary driver of variation in temporal and spatial site distribution and access to resource areas, whether salmon, berry grounds, quarries, or travel routes, was controlled by various social and economic mechanisms (Deur and Turner 2005; Matson and Coupland 1995; Moss 2011). Fish remains do dominate Late Period faunal assemblages, with salmon remains most abundant, followed by sturgeon, flatfish, herring, eulachon and rock cod. Wapiti and deer remains dominate land mammal assemblages. Bird remains consist largely of waterfowl, ducks and geese. Sea mammal is not common but is present (mostly seal).

Kamloops Horizon (1200 - 200 BP)

Sites sampled for the current project include multi-component pithouse village site Keatley Creek (EeRI-7). The use of upland base camps in locations proximal to major food resources, the continued use of mid-altitude and upland plant resources, a heavy reliance on salmon supplemented by deer and small animals, and well-developed interregional exchange networks characterize this horizon and show continuity from the Plateau Horizon (Hayden 2000a, 2000b, 2005).

3.3 Sites sampled

3.3.1 DgRr-1: Crescent Beach

Crescent Beach is situated on the eastern shore of Mud Bay and Boundary Bay, approximately 6.7 km north of the Canada-United States border. The mouth of the Nikomekl River forms the northeastern boundary of the Crescent Beach site, while a high bluff provides an approximate limit to the southeastern extent of the archaeological deposits. It is located within the traditional territory of the Semiahmoo First Nation (Conaty and Curtin 1983). Crescent Beach has been the focus of several archaeological investigations since the 1970's, due in large part to the size of the site and the persistent threat of development. Notable excavation reports for the site include Percy (1974), Trace (1981), and Ham (1982) and subsequent work by Matson et al. (1990). Excavations at different localities of the site, resulted in the overall conclusion that there were at least four 'culturally' distinct components present at Crescent Beach, representing several thousand years of almost continuous occupation. Crescent Beach is the only known intact mainland deposit with both pre-Locarno Beach Phase deposits, Locarno Beach Phase material, and early Marpole Phase material. Dog remains from DgRr-1 1989 and 1990 excavations were recovered mainly from the South Trench (15.4% of identified mammal remains versus 1.8% from the North Trench), an excavation area characterized by intact midden deposits and representing multiple temporal components (Matson et al. 1990). Crockford (1990) notes in her faunal analysis as well that a number of young dog remains, likely between two and four months, were recovered which represents summer as a time of death for these individuals. Ham (1982) reports 2.9% (n=63) of mammal remains identified to dog

recovered from 10 layers and including all age classes and elements during his excavation at DgRr-1. Earlier excavations did not complete detailed faunal analyses.

3.3.2 DgRs-2: Tsawwassen

DgRs-2 is an archaeological shell midden, situated on eastern shore of the Strait of Georgia on the physiographic boundary between the Fraser River Delta to the north and Tsawwassen upland to the south. The earliest reference to the site in archaeological literature appears in fieldnotes of Harlan I. Smith, in Sept. 1921. More recent archaeological work involved an impact assessment begun in 1988 by Arcas Associates, from where the dog remains sampled for the current project were excavated. A total of 335 specimens identified to *C. familiaris* were recovered across 4 excavation areas, with remains largely fragmentary in nature. An exception was 10 dog crania recovered in the same stratigraphic layer in Zone A, exhibiting little weathering and all lying dorsal side of the skull up and maxillae teeth down into the surface (Arcas 1994b). Samples for the current study were obtained for 9 of these individuals. The intentional placement of dog crania observed at DgRs-2 could indicate the ceremonial and ritualistic treatment of dogs that "could be related to the important role of dogs (and dog skins) in the first ancestor legends of the Tsawwassen" (*ibid*:38). Several isolated dog burials and articulated dog remains were also found in association with hearth material during the excavation.

3.3.3 DgRs-30: Water Hazard

DgRs-30 is located on the Point Roberts peninsula at the western end of Boundary Bay, in southwestern British Columbia. The site is on low ground, about 150 m seaward from the north-south oriented bluff along the edge of the Pleistocene Point

Roberts upland. Site occupation dates to ca. 1800 cal BP, corresponding to the second half of the Marpole Phase. DgRs-30 was excavated in summer 1988, where a large wetsite component was discovered and recovery of perishable artifacts including basketry, cordage, wedges, and fishhooks, among others were recovered and successfully preserved as part of the overall project. Faunal remains, while recovered, were not the focus of the excavation or subsequent analysis and so detailed contextual information is not available. The samples obtained from this site were part of those analyzed by Susan Crockford and currently held in the Laboratory of Archaeology at UBC.

3.3.4 DhRp-17: Port Hammond

The Port Hammond site (DhRp-17) is located within the Fraser lowland, a portion of the Northwest Coast Gulf of Georgia region of the. DhRp-17 is a pre-contact and post-contact period archaeological site first recorded by Waiter Kenyon in 1953 but has been the topic of continued research (Ames and Maschner 1999; Carlson 1990; Matson and Coupland 1995). Artifacts recovered from various sections of this large site suggest that it was a large permanent riverine and terrestrial economy village occupied primarily during the Marpole phase. The samples included in the current study were excavated during the 2000-2001 archaeological monitoring project conducted by Antiquus Archaeological Consultants Ltd. (Antiquus 2001), with faunal remains currently being held at the Maple Ridge Museum.

3.3.5 EeRI-4: Bridge River

EeRl-4 is a complex hunter-gatherer-fisher village consisting of approximately 80 semi-subterranean pithouses and over 100 extra-mural pit features (storage pits and food-roasting ovens) (Prentiss et al. 2014). Bridge River is one of several large

villages dating to the Plateau Horizon and was occupied discontinuously from 1800 to 200 cal BP, though the faunal assemblage sampled for this project is dated from 1400-1200 years ago. Salmonid species, geophytes, as well as berries, deer and other resources characterize archaeological recovered diet at Bridge River. Emergent social inequality is evident throughout the occupation of the site. Faunal samples for this project were obtained as part of a collaboration between UBC and the Dr. Anna Prentiss at the University of Montana as part of the larger Bridge River Project.

3.3.6 EeRI-7: Keatley Creek

EeRI-7 is a large pithouse village site situated about 360m above the Fraser River in the Mid-Fraser region of the province, with 119 housepit sized depressions, some with a diameter of 21 m², and an approximately equal number of smaller identifiable external features, most of which are probably cache pits (Hayden 2000a). Like Bridge River, Keatley Creek supported a large population at its height of habitation. At its peak population, occurring approximately 1250 cal BP, Keatley Creek's population potentially numbered at nearly 1000 inhabitants. Hunter-fisher-gatherers occupying the site during the winter months supported these large numbers through a variety of food storage, including both harvest and material storage (Hayden and Spafford 1993). Resources utilized at the site include salmon, geophytes, and deer, and evidence of corporate groups, and social and economic inequality is present throughout the occupation. The majority of the remains for this study were recovered from the Kamloops Horizon occupation, dating to approximately 1200 cal BP.

3.4 Susan Crockford Project

One of the most comprehensive archaeological projects involving canid analysis is Crockford's (1997) study of over 640 dogs from 28 archaeological sites in the Gulf of Georgia region. The study focused on differentiating between dog types using osteometry and conclusions suggest a bimodal distribution in sizes of individuals with variation in the dataset representing two different breeds of dog, the smaller (wool) dog and the larger (village/hunting) dog. Overall, the wool dogs exhibited much less intragroup osteometric variation than the village dogs. Studies predating that of Crockford (1997) similarly focused on osteometrics, but were all site-specific, a weakness at this time when the variability of archaeological dog remains was yet to be regionally described (see Digance 1986; Gleeson 1970; Montgomery 1979). A large portion of dogs analyzed by Susan Crockford are currently held in the Laboratory of Archaeology at UBC and were sampled for the current project. Eighty-nine of the 147 (60.5%) dog samples obtained were part of her original analysis, including all of the dogs representing DgRr-1, DgRs-2, and DgRs-30.

4 Ecology along the Fraser River

This chapter focuses on assessing problems posed in research question #3. If we can understand prehistoric ecological communities as holistic and integrative of living components, then relationships between resources and species groups can be characterized isotopically. Inter- and intra- site and species variability is examined with regard to this hypothesis and in relation to the relationships between resources and domestic dogs in Chapter 5.

4.1 Results

Carbon and nitrogen isotopic compositions, as well as associated elemental data and preservation criteria (%C, %N, C:N, collagen yield) for all archaeological fauna sampled are presented in Table 4.1. Following the discussion in Chapter 2, only collagen samples that met all the following criteria were included in summary plots and statistical analyses (following recommendations of Ambrose 1990; DeNiro 1985; Harbeck and Grupe 2009; Szpak 2011; van Klinken 1999): collagen yield > 1%, %C ≥ 13%, %N ≥ 4.8%, C:N ratio > 2.9 and < 3.6. Sulphur compositions, as well as associated C and N isotopic data and preservation criteria (%S, C:S, N:S) are presented in Table 4.2. Collagen samples that met all of the following criteria for sulphur samples were included in summary plots and statistical analyses (following recommendations of Nehlich and Richards 2009): for mammalian/avian bone (%S from 0.15% to 0.35%, C:S ratio 600 ± 300, N:S ratio 200 ± 100) and for fish (%S from 0.4% to 0.8%, C:S ratio 175 ± 50, N:S ratio 60 ± 20).

Acceptable carbon and nitrogen isotopic compositions for fauna were generated from the following individuals: n=13 from Crescent Beach (DgRr-1), n=4 from St.

Mungo and Glenrose (DgRr-2 and DgRr-6), n=3 from Port Hammond (DhRp-17), n=53 from Bridge River (EeRl-4), and n=20 from Keatley Creek HP 7 (EeRl-7). Mean δ^{13} C, δ^{15} N and elemental data values for all sites are presented in Table 4.1. Isotopic and elemental data for all samples are presented in Appendix A.

Common Name	n	δ ¹³ C (‰, VPDB)	δ ¹⁵ N (‰, AIR)	%C	%N	C:N Ratio		
Crescent Beach (DgRr-1)								
Deer	2	-22.6 ± 0.9	6.2 ± 2.4	41.9 ± 0.3	14.9 ± 0.4	3.3 ± 0.1		
Bear	1	-19.9	5.9	41.7	10.4	3.3		
Beaver	1	-21.6	4.8	37.3	12.9	3.3		
Salmon	6	-15.4 ± 0.1	11.8 ± 0.6	40.9 ± 0.5	14.7 ± .3	3.3 ± 0.03		
Sturgeon	3	-12.2 ± 0.7	15.2 ± 0.3	32.4 ± 10.3	10.9 ± 3.7	3.5 ± 0.2		
Glenrose and St. Mungo (DgRr-2 and DgRr-6)								
Deer	2	-22.1 ± 0.4	5.43 ± 0.3	32.18 ± 13.6	11.02 ± 5.2	3.5 ± 0.2		
Beaver	2	-21.8 ± 0.2	5.53 ± 1.4	33.43 ± 7.5	13.90 ± 0.9	3.4 ± 0.1		
Port Hammond (DhRp-17)								
Deer	1	-24.6	1.8	34.6	12.1	3.3		
Lynx	1	-15.5	13.5	40.6	14.9	3.2		
Bald Eagle	1	-15.5	16.6	42.2	14.9	3.4		
Bridge River (EeRl-4)								
Canid	4	-20.3 ± 0.4	4.0 ± .2	42.5 ± 0.2	15.2 ± 0.9	3.3 ± 0.2		
Wolf	2	-20.4 ± 0.5	3.2 ± 0.1	40.2 ± 1.5	14.2 ± 0.9	3.3 ± 0.1		
Deer	6	-20.9 ± 0.7	3.9 ± 0.9	42.4 ± 0.8	15.3 ± 0.5	3.3 ± 0.1		
Mule Deer	23	-20.5 ± 0.6	3.8 ± 0.9	41.7 ± 1.5	14.8 ± 0.7	3.3 ± 0.1		
Bighorn Sheep	2	-19.8 ± 0.7	5.0 ± 1.2	41.5 ± 1.6	14.8 ± 0.9	3.3 ± 0.1		
Beaver	2	-20.8 ± 0.2	4.4 ± 1.3	41.7 ± 0.2	14.5 ± 0.2	3.4 ± 0.03		
Salmon	7	-16.1 ± 0.4	10.4 ± 0.6	39.9 ± 2.6	14.2 ± 1.1	3.3 ± 0.1		
Sockeye	7	-16.1 ± 0.8	10.6 ± 1.3	39.2 ± 0.8	14.2 ± 0.6	3.2 ± 0.1		
Keatley Creek-HP 7 (EeRl-7)								
Deer	16	-20.8 ± 0.7	4.6 ± 1.1	40.9 ± 1.7	14.1 ± 1.1	3.4 ± 0.1		
Grouse	1	-18.9	5.2	42.8	13.6	3.6		
Hare	2	-22.0 ± 1.9	2.8 ± 1.3	42.7 ± 0.7	14.1 ± 0.1	3.5 ± 0.1		
Lynx	1	-21.1	4.8	42.3	14.3	3.5		
Aves Sp.	1	-21.3	7.2	42.7	12.9	3.4		

Table 4.1 Mean faunal values for $\delta^{13}C$ and $\delta^{15}N$

Acceptable sulphur isotopic compositions for fauna were generated from the following individuals: n=1 from Port Hammond (DhRp-17), n=29 from Bridge River (EeRl-4), and n=10 from Keatley Creek HP 7 (EeRl-7). Mean δ^{34} S and elemental data values for all sites are presented in Table 4.2. Isotopic and elemental data for all samples are presented in Appendix A.

			δ ¹³ C (‰,	δ ¹⁵ N (‰,				
Species	n	δ ³⁴ S (‰)	VPDB)	AIR)	%S	C:S Ratio	N:S Ratio	
Port Hammond (DhRp-17)								
Bald Eagle	1	9.5	-15.5	16.6	0.3	441.9	133.6	
Bridge River (EeRl-4)								
Canid	3	-0.7 ± 2.1	-20.3 ± 0.5	4.1 ± 0.2	0.2 ± 0.04	478.5 ± 72.8	144.8 ± 25.3	
Deer	3	-0.6 ± 2.4	-20.6 ± 0.4	4.6 ± 0.7	0.3 ± 0.01	458.0 ± 8.8	145.7 ± 2.0	
Mule Deer	10	-2.3 ± 3.2	-20.2 ± 0.4	4.0 ± 0.8	0.2 ± 0.02	523.3 ± 60.1	158.8 ± 19.9	
Beaver	2	-4.5 ± 1.0	-20.8 ± 0.2	4.4 ± 1.3	0.2 ± 0.04	527.2 ± 101.5	157.1 ± 28.5	
Salmon	10	14.0 ± 1.4	-16.1 ± 0.4	10.4 ± 0.6	0.5 ± 0.1	206.3 ± 16.8	63.4 ± 4.7	
Sockeye	1	11.8	-16.1	100.0	0.6	190.3	60.4	
Keatley Creek-HP 7 (EeRl-7)								
Deer	6	-3.7 ± 3.0	-20.9 ± 0.9	4.3 ± 0.9	0.2 ± 0.0	558.7 ± 15.5	169.2 ± 15.5	
Grouse	1	-1.4	-18.9	5.2	0.3	380.9	104.1	
Hare	2	-7.9 ± 2.0	-22.0 ± 1.9	2.8 ± 1.3	0.3 ± 0.04	419.9	117.1	
Lynx	1	-3.9	-21.1	4.8	0.2	502.7	145.5	

Table 4.2 Mean faunal values for δ^{34} S, along with associated measurements and means for δ^{13} C and δ^{15} N

4.2 Intra-site variability

4.2.1 Crescent Beach (DgRr-1)

Carbon and nitrogen isotopic compositions were analyzed for a total of 13 faunal

samples representing five taxa from DgRr-1; deer (n=2), bear (n=1), beaver (n=1),

salmon (n=6) and sturgeon (n=3). Carbon and nitrogen isotopic values are presented in

Figures 4.1 to 4.3. δ^{13} C values ranged from -23.3‰ (deer) to -11.6‰ (sturgeon). δ^{15} N

values ranged from 4.5‰ (deer) to 15.6‰ (sturgeon).

Distributions of both δ^{13} C and δ^{15} N values displayed in dot, box, and scatter plots (figures 4.1-4.3) show isotopically distinct groupings between terrestrial and aquatic faunal samples. The δ^{13} C values for deer, bear, and beaver samples correspond with expected values for C3 dependent terrestrial herbivores while salmon and sturgeon show elevated values due to varying marine-derived inputs. δ^{15} N values parallel the clustering observed in δ^{13} C values, though one deer sample has a δ^{15} N value that appears somewhat elevated relative to the other deer sample from DgRr-1 (7.9 versus 4.5‰).



Figure 4.1 Carbon (A.) and nitrogen (B.) isotopic compositions of bone collagen for fauna from the DgRr-1 (Crescent Beach). Dot plots represent individual values; box plots show summary distributions of species groups.



Figure 4.2 Bivariate multiplot of carbon and nitrogen isotopic compositions for DgRr-1 fauna.



Figure 4.3 Scatterplot of carbon and nitrogen isotopic compositions for DgRr-1 fauna showing terrestrial (green ellipse) and aquatic (blue ellipse) resource groupings.

Sample sizes are small for this site, but three species groups (deer, salmon, and sturgeon) have at least 2 samples, the minimum expected group size for statistical analysis. A Kruskal-Wallis test confirmed that δ^{13} C, $\chi^2(2, n=11) = 8.182$, p = .017, and δ^{15} N, $\chi^2(2, n=11) = 8.182$, p = .017 values for species groups were statistically significantly different. Post hoc analysis revealed statistically significant differences between deer (median δ^{13} C =-22.6 and δ^{15} N =6.2) and sturgeon (median δ^{13} C =-11.9 and δ^{15} N =15.1) (p = .015), groups but not between any other pairwise combination. Given the small sample sizes for deer and sturgeon, the statistical power of this test is low but still significant. There was a significant correlation (Pearson's r = 0.984, p<0.001) between δ^{13} C and δ^{15} N values across all samples.

4.2.2 St. Mungo (DgRr-2) and Glenrose (DgRr-6)

Carbon and nitrogen isotopic compositions were analyzed for four faunal samples representing two taxa from DgRr-2 and DgRr-6; deer (n=2), and beaver (n=2). Carbon and nitrogen isotopic values are presented in Figure 4.4. δ^{13} C values ranged from -22.5‰ (deer) to -21.6‰ (beaver). δ^{15} N values ranged from 4.6‰ (beaver) to 6.5‰ (beaver). Distributions of both δ^{13} C and δ^{15} N values show overlap between deer and beaver samples, with both having isotopic signatures consistent with C3 dominant terrestrial herbivores.



Figure 4.4 Bivariate multiplot (A.) and scatterplot (B.) of carbon and nitrogen isotopic compositions for DgRr-2 and DgRr-6 fauna.

4.2.3 Port Hammond (DhRp-17)

Carbon and nitrogen isotopic compositions were analyzed for three faunal samples each representing different taxa from DhRp-17; deer (n=1), lynx (n=1), and bald eagle **A**. (n=1). Carbon and nitrogen isotopic values are presented in Figure 4.5. δ^{13} C values ranged from -24.6‰ (deer) to -15.5‰ (lynx). δ^{15} N values ranged from 1.8‰ (deer) to 16.6‰ (bald eagle). The deer sample from Port Hammond has depleted δ^{13} C values and very low δ^{15} N values, but within the range of terrestrial herbivores eating a C3 dominant diet. Both bald eagle and lynx have elevated isotope values, likely due to diets comprised largely of salmon.



52

Sulphur isotopic compositions were analyzed for the single bald eagle sample from DhRp-17. Sulphur isotopic values are presented in Figure 4.6. The value for the bald eagle was 9.5‰, within the range for consumption of aquatic resources but too low for a purely marine input (~ +21‰). This corresponds with the enriched δ^{13} C value and elevated δ^{15} N value that also point to the bald eagle consuming aquatic resources that don't have a purely marine signal. This will be discussed further in Section 4.3.



Figure 4.6 Scatterplots of carbon and sulphur (A.) and nitrogen and sulphur (B.) isotopic compositions for DhRp-17 fauna.

4.2.4 Bridge River (EeRl-4)

Carbon and nitrogen isotopic compositions were analyzed for 53 faunal samples representing eight taxa from EeRl-4; canid (n=4), wolf (n=2), deer (n=6), mule deer (n=23), bighorn sheep (n=2), beaver (n=2), salmon (n=7) and sockeye (n=7). Carbon and nitrogen isotopic values are presented in Figures 4.7 to 4.9. δ^{13} C values ranged from -22.1‰ (deer) to -14.7‰ (sockeye). δ^{15} N values ranged from 2.0‰ (mule deer) to 13.2‰ (sockeye). Faunal analysis for fish specimens was conducted as part of the Bridge River project and took place in laboratory facilities at the Department of Anthropology at University of Montana, Missoula (Walsh and Tifental 2015). Salmon remains represented in the Bridge River assemblage to date are nearly all of vertebral elements. Relative size of fish vertebrae was designated "small" if trout-sized, "medium" if Sockeye-sized, and "large" if Chinook-sized, or in the case of overly-fragmentary specimens, relative size was recorded as "indeterminate".



Figure 4.7 Carbon (A.) and nitrogen (B.) isotopic compositions of bone collagen for fauna from EeRI-4 (Bridge River). Dot plots represent individual values; box plots show summary distributions of species groups.

Distributions of both δ^{13} C and δ^{15} N values show isotopically distinct groupings in the Bridge River faunal samples; those with relatively high δ^{13} C and high δ^{15} N values, made up of salmonids (sockeye (n=6) and salmon (n=7)) and samples with relatively depleted δ^{13} C and low δ^{15} N values, made up of terrestrial mammals, including all canids and wolves (figure 4.8). δ^{13} C values for deer, Mule deer, sheep, and beaver samples are generally typical of those reported for temperate environments with the exception of the wolves (n=2) and Canids (n=4). The wolves, osteometrically identified as C. lupus (Walsh & Tifental 2015), and their low δ^{15} N values are unexpected. Isotopic variability among individual wolves has been observed (Urton and Hobson 2005), but not as low as those measured at Bridge River. Potential causes for this will be discussed further in Section 4.3.



Figure 4.8 Bivariate multiplot (A.) and scatterplot (B.) of carbon and nitrogen isotopic compositions for EeRl-4 fauna. The bottom right scatterplot (C.) shows significant terrestrial and aquatic resource groupings.

A one-way multivariate analysis of variance (MANOVA) confirmed the observed differences between species groups for both δ^{13} C and δ^{15} N values. Distributions are statistically significant, F(14, 88) = 22.814, p < .0005; Wilks' Λ = .047; partial η 2 = .784. Follow-up univariate ANOVA tests showed δ^{13} C and δ^{15} N values significantly differed between species groups (see Figure 4.9 for means), δ^{13} C: F(7, 45) = 86.396, p < .0005, ω 2 = 0.92 and δ^{15} N: F(7, 45) = 78.815, p < .0005, ω 2 = 0.91. Tukey post hoc analysis revealed statistically significant differences between terrestrial species groups including deer (δ^{13} C \bar{x} = -20.9 ± 0.7, δ^{15} N \bar{x} = 3.9 ± 0.9), Mule deer (δ^{13} C \bar{x} = -20.5 ± 0.6, δ^{15} N \bar{x} = 3.8 ± 0.9), sheep (δ^{13} C \bar{x} = -19.8 ± 0.7, δ^{15} N \bar{x} = 5.0 ± 1.2), beaver (δ^{13} C \bar{x} = -20.8 ± 0.2, δ^{15} N \bar{x} = 4.4 ± 1.3), Canids (δ^{13} C \bar{x} = -20.3 ± 0.4, δ^{15} N \bar{x} = 4.0 ± .29), and wolves (δ^{13} C \bar{x} = -20.4 ± 0.5, δ^{15} N \bar{x} = 3.2 ± 0.1), and aquatic species groups including salmon $(\delta^{13}C \ \bar{x} = -16.1 \pm 0.4, \delta^{15}N \ \bar{x} = 10.4 \pm 0.6)$, and sockeye $(\delta^{13}C \ \bar{x} = -16.1 \pm 0.8, \delta^{15}N \ \bar{x} = 10.6 \pm 1.3)$ (p < .0005 for both isotopic distributions). There was a significant correlation between $\delta^{13}C$ and $\delta^{15}N$ values across all samples (Pearson's r = 0.956, p < 0.001).



Figure 4.9 Means plot of carbon (A.) and nitrogen (B.) isotopic compositions for each species group. Error bars represent 1 standard deviation.

Sulphur isotopic compositions were analyzed for 29 faunal samples from EeRl-4 representing six taxa; canid (n=3), deer (n=3), mule deer (n=10), beaver (n=2), salmon (n=10), and sockeye (n=1). Sulphur isotopic values are presented in Figures 4.10 to 4.12. δ^{34} S values ranged from -8.3‰ (mule deer) to 16.1‰ (salmon). δ^{34} S value distributions in the Bridge River faunal samples show isotopically distinct groupings between terrestrial and aquatic resources, paralleling δ^{13} C and δ^{15} N distributions. δ^{34} S values for terrestrial fauna at Bridge River is highly variable ($\bar{x} = -2.2 \pm 2.7$) compared to lower variability in aquatic faunal values ($\bar{x} = 13.1 \pm 1.5$). However, variability is lower within the individual species groups, with the exception of Mule Deer values, which have a large range. This will be discussed further in Section 4.3.



Figure 4.10 Sulphur isotopic compositions of bone collagen for fauna from EeRl-4 (Bridge River). Dot plots represent individual values; box plots show summary distributions of species groups.

Bivariate distributions of δ^{34} S values with corresponding δ^{13} C and δ^{15} N values show similar distinctions between terrestrial and aquatic resources. δ^{34} S values are positively correlated with both δ^{13} C (Pearson's r = 0.948, p<0.001) and δ^{15} N (Pearson's r = 0.917, p<0.001) values. A one-way multivariate analysis of variance (MANOVA) confirmed the observed differences between species groups for δ^{34} S, δ^{13} C and δ^{15} N values. Distributions are statistically significant, F(12, 47.915) = 16.457, *p* < .0005; Wilks' Λ = .013; partial η^2 = .763. Follow-up univariate ANOVAs showed δ^{34} S values were statistically significantly different between species groups F(4, 20) = 57.118, *p* < .0005, ω^2 = 0.92. Tukey post hoc analysis revealed statistically significant differences between terrestrial species groups including deer (\bar{x} = -1.6 ± 0.1.5), Mule deer (\bar{x} = -2.3 ± 3.2), beaver (\bar{x} = -4.5 ± 1.0) and Canids (\bar{x} = -.7 ± 2.1), and aquatic species groups including salmon (\bar{x} = 14.2 ± 1.4) with p< .0005 for all pairwise comparisons.


Figure 4.11 Scatterplots of carbon and sulphur isotopic compositions for fauna from EeRl-4. The right scatterplot shows significant terrestrial and aquatic resource groupings.



Figure 4.12 Scatterplots of nitrogen and sulphur isotopic compositions for fauna from EeRI-4. The right scatterplot shows significant terrestrial and aquatic resource groupings.

4.2.5 Keatley Creek HP 7 (EeRI-7)

Carbon and nitrogen isotopic compositions were analyzed for 20 faunal samples from EeRl-7 representing five taxa; deer (n=16), grouse (n=1), hare (n=2), lynx (n=1), and Aves Sp. (n=1). Carbon and nitrogen isotopic values are presented in Figures 4.13 and 4.14. δ^{13} C values ranged from -23.4‰ (hare) to -18.9‰ (grouse). δ^{15} N values ranged from 1.8‰ (hare) to 6.7‰ (deer). Though both δ^{13} C and δ^{15} N distributions range across species groups, there is overlap across all ranges. Deer have the largest range as well as the largest sample size, with nitrogen values being more dispersed relative to carbon values (δ^{15} N range = 3.5‰ versus δ^{13} C range = 2.9‰). Despite some visual differences, a Kruskal-Wallis test indicated species groups do not differ

statistically for either δ^{13} C or δ^{15} N distributions.



Figure 4.13 Carbon (A.) and nitrogen (B.) isotopic compositions of bone collagen for fauna from EeRI-7 HP 7 (Keatley Creek). Dot plots represent individual values; box plots show summary distributions of species groups.



Figure 4.14 Bivariate multiplot of carbon and nitrogen isotopic compositions for EeRl-7 HP 7 fauna.

Sulphur isotopic compositions were analyzed for 10 faunal samples representing four taxa from EeRl-7; deer (n=6), grouse (n=1), hare (n=3), and lynx (n=1). Sulphur isotopic values are presented in Figure 4.15 and plotted with δ^{13} C and δ^{15} N values in Figure 4.16. δ^{34} S values ranged from -9.3‰ (hare) to -0.7‰ (deer). δ^{34} S values across species groups, with deer having the largest range at 8.0‰. There was no statistical difference across species groups for δ^{34} S distributions. Sulphur mechanisms as they relate to wide value ranges and negative values will be discussed in the following section.



Figure 4.15 Sulphur isotopic compositions of bone collagen for fauna from EeRl-7 HP 7 (Keatley Creek). Dot plots represent individual values; box plots show summary distributions of species groups.



Figure 4.16 Scatterplots of sulphur isotopic compositions with carbon values (left) and nitrogen values (right) for fauna from EeRI-7 HP 7.

4.3 Discussion

While there is inter-site variability between certain species groups, specifically deer and salmonid species, there are still clear delineations between terrestrial and aquatic resources in C, N, and S values. Overall values of species groups are consistent across sites and demonstrate similar species-specific behavioural strategies employed within the study area. The environmental dynamics and paleoecological relationships discovered by the current study show regionally specific interactions between animal consumer, plant, soil, and substrate communities. Variation observed within species groups is largely due to differences in how they interact with their environment and

how widespread their ranges are. Perhaps the biggest thing is what is missing - namely all the species that encompass this prehistoric ecology.

4.3.1 Inter-site variability for terrestrial fauna

Deer

Mule and Black-tailed deer, both members of the same species, *Odocoileus hemionus*, are the most widespread members of the Cervidae family in British Columbia. A ubiquitous and adaptable species, they inhabit a broad range of habitats across North America. Both sub-species make seasonal altitudinal migrations (Klinkenberg 2017), moving to higher elevations in summer. In spring, these deer move from their winter range to wetter areas with a greater variety and biomass of forages available in summer, thus maximizing their nutritional opportunities. In fall and early winter, snow accumulation at the higher elevations forces the deer back to the lower valleys. Black-tailed deer seem to move less than Mule deer, restricting their seasonal migrations to within watersheds. Both sub-species are excellent swimmers and have been known to swim between islands along the coast.

Although Mule deer and Black-tailed deer are primarily browsing herbivores, they eat a variety of plant foods, related to local conditions. Rocky Mountain Mule deer tend to eat more grasses than coastal sub-species, though all species will browse on Douglas-fir, Saskatoon and willows as well as eating many species of forbs, such as Fireweed, salmonberry, Salal, maple, and other shrubs or trees. In winter, important forages are Douglas-fir, Red Huckleberry, Salal and Western Red-cedar, as well as Deer Fern and arboreal lichens (e.g., *Alectoria, Bryoria* and *Usnea*).

Odocoileus Sp. are the most represented species among sampled fauna for the current project, comprising 46.4% of the assemblage (n=51). Deer were identified to species (Mule Deer) for specimens from EeRI-4, as part of the faunal analysis for the Bridge River Project (Prentiss 2015). All materials were analyzed and identified utilizing comparative collections at the University of Montana (Walsh & Tifental 2015). Deer specimens from other sites were identified as part of the current study to taxa and could potentially represent either *Odocoileus* sub-species. δ^{13} C and δ^{15} N values for deer samples across sites have ranges greater than 1.5‰ and ranges for δ^{34} S between 8-10‰. Figure 4.17 indicates δ^{13} C values in coastal sites (DgRr-1 and DgRr-2) are lower and less variable than sites further inland (EeRl-4 and EeRl-7). δ^{15} N values are similarly grouped (figure 4.17B.) with coastal sites having higher values than inland sites. A Kruskal-Wallis test confirmed that δ^{13} C values for archaeological sites were statistically significantly different, $\chi^2(3, n=49) = 12.950$, p = .005, and $\delta^{15}N$ values, $\chi^2(3, n=49) = 9.992$, p = .019, with EeRI-4 having significantly different values from DgRr-1 and DgRr-2 (δ^{13} C *p* = .011 and .014 and δ^{15} N *p* = .038 and .043, respectively).



Figure 4.17 Box plots showing variability in carbon (A.) and nitrogen (B.) isotopic compositions in deer across sites sampled for the current study.

The significant variability across the isotopic suite analyzed for these samples is notable. Large inter-regional ranges for both δ^{13} C and δ^{15} N values have been reported previously for deer (Cormie and Schwarcz 1994, 1996; Drucker et al. 2011; Stevens et al. 2006) and likely represent both dietary and mobility differences in the paleoecological relationships of these individuals with their environments. Climatic and environmental factors including, altitude, precipitation, soil dynamics and the canopy effect influence deer δ^{13} C and δ^{15} N values (e.g., Cormie and Schwarcz 1994, 1996; Drucker et al. 2008, 2010). The association of elevated δ^{15} N and lower δ^{13} C values in the current study for coastal sites and lower δ^{15} N with higher δ^{13} C values in the interior sites (Figure 4.18) reflects these effects along with species differences between Blacktailed deer and Mule deer. Canopy effects in deep forests can decrease the δ^{13} C due to recycling of isotopically light CO₂ from plant respiration and decomposition in soil litter (Vogel, 1978; Van der Merwe and Medina, 1991; Tieszen 1991).



Figure 4.18 Bivariate multiplot of carbon and nitrogen isotopic compositions for deer species across sites sampled for the current study.

Black-tailed deer, potentially represented by the DgRr-1 and DgRr-2 samples, inhabit dense coastal rainforests, while also accessing riparian, subalpine and alpine areas and the underbrush of old-growth forest for the forages that grow in them. Sampled deer values representing occupied habitats with a dense forest canopy agree with expected lower δ^{13} C values relative to Mule deer, who would have lived in drier areas with high summer temperatures and would have occupied xeric and more arid foraging areas (Cormie and Schwarcz 1994; Stewart et al. 2003).

The δ^{15} N of mammalian herbivore bone collagen is primarily affected by variations in soil δ^{15} N, largely a product of mean annual temperature and precipitation (Amundson et al. 2003), but it can also be influenced by amounts of leguminous or woody plants in the animal's diet (Cormie and Schwartz, 1994; Ambrose and DeNiro, 1986; Vogel et al., 1990). Higher δ^{15} N involves an increased nitrogen cycling process in soils due to increased pedogenic and biological activity. (e.g., Hobbie et al. 1999, 2005; Nadelhoffer and Fry, 1988), which would be present in the forested habitats of the coastal sites versus the interior habitats occupied by Mule deer.

Wild Canids

Faunal analyses for all canids were conducted following widely accepted methods outlined (e.g. Cannon 1987; Gilbert 1990; Gilbert et al. 1996; Grayson 1984; Lyman 1994; 2008; Reitz and Wing 2008) and took place in laboratory facilities at the Department of Anthropology at University of Montana, Missoula. All materials were

analyzed and identified with the aid of the vertebrate collection at the Phillip L. Wright Zoological Museum and Montana Comparative Skeletal Collection at the University of Montana. Canid specimens were identified in reference to size as compared with type specimens (Walsh & Tifental 2015). Size designations were based on the relative size of the animal to which a specimen could be attributed to, not the size of the specimen itself. Four specimens identified to *Canis Sp.* and two specimens identified to *Canis lupus* were sampled for the current study, all from EeRl-4 (n=6). All

specimens likely represent a single species, *Canis lupus*, as *Canis latrans* at EeRl-4, has previously been ruled out by genetic analysis (Rodrigues 2015). Collagen quality criteria for all canid specimens met established acceptable ranges (see Table 2.1; Appendix 1), situating any isotopic patterning within the actual resource relationships that occurred between these wild canids and their prey in the past. The means for δ^{13} C and $\delta^{15}N$ (-20.3±0.4 and 3.7±0.5‰, respectively) are more characteristic of a terrestrial herbivore than a top-level consumer. Terrestrial carnivores such as wolves generally exist at low densities, move frequently within large home ranges, and feed opportunistically, which results in complex and highly variable patterns of prey selection (Fox-Dobbs et al. 2007; Mech and Boitani 2003; Peterson and Ciucci 2003). Modern day wolf diets in British Columbia are variable and often opportunistic in their constitution. In northern British Columbia, wolf diets are most commonly comprised of deer, moose, caribou, and beaver, with regional differences in these dietary resources (Milakovic & Parker 2011; Stotyn 2007). In a recent study looking at ecological and habitat selection of caribou, wolf scats from den sites in the Peace region were found to contain mostly beaver, with minor components of birds, moose and caribou calves (Culling et al. 2006). Few studies from other areas of British Columbia have examined diet composition, but anecdotal work and inferences from other regions (e.g., Alaska; Ballard et al. 1987) suggest that moose and caribou are the most common prey items in the north, while deer and elk are most common in the south (Hatler et al. 2008).

The low nitrogen values represented by the wolf and canid samples here preclude deer, or at least deer represented by the sampled material, as being the primary component of their diet, as the overall mean of deer from EeRl-4 is 4.2±1.2‰,

which is higher than the wolf and canid means. While isotopic variability among individual wolves has been observed in modern wolf populations (Urton and Hobson 2005), no values have been recorded as low as those observed here. That all canid specimens represent a single archaeological site suggests a potential location specific anomalous values that do not reflect isotopic values for archaeological canids as a whole. I argue that these values reflect a diet comprised of species not represented in the current study, potentially comprised predominantly of moose, caribou or sheep. Modern wolf populations are associated with the distribution of all three ungulate species and while moose are certainly sparser in the Southern Interior than in parts of the north, the recovery of wolf populations has followed local increases in moose (Mowat 2007). Isotopically, published δ^{15} N values for modern moose, caribou and sheep in comparable regions are low (Adams et al. 2010; Ben-David et al. 2001; Drucker et al. 2010; Milakovic & Parker 2011), with values averaging between 0-3‰. When corrected to reflect collagen isotope data, these values agree well with the trophic placement of moose, sheep, or caribou as diet for wolves.

The low isotopic values for wild canids obtained in the current study that disagree with expected values for terrestrial predators confirm species-based and locally oriented ecological relationships existed in the past and are observable isotopically. Comparable in the verification of locally-oriented and species-specific wolf-prey relationships is the consumption of Pacific salmon by coastal wolf populations (Szepanski et al. 1999; Darimont and Reimchen 2002; Darimont et al. 2003, 2008), where salmon have been recognized as an important diet constituent. The potential for salmon as an important inland food source has even been suggested and

indicated by some studies (e.g. Adams et al. 2010; Darimont and Reimchen 2002; Darimont et al. 2003). Ultimately, the unexpected and unusually low $\delta^{15}N$ values obtained in the current study highlight the necessity for establishing a greater understanding of animal interactions in the past and determining these complex isotopic relationships within the context of spatial and species-specific parameters.

Other Terrestrial Fauna

The remaining samples characterized by relatively depleted δ^{13} C and low δ^{13} N values, are made up exclusively of terrestrial fauna and non-*C. familiaris* canid species. Mean δ^{13} C and δ^{15} N values are typical of terrestrial values reported for temperate environments, while the total mean δ^{13} C and δ^{15} N values for all fauna represented by the cluster (-20.5 ±.6‰ and 3.9±.9‰) is similarly representative of the individual species. Often regarded as the baseline faunal data with which to compare human and socio-economically regarded fauna, these terrestrial values provide us with an ideal set of values to compare our domesticated dog samples as well as other species groups previously discussed. The Bald Eagle sample has enriched carbon and nitrogen values, likely reflective of the incorporation of riverine species, namely salmon, into its diet. Bald Eagles are opportunists and shift quickly from one food to another as it becomes available, though the main prey of the Bald Eagle is fish, with fish comprising 90% or more of the Bald Eagle annual diet in many areas (Blood and Anweiler 1994).

4.3.2 Inter-site variability for aquatic fauna

As expected, there were significant differences in carbon and nitrogen isotope ratios among aquatic fauna from terrestrial fauna sampled in the current study. Anadromous species, comprised of fish identified to *Oncorhynchus Sp.* (n=13) and fish

identified to sockeye (n=7) and sturgeon (n=3), were enriched in δ^{15} N and δ^{13} C relative to all terrestrial fauna except domesticated dogs, which will be discussed at length in the next chapter. As demonstrated above, species that would have incorporated riverine species as a main component of their diet, such as bald eagles and potentially lynx, were similarly enriched in δ^{13} C and δ^{15} N relative to terrestrial fauna sampled. These isotopic differences exist primarily because of differences in stable carbon and nitrogen isotope ratios at the base of terrestrial vs. aquatic food webs (i.e., terrestrial plants vs. phytoplankton) (see Chapter 2; Beaudoin et al. 2001; DeNiro and Schoeninger 1983; France 1995; Persaud et al. 2012; Ventura and Catalan 2008). In contrast, freshwater ecosystems tend to be enriched in ¹⁵N relative to terrestrial ecosystems due to increased trophic interactions (Kraemer et al. 2012).

Salmonids

Salmonid remains were sampled from two sites, DgRr-1 and EeRl-4. Faunal analysis conducted prior to and independently from the current project at EeRl-4 differentiates between "sockeye" and "salmonid" specimens, based on size differences in vertebral remains (see Section 4.2.4). In fact, virtually all salmon remains that have been genetically identified at EeRl-4 were sockeye (Speller, pers. comm.) so salmonid and sockeye categorizations likely represent the same species. Mean sockeye salmon δ^{13} C values plot very closely to overall salmonid values (-16.1 ±.8‰ versus -15.8 ±0.4‰) with both reflecting a partially marine-derived isotope signature. Mean δ^{15} N values track similarly (10.6 ±1.3‰ versus 11.0 ±0.9‰) apart from an *O. nerka* specimen having elevated nitrogen values. Salmonid values are also close, though somewhat lower, to those reported by Szpak et al. (2009), (n=19, mean δ^{13} C‰ = -15.1±0.7‰,

mean $\delta^{15}N = 12.2\pm0.8\%$) and Schwarcz et al. (2014) (n=4, mean $\delta^{13}C = -17.8\pm1.3\%$, mean $\delta^{15}N = 15.4\pm0.5\%$). There are observable differences in both isotopic distributions between salmonids sampled from DgRr-1 and EeRl-4, with DgRr-1 salmonids having higher values (Fig. 4.19). Isotopic values were statistically significantly higher for DgRr-1 ($\delta^{13}C$ mean rank=16.3; $\delta^{15}N$ mean rank = 15.8) than for EeRl-4 ($\delta^{13}C$ mean rank=8.0; $\delta^{15}N$ mean rank = 8.2), $\delta^{13}C$: U = 7.000, z = -2.887, p = .002, $\delta^{15}N$: U = 10.000, z = -2.639, p = .006. The deviation among all salmonids from a completely marine based isotopic signature indicates various inputs of non-marine diet and from inter-site differences between salmon groups they reflect more locally determined signatures, given salmon life histories and time spent travelling the Fraser to the Gulf of Georgia or Mid-Fraser regions.



Figure 4.19 Carbon and Nitrogen values for aquatic species sampled in the current study.

The five species of salmon that spawn in the Fraser basin have variable life cycles, typically spawning at different ages and at different adult sizes (Quinn 2004) which is paralleled by variation in their isotopic signatures. Isotopic research on the five species of Pacific salmon has demonstrated three isotopically distinctive subgroups based on general salmonid dietary trends (Satterfield and Finney 2002); pink, chum,

and sockeye salmon, lower trophic level consumers (zooplankton) have low δ^{13} C and δ^{15} N values; Coho salmon, with some chum and sockeye comprise the group with intermediate δ^{13} C and δ^{15} N values; and chinook salmon have the highest δ^{13} C and δ^{15} N values, likely attributable to the species consuming higher proportions of fish. Johnson and Schindler (2008) similarly found species differences between Pink, chum, and sockeye salmon showing high degrees of isotopic overlap and Chinook and Coho having elevated $\delta^{15}N$ and enriched $\delta^{13}C$ values. $\delta^{13}C$ enrichment was attributed to more extensive use of coastal food webs relative to the more depleted pelagic signatures represented by pink, chum, and sockeye salmon. Orchard and Szpak (2011:25) note, however, that values derived from muscle tissue are not comparable to archaeological assemblages, which are represented by bone. As bone remodels very differently than muscle these isotopic values would not reflect the slower remodeling rate at which bone and bone collagen develops. Other isotopic studies have similarly demonstrated, albeit based on limited datasets, that there is indeed variability across species and age groups (Schoeninger and DeNiro 1984).

Sturgeon

Two species of sturgeon, white sturgeon (*Acipenser transmontanus*) and green sturgeon (*A. medirostris*), are found in the Lower Fraser River. White sturgeon have a large geographic distribution in the Fraser River that extends from where it empties into the Salish Sea, upstream to as far north as McBride, a distance of over 1,100 km (Hatfield 2005). Like salmonids, they are anadromous, with documented large-scale marine movements between estuaries (Welch et al. 2006) and records of sturgeon being caught in marine waters (Scott and Crossman 1973:91). Sturgeon have no teeth

and use their downward-oriented mouths to create suction to ingest food on river bottoms. Their diet generally consists of invertebrates, insects and fish (Gray et al. 2017; Scott and Crossman 1973) while mature fish tend to eat larger anadromous fish, including eulachon, salmon sculpins, and stickleback. They are known to follow sockeye runs and will move throughout the lower Fraser River to exploit fish resources at specific locations (Hatfield 2005).

Sturgeon ($\delta^{13}C \bar{x} = -12.2 \pm 0.7$, $\delta^{15}N \bar{x} = 15.2 \pm 0.3$) is significantly enriched in both $\delta^{13}C$ (F(2, 20) = 54.520, p < .0005, $\eta^2 = 0.845$) and $\delta^{15}N$ (F(2, 20) = 24.143, p < .0005, $\eta^2 = 0.71$) relative to all salmonid species, regardless of site. The values determined in the current study align with sturgeon incorporating anadromous fish such as salmon into their diets. However, while $\delta^{15}N$ values are consistent with a second-level anadromous consumer all samples have enriched $\delta^{13}C$ values compared to modern sturgeon isotopic studies conducted for estuarine sturgeon populations, (e.g., Stewart et al. 2004; Gu et al. 2001; Zeug et al. 2014), even when accounting for isotopic differences between body tissue and collagen. The elevated isotopic composition may indicate the age and relative size of the individual.

4.3.3 Sulphur mechanisms in soil and water.

All sampled terrestrial fauna have δ^{34} S values ranging between 0 and -10‰, which, while certainly more negative than other ³⁴S values reported for fauna, parallels the bedrock geology in the study area. Isotopic and elemental hydrogeochemistry conducted on the Fraser River has shown that the primary control on chemistry on the watershed is the diverse geological terranes that are drained (Cameron et al. 1995). For example, SO₄ in the headwaters comes from dissolution of sedimentary sulphate

minerals, while towards the coast, weathering of sulphide minerals become progressively more important as a source of SO₄, including igneous sulphides that contribute a substantial flux of elements such as Se and Sb.

Among analyzed fauna, deer values have the highest dispersion, likely reflecting their wider ecological range relative to other species groups represented. Similarly, higher variability in both δ^{13} C and δ^{15} N values supports the conclusion that negative sulphur isotope values among terrestrial species groups reflect geologically determined variation among sulphur isotope values that is incorporated via diet. However, with no discernible differences across sites for δ^{34} S values, either the documented geology within the environs of the Fraser River, while variable in origin and composition, is not as variable in its sulphur isotope uptake or the faunal specimens sampled in the current study did not pick up possible differences. The diversity of bedrock formations coupled with sulphur biodynamics in soil is undoubtedly reflected in the range of sampled fauna sulphur isotope values. However, among terrestrial and aquatic faunal groups, there are clear, statistically significant distinctions between sulphur isotope distributions. Bedrock geology within the study area includes undivided sedimentary, quartz dioritic, andesitic volcanic, granodioritic, marine sedimentary and volcanic formations from a similarly wide breadth of ages (BC Geological Survey, 2017). Sulphur values for schists, shales, and greywacke within the Bridge River formation, for example are highly negative ($\bar{x} = -18.9\%$ across 3 rock types) while Bridge River basalt has values with an average of +3.4‰ (Moore et al. 2009).

Sulphur in sediments, in sea water, and in materials such as coal and petroleum that have participated in the biological sulphur cycle, displays a much wider range of

 δ^{34} Svalues. In general, evaporites (sulphates) tend to be enriched and sedimentary sulphides depleted in ³⁴S with large deviations of δ^{34} S from zero due largely to the fractionation of the sulphur isotopes in biologically mitigated reactions at low temperatures.

 δ^{34} S values ($\bar{x} = 13.1 \pm 1.5$) obtained for aquatic species are represented by salmonid species exclusively and deviate from a purely marine isotopic signal (+21%), which is consistent with salmon being anadromous and incorporating both freshwater and marine resources throughout their life cycles. Nehlich (2015) cites values approaching 13‰ as indicating a freshwater influence, based on faunal results from Scandinavia. Variability between marine, freshwater, and estuarine environments is notable in their sulphur isotopic ratios. Aquatic faunal δ^{34} S values are related to the δ^{34} S value of the water sulphate, which is then obtained from aquatic fauna by aquatic plants and then upwards through aquatic food webs (Nehlich 2015). As discussed previously, marine ecosystems display relatively little variation, with average δ^{34} S values measured in modern marine fish at $+16.8 \pm 0.7\%$ (e.g. Beavan-Athfield et al. 2008; Fry 1988; Kwak and Zedler 1997; Nehlich et al. 2013; Thomas and Cahoon, 1993). Values in the current study correspond with a mixture of marine and freshwater sulphur inputs but given the importance of understanding sulphur isotope ratios on a locally-oriented scale (Nehlich 2015) it is crucial to evaluate locally determined sulphur isotope values for riverine ecologies within British Columbia.

5 Human-animal (Dog) interactions in the Fraser Watershed: Insights from Stable Isotope Analysis

The perspective of the environment and relationships between human and nonhumans as counterparts within a locally oriented holistic ecology offers an assessment of human-animal interaction beyond subsistence-based, economic, or political contexts (e.g., Cannon 2011; Ingold 2000, 2011; Losey 2010; Pierotti 2011). The individualized nature of human-animal relationships has been discussed mainly for companion animals investigating individual treatment of animals in archaeological contexts (Byrd et al. 2013; Losey et al. 2011; Prummel 2006). Drawing on TEK paradigms that all things are connected, conceptually related to community ecology, and that all things are related, changes the emphasis from the human to the ecological community as the focus of theories concerning these relationships (Pierotti 2011; Pierotti and Wildcat 2000).

This chapter presents the results of the isotopic analysis of domesticated dogs from the perspective that these isotopic measurements reflect the fundamental incorporation of an ecological community into its members, whether human, plant, or animal. Intra-, inter-site, temporal, and inter-species variability is examined in order to understand ecological interactions and offer a comprehensive assessment of the range of variability in the archaeological record.

5.1 Results

Carbon and nitrogen isotopic compositions, as well as associated elemental data and preservation criteria (%C, %N, C:N, collagen yield) for all archaeological dogs sampled are presented in Appendix A. Following the discussion in Chapter 2, only collagen samples that met all the following criteria were included in summary plots and

statistical analyses (following recommendations of Ambrose 1990; DeNiro 1985; Harbeck and Grupe 2009; Szpak 2011; van Klinken 1999): collagen yield > 1%, %C ≥ 13%, %N ≥ 4.8%, C:N ratio > 2.9 and < 3.6. Sulphur compositions, as well as associated C and N isotopic data and preservation criteria (%S, C:S, N:S) are presented in Appendix A. Collagen samples that met all of the following criteria were included in summary plots and statistical analyses (following recommendations of Nehlich and Richards 2009): for mammalian/avian bone (%S from 0.15% to 0.35%, C:S ratio 600 ± 300, N:S ratio 200 ± 100) and for fish (%S from 0.4% to 0.8%, C:S ratio 175 ± 50, N:S ratio 60 ± 20).

Acceptable carbon and nitrogen isotopic compositions for domestic dogs were generated for 152 samples from the following number at each site: n=9 from Tsawwassen (DgRs-2), n=49 from Water Hazard (DgRs-30), n=47 from Crescent Beach (DgRr-1), n=12 from Port Hammond (DhRp-17), n=9 from Bridge River (EeRl-4), and n=21 from Keatley Creek HP 7 (EeRl-7). The total mean values for δ^{13} C and δ^{15} N were -14.4±1.9‰ and 15.1±2.1‰, respectively. δ^{13} C values ranged from -23.0 to -11.3‰ (range = 11.7) while δ^{15} N values ranged from 5.4 to 20.1‰ (range = 14.7). Table 5.1 presents mean δ^{13} C, δ^{15} N and elemental data values for all sites.

Acceptable sulphur isotopic compositions for domestic dogs were generated for 60 samples from the following number at each site: n=4 from Tsawwassen (DgRr-1), n=2 from Water Hazard (DgRs-30), n=24 from Crescent Beach (DgRr-1), n=11 from Port Hammond (DhRp-17); n=9 from Bridge River (EeRl-4), and n=10 from Keatley Creek HP 7 (EeRl-7). The total mean value for δ^{34} S was 10.3±5.0‰ and ranged from -

10.2 to 13.9‰. Mean δ^{34} S and elemental data values for all sites are presented in Table 5.2.

The range of isotopic values for domestic dogs is relatively consistent across samples with the majority of dog values clustering around the means for both δ^{13} C and δ^{15} N. There are three samples with low δ^{13} C and δ^{15} N values (SUB-C 429, SUB-C 4118, and SUB-C 10033) that appear to be outliers, and one with elevated δ^{15} N values (SUB-C 4129). These correspond somewhat to δ^{34} S values that deviate from the overall clustering of samples, but not absolutely. These will be discussed in Section 5.3.

5.2 Intra-site variability

5.2.1 Tsawwassen (DgRs-2)

Carbon and nitrogen isotopic compositions were analyzed for a total of nine domestic dog samples from DgRs-2. Carbon and nitrogen isotopic values are presented in Figures 5.1 and 5.2. The mean δ^{13} C value for was $-13.5\pm0.6\%$ and ranged from -14.2to -12.5%. The mean δ^{15} N value was $15.3\pm0.4\%$ and ranged from 14.6 to 16.1\%. Sulphur isotopic compositions were analyzed for a total of 4 domestic dog samples from DgRs-2. Sulphur isotopic values are presented in Figure 5.1 and 5.3. The mean δ^{34} S value for dogs was $11.6\pm1.9\%$ and ranged from 8.7 to 12.9%. Values for δ^{13} C and δ^{15} N are tightly dispersed with no outliers and small standard deviations.

Site Number	n	δ ¹³ C (‰, VPDB)	δ ¹⁵ N (‰, AIR)	%C	%N	C:N Ratio
DgRs-2	9	-13.5 ± 0.6	15.3 ± 0.4	41.1 ± 1.1	14.6 ± 0.2	3.2 ± 0.1
DgRs-30	48	-13.5 ± 0.6	15.6 ± 0.5	41.4 ± 0.6	14.7 ± 0.3	3.3 ± 0.1
DgRr-1	47	-13.7 ± 1.3	15.7 ± 1.1	41.7 ± 0.8	15.2 ± 0.6	3.3 ± 0.1
DhRp-17	12	-14.7 ± 2.6	16.0 ± 2.6	40.0 ± 1.2	13.9 ± 0.7	3.4 ± 0.1
EeRl-4	9	-15.4 ± 0.4	14.1 ± 0.5	41.4 ± 0.7	14.9 ± 0.3	$3.3 \pm .04$
EeRl-7 HP 7	21	-16.5 ± 1.3	13.8 ± 2.3	41.6 ± 3.6	14.3 ± 1.3	3.4 ± 0.1

Table 5.1 Mean carbon and nitrogen isotopic values and elemental data for dogs

Site Number	n	δ ³⁴ S (‰)	δ ¹³ C (‰, VPDB)	δ ¹⁵ N (‰, AIR)	%S	C:S Ratio	N:S Ratio
DgRs-2	4	11.6 ± 2.0	-13.2 ± 0.5	15.5 ± 0.5	0.3 ± .02	432.6 ± 37.9	131.7 ± 9.5
DgRs-30	2	5.4 ± 2.9	-13.2 ± 1.4	16.0 ± 1.3	0.3 ± .04	368.3 ± 42.9	111.8 ± 12.4
DgRr-1	24	10.3 ± 5.0	-13.6 ± 1.4	15.7 ± 1.5	$0.2 \pm .02$	491.7 ± 29.3	153.4 ± 14.4
DhRp-17	11	11.0 ± 3.0	-14.8 ± 2.8	16.0 ± 2.8	$0.2 \pm .02$	473.1 ± 43.2	140.7 ± 11.9
EeRl-4	9	11.7 ± 1.9	-15.4 ± 0.4	14.1 ± 0.5	$0.2 \pm .01$	487.3 ± 42.9	11.7 ± 1.9
EeRl-7 HP 7	10	10.0 ± 1.8	-16.1 ± 0.7	14.6 ± 1.2	0.3 ± .01	476.7 ± 25.7	141.9 ± 9.4

Table 5.2 Mean sulphur isotopic values and elemental data for dogs



Figure 5.1 Scatterplot of carbon, nitrogen (A) and sulphur (B) isotopic compositions for dogs grouped by archaeological site.



Figure 5.2 Carbon (left) and nitrogen (right) isotopic compositions of bone collagen for dogs from all sampled sites. Dot plots represent individual values; box plots show summary distributions of sites.



Figure 5.3 Sulphur isotopic compositions of bone collagen for dogs from all sampled sites. Dot plots represent individual values; box plots show summary distributions of sites.

Both δ^{13} C and δ^{15} N values for dogs analyzed from DgRs-2 indicate the

consumption of protein from a higher trophic level, most likely aquatic resources.

There is some variability in the sulphur values from DgRr-2, however, as discussed in

Chapter 4, δ^{34} S values rely on both hydrologic and geologic mechanisms which can vary

greatly given locale and diet. No individual from this site had sulphur values approaching purely marine-derived values (+21‰), which, given the elevated carbon and nitrogen values, offers insight into potential variability in the dietary consumption of aquatic resources. This will be discussed further in Section 5.3.

5.2.2 Water Hazard (DgRs-30)

Carbon and nitrogen isotopic compositions were analyzed for 49 domestic dog samples from DgRs-30. Carbon and nitrogen isotopic values are presented in Figures 5.1 and 5.2. The mean δ^{13} C value for dogs was $-13.5\pm0.6\%_0$ and ranged from -14.8 to - $11.9\%_0$. The mean δ^{15} N value for dogs was $15.6\pm0.5\%_0$ and ranged from 14.6 to 17.0. Sulphur isotopic compositions were successfully analyzed for a total of 2 domestic dog samples from DgRs-2. Sulphur isotopic values are presented in Figure 5.1 and 5.3. The mean δ^{34} S value for dogs was $5.4\pm2.9\%_0$. Values from DgRs-30 are tightly distributed with standard deviations less than $1\%_0$ and interquartile ranges (measuring the middle 50% of values) for both δ^{13} C and δ^{15} N less than $1\%_0$ (.68 and .59, respectively). Both δ^{13} C and δ^{15} N values for dogs analyzed from DgRs-30 indicate consumption of protein from a higher trophic level, most likely aquatic resources, while sulphur values are low relative to a marine-derived sulphur value (3.3 and 7.4‰ vs. ~21‰), which indicates resources different than those at DgRs-2 were being consumed (See Section 5.3).

5.2.3 Crescent Beach (DgRr-1)

Carbon and nitrogen isotopic compositions were analyzed for 47 domestic dog samples from DgRr-1. Carbon and nitrogen isotopic values are presented in Figures 5.1 and 5.2. The mean δ^{13} C value for dogs was -13.7±1.3‰ and ranged from -19.1 to -11.3‰. The mean δ^{15} N value for dogs was 15.72±1.1‰ and ranged from 9.4 to 17.1‰.

Values for δ^{13} C and δ^{15} N have relatively low variability apart from one sample that has low values for both isotopic compositions (SUB-C 10033). Sample SUB-C 10033 was obtained from a vertebra included in Crockford's (1997) osteometric analysis of Crescent Beach material. The osteological identification appears to be robust and the outlying isotopic values highlight the variability of dog diet rather than representing a potentially misidentified dog. When this sample is excluded from calculations standard deviations for δ^{13} C and δ^{15} N values are less than 1‰ (.9 and .6‰, respectively). All samples except SUB-C 10033 indicate the consumption of protein from a higher trophic level, most likely aquatic resources, while SUB-C 10033 has values corresponding to a terrestrial derived diet (See Section 5.3 for discussion).

Sulphur isotopic compositions were analyzed for 24 domestic dog samples from DgRr-1. Sulphur isotopic values are presented in Figure 5.1 and 5.3. The mean δ^{34} S value for dogs was $10.3\pm5.1\%_0$ and ranged from -10.2 to 13.9‰. The high variability of sulphur values is largely due to 2 samples with lower values than the rest of the sample set (SUB-Cs 10032 and 10033). SUB-C 10033 has similarly low δ^{13} C and δ^{15} N values. As with other sites, no individual from this site had sulphur values approaching purely marine-derived values (+21‰).

5.2.4 Port Hammond (DhRp-17)

Carbon and nitrogen isotopic compositions were analyzed for 12 domestic dog samples from DhRp-17. Carbon and nitrogen isotopic values are presented in Figures 5.1 and 5.2. The mean δ^{13} C value for dogs was -14.7±2.6‰ and ranged from -23.0‰ to -13.2‰. The mean δ^{15} N value for dogs was 16.0±2.6‰ and ranged from 8.6 to 20.1‰. Values for δ^{13} C and δ^{15} N have relatively low variability apart from one sample that has

low values for both isotopic compositions (SUB-C 4118) and one sample with elevated nitrogen (SUB-C 4129). The remaining samples indicate the consumption of protein from a higher trophic level and are consistent with dog values from other sites in the current study.

Sulphur isotopic compositions were analyzed for 11 domestic dog samples from DhRp-17. Sulphur isotopic values are presented in Figure 5.1 and 5.3. The mean δ^{34} S value for dogs was 11.0±3.0‰ and ranged from 2.1 to 11.1‰. The high variability is due to one sample having a δ^{34} S value significantly lower than other samples in the group (δ^{34} S=2.1‰; SUB-C 4118). Standard deviation decreases to .8 when it is removed from calculations. This sample meets all preservation criteria, had been identified to *Canis familiaris* during the analysis phase of the Port Hammond project, occurring prior to the current study (Antiquus 2001) and was confirmed during the current project as part of the analysis. It indicates terrestrial protein was being consumed by this animal rather than aquatic resources.

5.2.5 Bridge River (EeRl-4)

Carbon and nitrogen isotopic compositions were analyzed for 13 domestic dog samples from EeRl-4. Carbon and nitrogen isotopic values are presented in Figures 5.1 and 5.2. The mean δ^{13} C value for dogs was $-15.4\pm0.4\%_0$ and ranged from -15.9 to -14.8‰. The mean δ^{15} N value for dogs was $14.1\pm0.5\%_0$ and ranged from 13.5 to 15.0‰. Carbon and nitrogen isotopic distributions for EeRl-4 are somewhat depleted relative to other sites, apart from EeRl-7. Even with the apparent depletion, δ^{13} C and δ^{15} N values for dogs indicate they were consuming aquatic resources and, contrasting nondomesticated Canids and wolves sampled from the site, there is no observable

terrestrial based protein in their diets. Rather, they track the Bridge River salmonids values very well.

In testing the observed inter-site variability between EeRl-4 and other sites' δ^{13} C and δ^{15} N distributions, a Kruskal-Wallis test confirmed that δ^{13} C, $\chi^2(5, n=147) = 72.347$, p < .001, and δ^{15} N, $\chi^2(5, n=147) = 50.713$, p < .001 values for sites were statistically significantly different. Post hoc analysis with pairwise comparisons were performed using Dunn's (1964) procedure with a Bonferroni correction for multiple comparisons. Adjusted p-values are presented. Analysis revealed statistically significant differences in median values between EeRl-4 (δ^{13} C=-15.5 and δ^{15} N=14.1‰) and DgRs-30 (δ^{13} C=-13.5‰; p < .001 and δ^{15} N=15.6‰; p = .002), DgRr-1 (δ^{13} C=-13.7‰; p=.003 and δ^{15} N=15.9‰; p < .001), and DhRp-17 (δ^{15} N=16.3‰; p < .001).

Sulphur isotopic compositions were analyzed for 9 domestic dog samples from EeRl-4. Sulphur isotopic values are presented in Figures 5.1 and 5.3. The mean δ^{34} S value for dogs was 11.7±1.9‰ and ranged from 8.2 to 14.4‰. While δ^{15} S values for dogs is somewhat variable at Bridge River, they are consistent with the majority of values for other sites and the mean is close to the overall mean of 10.3‰.

5.2.6 Keatley Creek HP 7 (EeRI-7)

Carbon and nitrogen isotopic compositions were analyzed for 21 domestic dog samples from Housepit (HP) 7 at EeRl-7. Carbon and nitrogen isotopic values are presented in Figures 5.1 and 5.2. The mean δ^{13} C value for dogs was -16.6±1.3‰ and ranged from -20.9 to -14.8‰. The mean δ^{15} N value for dogs was 13.8±2.3‰ and ranged from 6.2 to 17.1‰. Carbon and nitrogen isotopic distributions for EeRl-7 are somewhat depleted relative to other sites apart from EeRl-4, though more so for δ^{13} C values. In testing the observed inter-site variability in δ^{13} C and δ^{15} N distributions, a Kruskal-Wallis test confirmed that δ^{13} C, $\chi^2(5, n=147) = 72.347$, p < .001, and δ^{15} N, $\chi^2(5, n=147) = 50.713$, p < .001 values for sites were statistically significantly different. Post hoc analysis with pairwise comparisons were performed using Dunn's (1964) procedure with a Bonferroni correction for multiple comparisons. Adjusted p-values are presented. Analysis revealed statistically significant differences in median values between EeRl-7 (δ^{13} C=-15.5‰ and δ^{15} N=14.1‰) and DgRs-30 (δ^{13} C=-15.5‰; p < .001 and δ^{15} N=14.1‰; p = .003), DgRr-1 (δ^{13} C=-15.5‰; p < .001 and δ^{15} N=14.1‰; p < .001), and DhRp-17 (δ^{13} C=-15.5‰; p=.017 and δ^{15} N=14.1‰; p < .001).

Sulphur isotopic compositions were analyzed for 10 domestic dog samples from EeRI-7 HP 7. Sulphur isotopic values are presented in Figures 5.1 and 5.3.

The mean δ^{34} S value for dogs was 10.0±1.8‰ and ranged from 5.6 to 12.0‰. As with all other sites analyzed in the current project δ^{34} S values for dogs is variable but consistent at Keatley Creek and the mean is close to the overall mean of 10.3‰.

5.3 Discussion

5.3.1 Variability and consistency in dog diet along the Fraser River

Figure 5.4 and Figure 5.5 present δ^{13} C, δ^{15} N, and δ^{34} S values for all domestic dogs sampled in the current study as well as means and standard deviations for other sampled species groups. There are two deviations within dog sample carbon and nitrogen isotope values; however, values are overall remarkably consistent and cluster tightly, with the majority of samples falling within 2 per mil of each overall mean. δ^{13} C and δ^{15} N values for individuals identified as domestic dogs indicate they were consuming aquatic resources and, contrasting the canids and wolves discussed previously, there is no observable terrestrial based protein in their diets (Figure 5.4). Apart from the two outliers exhibiting depleted δ^{13} C values, dogs are clearly eating or being fed aquatic species to the near exclusion of terrestrial food resources. They align most closely with salmonid species among the sampled fauna; the mean δ^{15} N value for dogs (15.1‰) is +3‰ enriched relative to the mean for salmonid species (10.8‰). Dogs from the Fraser Delta or Gulf of Georgia region may have eaten quantities of sturgeon, though this was unlikely to have comprised a substantial portion of their diet.

Dog diet, then reflects resources that could only have been procured by human counterparts that were either given to them or scavenged by them. This is especially noteworthy as it provides direct subsistence-oriented evidence of the prolonged relationship between dogs and humans at the scale of individual dogs and at the scale of nearly all dogs in the Fraser watershed through time. At the scale of individual dogs, the averaging of isotopic values to reflect their primary dietary components demonstrates that the dogs in the current study were fed or scavenged fish for the duration of their lives and were consistently supplied with food by their human companions. When oral histories, ethnography, and myths are considered (see below), the dietary evidence for the close relationship between dogs and humans is strongly supported. At the scale of a region-wide consistency of dog-human relationships, the stability and resilience of dog diet across the sites sampled for the current study, which represent a vast spatial area in British Columbia, and the constancy across time periods, as discussed below, the results presented here reflect established and enduring interactions between dogs and humans throughout the past 3000 years at least and very likely for longer.



for other species groups.



Figure 5.5 Scatterplots of δ^{34} S, δ^{13} C and δ^{15} N values for dogs plotted with means and bivariate standard deviations (1 SD) for other species groups.

Previous isotopic evidence from Pacific Northwest sites (n=4) has demonstrated similarly consistent δ^{13} C and δ^{15} N values among domestic dogs to the current study $(\delta^{13}C \bar{x} = -14.38 \pm 1.9\%)$ and $\delta^{15}N \bar{x} = 15.05 \pm 2.1\%)$. Ames et al. (2015) cite means for five dogs from Cathlapotle, a large village site located along the Lower Columbia River, at -14.5±0.6‰ and 16.4±0.8‰ for δ^{13} C and δ^{15} N, respectively. Colin Grier's (2006)

work at the Dionisio Point village site in the Gulf of Georgia include isotopic distributions for δ^{13} C and δ^{15} N values for five dogs, with values sitting at approximately -13.0‰ and 16‰, respectively, that he concludes indicate domestic dogs at the site were consuming aquatic resources including herring or dogfish. Barta's (2006) isotopic values from dogs at Keatley Creek (n=6), with a δ^{13} C mean at -16.1±0.9‰ and a δ^{15} N mean at 13.7±1.7‰ align very well with values presented here. Barta suggests the lower values represented in her samples at Keatley Creek indicate an increased amount of terrestrial protein in their diet, relative to more coastal sites like Namu (see below), and positioning indicates a mix of two dietary components, likely herbivore meat for the terrestrial portion of their diet and higher trophic level fish like salmon for the marine input. While this is certainly plausible, the inclusion of non-salmonid aquatic resources and riverine species, as well as potential depletion of carbon in specific salmon species (i.e. sockeye) as they swim up the Fraser River are reasonable explanations for the more depleted isotope values at Keatley Creek (see also Ames et al. 2015 and Section 5.3.2).

Extending the geographic region beyond those sampled for the current project somewhat, Rick et al. (2011) cite a clear marine-based protein signature among five domestic dog specimens they sampled from CA-SRI-2 on Santa Rosa Island in California's Channel Islands, with mean δ^{13} C and δ^{15} N values at -13.5±0.7‰ and 17.4±3.1‰, respectively. Cannon et al. (1999), demonstrated a similarly marineoriented isotopic signature among domestic dogs (n=14) at the village site of Namu, on the central coast of British Columbia, with mean δ^{13} C and δ^{15} N values at -13.1±0.6‰ and 16.4±0.8‰ while Barta's (2006) isotopic analysis of Namu dogs (n=14) had mean

 δ^{13} C and δ^{15} N values of -12.9±.4‰ and 16.9±.7‰, respectively. Both samples from Namu indicate purely marine-derived aquatic resources were being included into dog diet, while the current study as well as Barta's values from Keatley Creek and Ames et al.'s values indicate potentially terrestrial or, more likely, other aquatic resources being incorporated into dog diets.

Herring, dogfish, eulachon, and potentially lamprey (Ames et al. 2015; Grier 2006) have all been cited as food items isotopically consistent with a +3-5‰ trophic level shift in δ^{15} N values for dogs in previous studies. Ames et al. (2015) identified eulachon, with a mean δ^{15} N value of 13.9‰ (n=3), as the most probable marineanadromous taxa given sampled values for Cathlapotle aquatic resources. Neither salmon (offset = +1.86‰) nor sturgeon (offset = 0.0‰) were isotopically distinct enough from δ^{15} N values for dogs to comprise the bulk of their diet. Eulachon, however had an δ^{15} N offset of +2.5‰. Published δ^{15} N values for modern eulachon agree well with the value obtained by Ames et al. (2015) with δ^{15} N values of -13.7‰ (Stricker et al. 2015) (bulk sampled, corrected for tissue-fractionation) and 12.4‰ (Witteveen 2008) (n=54, corrected for tissue-fractionation) being reported for eulachon.

Looking at sulphur values for both taxa, there is variability among dogs that indicates aquatic species with δ^{34} S values lower than a purely marine derived signature were being consumed by domestic dogs, likely comprised of a significant portion of salmonid species but also potentially including other fish and terrestrial species. Sulphur isotope values for dogs clearly indicates the consumption of aquatic resources, but they do not approach a purely marine-derived sulphur signature of +21‰ or modern marine fish and mammal signature (~17‰). Interestingly, salmonid values do

not approach these values either, which as discussed previously, is consistent with salmon being anadromous and incorporating both freshwater and marine resources throughout their life cycles. In considering the contribution of terrestrial species to dog diet, as discussed in Section 4.3.3, all terrestrial fauna have δ^{34} S values ranging between 0 and -10‰, which preclude any species from comprising a significant portion of diet for nearly all of dogs measured for the current study. SUB-C 10033 had a sulphur value -10.2‰, a value paralleling the negative terrestrial faunal values obtained in the current study. This value also corresponds with the more terrestrially oriented carbon and nitrogen isotope values obtained and discussed previously for this sample.

While published results for potential non-salmonid aquatic resources previously discussed have determined δ^{13} C and δ^{15} N values, none of these studies utilizing carbon and nitrogen isotope values for dogs and related fauna have incorporated sulphur into their analyses. Modern δ^{34} S values for herring from Japan have been recorded at 19.5 $\pm 0.3\%_0$, with smelt, rockfish species, and sculpin having similarly high and more marine-derived sulphur signatures (Kiyashko et al. 2011). Flounder and plaice, from the same study, however, had δ^{13} C and δ^{15} N values comparable to salmonid species in the current study, and so within acceptable trophic range to dog diet, but with δ^{34} S values between 11.2 $\pm 1.4\%_0$ and 13.4 $\pm 1.0\%_0$. While the suggestion that prehistoric domestic dogs were eating Japanese flounder is certainly not being made, I hope to highlight the probability that other aquatic resources available to humans and thus to dogs during the Late Period were likely incorporated into their diets and would be visible isotopically. Eulachon, while potentially aligning with smelt values found by

Kiyashko et al. (2011), could be a viable resource that comprised a portion of dog diet at sites along the Fraser River.

The sulphur data presented here then, while limited in delineating all potential aquatic species contributions to dog diet, does support the hypothesis posited in the second research question for this project, that the addition of sulphur analyses can differentiate between riverine and marine resources. The contribution of other aquatic resources is indeed visible in the isotopic signatures of domestic dogs, which, supports a breadth of resource use among their human counterparts.

Aquatic species successfully sampled for the current study are limited to salmonids and two sturgeon samples, thus identification of all aquatic resources potentially comprising dog diet was not possible in this project. Sampling for this project was drawn exclusively from faunal assemblages that were previously excavated, using methodologies that potentially missed smaller fish species during screening, as well as using bulk counts and masses of faunal material rather than taxa identified to species, which precluded a more representative and diverse faunal assemblage with which to compare the dog isotope value presented here. Taxa that might not have been recovered due to methodological parameters such as mesh screening size was not available for analysis.

Herring is a notable example where substantial quantities have been recovered from sites utilizing bulk augering analysis and screen sizes smaller than 1/8" over the standard ¼" screen size (McKechnie and Moss 2016; McKechnie et al. 2014). Beyond the samples available for this study and the successful extraction of collagen from various aquatic species, the enduring issue of preservation becomes a consideration,

where differential preservation and recovery methods exclude food materials that either do not preserve in archaeological deposits, including most plant materials and bone material in general, including smaller elements from aquatic species.

While the incorporation of aquatic resources in dog diet does vary spatially throughout the Pacific Northwest, all published results on dog isotopes as well as the current study demonstrate that dogs had a diet that was fundamentally different than any other non-domesticated or non-commensal animal, including other canid species such as wolves or covotes. Domestic dogs show clear dietary differences relative to wild canids represented in this study. The remarkably low δ^{15} N values for wild canids, as discussed previously, potentially reflect a diet primarily composed of moose or sheep versus other terrestrial herbivores and offers a clear distinction between dog diet and any other canid species. Even comparing isotopic compositions more characteristic of wolves as a predator, modern wolves have relatively low δ^{15} N values (7.06±2.34‰) (Fox-Dobbs et al. 2007; Schwarcz 1991; Urton and Hobson 2007) relative to dog values observed in the current study. Wild canids, including wolves, do not regularly have access to anadromous or freshwater fish, despite being opportunistic predators that consume hunted prey and carrion (Paradiso and Nowak 1982; Samuel and Nelson 1982; Voigt 1987) though coastal wolf populations and some inland populations incorporate salmon into their diets (Adam et al. 2010; Darimont and Reimchen 2002; Darimont et al. 2003, 2008; Szepanski et al. 1999). The overwhelming conclusion then, in this study and in previous analyses of dog isotopic values, is dogs were being fed food procured by humans, or at the very least, allowed to scavenge and live amidst their human counterparts. As members of the same ecological communities, dogs and human

relationships and interaction were and still are constituted through their involvement with one another and the various roles dogs played in the past. Ultimately, domestic dog relations with humans and other faunal species as well are contingent on human behavior and action, which their isotopic signatures reflect as an aspect of this connection.

5.3.2 Spatial and temporal variability among dogs

Spatial variability

The first research question of this dissertation queries that given the limited temporal and especially spatial resolution of previous research involving dogs and isotope studies, can the current study identify if any spatial or temporal differences in diet, particularly in the contribution to salmon, existed in the past, given a multi-site approach. The hypothesis suggests that regional variability will be visible while temporal variability might be limited. The higher variability in dogs sampled for the current study δ^{13} C values is largely due to the statistically distinct sample values from EeRl-4 and EeRl-7, both pithouse villages located in the Mid-Fraser region of the study area. Bridge River carbon isotope values are elevated relative to EeRl-7 values, with a mean difference of 1.13‰. The depletion of δ^{13} C in both Mid-Fraser sites suggests a regionally variable difference between sites in closer proximity to the Fraser Delta and those further along the Fraser River.

However, rather than δ^{13} C values representing dietary differences being represented across sites, I argue that dog diet reflects aquatic resources being incorporated across all sites, and instead it is the physiological differences in carbon uptake in anadromous fish species, as well as the overall inclusion of other aquatic

species into dog diet across all sites, that are more likely explanations for the isotopic variability observed across δ^{13} C, δ^{15} N, and δ^{34} S distributions in domestic dogs. Previously conducted ancient DNA analysis for EeRl-4 found sockeye salmon (*O. nerka*) DNA in nine of the ten dog coprolites tested, with one sequence being identified as Chinook salmon (Rodrigues 2015), while ancient DNA analyses on salmon remains from Keatley Creek identified sockeye as the predominant species in faunal assemblages in several of the housepits, comprising 81.8% (n=45) of the tested specimens with Chinook (31%) and Coho (4%) falling a distant second and third (Speller et al. 2005).

Published stable isotope data for modern Pacific salmon species indicate a distinct pattern of trophic partitioning among the five species of Pacific salmon. Three isotopically distinctive subgroups based on general salmonid dietary trends have been observed (Johnson and Schindler 2009; Satterfield and Finney 2002); pink, chum, and sockeye salmon, low trophic level consumers (zooplankton) with low δ^{13} C and δ^{15} N values; Coho salmon, along with some chum and sockeye forming a group with intermediate δ^{13} C and δ^{15} N values; and chinook salmon having the highest δ^{13} C and δ^{15} N values, likely attributable to the species consuming higher proportions of fish.

Given the available ancient DNA data for the confirmed presence of sockeye and the evidenced trophic partitioning of salmon species, it is reasonable to conclude while isotopic values that indicate the inclusion of salmon in dog diet do vary spatially, it is salmon physiology, feeding strategies, and life-cycles, that are represented isotopically rather than absolute differences in dogs being fed or supplied with salmon. Conversely, while the inclusion or salmon appears widespread, the relative proportion of salmon to

other aquatic or terrestrial resources is what appears to be more regionally variable. Specific sites have isolated values aligning more closely with terrestrial isotopic signatures (DgRr-1, SUB-C 20033; DhRp-17, SUB-C 4118, EeRl-7, SUB-C 429), rather than spatial patterning that sees terrestrial versus aquatic protein consumption among dogs relative to location.

Temporal Variability

Table 5.3 and Figure 5.6 present summarized isotopic information for dogs organized in temporal periods. Dates were compiled from previously published data where dates were variously recorded. The temporal periods listed correspond approximately with Locarno Beach, Marpole/Plateau, and Gulf of Georgia/Kamloops horizons in the Late period. All values are within 2 per mil of one another, with overlapping standard deviations, suggesting no temporal variability that is not otherwise attributable to sample variation. While the mean δ^{13} C value for samples dated to between 1400-200 appears somewhat depleted, this is likely due to all samples from EeRI-4 and EeRI-7 belonging to this category. Variability, in this case, can be ascribed to regional differences and uneven sampling across time periods rather than real changes in dog diet through time. Available data for dated components of isotopically tested dog material are both from Namu (Barta 2006; Cannon et al. 1999), with δ^{13} C and δ^{15} N values for the Late period consistent with those in the current study (δ^{13} C means at -13.1‰ for both studies and δ^{15} N means at 15.9‰ and 16.1‰, respectively).
Temporal Period (cal BP)	δ ¹³ C			δ ¹⁵ N			δ ³⁴ S		
	N=	Mean	S.D.	N=	Mean	S.D.	N=	Mean	S.D.
3000 - 2400	6	-13.2	.9	6	15.9	.7	6	11.4	1.1
2400 - 1400	65	-13.9	1.5	65	15.5	1.4	13	10.1	3.6
1400 - 200	62	-14.6	1.4	62	15.1	1.2	40	10.5	4.1

Table 5.3 Summary of Isotope Data for Temporal Periods across all sites

In testing the significant differences between δ^{13} C, δ^{15} N, and δ^{34} S distributions across the 3 temporal periods, a Kruskal-Wallis test confirmed that the distribution of δ^{15} N, $\chi^2(2, n=132) = 4.735$, p = .094 and δ^{34} S, $\chi^2(2, n=57) = .004$, p = .998 is statistically the same across temporal periods for dogs. δ^{13} C values, $\chi^2(2, n=132) =$ 15.677, p < .001, however, were statistically significantly different. Post hoc analysis with pairwise comparisons were performed using Dunn's (1964) procedure with a Bonferroni correction for multiple comparisons. Adjusted p-values are presented. Analysis revealed statistically significant differences in median values between the 1400-200 year time period (δ^{13} C=-14.3‰, p = .001) and the 2400-1400 year time period (δ^{13} C=-13.6‰).

Temporality then, does not see a significant change, either in intensification or depression of resources being fed to dogs, a point echoed in zooarchaeological assessments of resource use in British Columbia (see Butler and Campbell 2004; McKechnie 2013). While numerous species are abundant only during seasonal aggregations, which is indicated in overall variability in resources incorporated into dog diet, overall intensification through time of certain key resources has not been supported in previous analyses of faunal assemblage through time (Butler and Campbell 2004). The current trend in dog diet through time supports this as well.



Figure 5.6 Graphs at left show scatterplots of carbon and nitrogen (a.), carbon and sulphur (b.) and nitrogen and sulphur (c.) isotopic compositions for domestic dogs with available temporal associations (n=133). Graphs at right show carbon (d.), nitrogen (e.), and sulphur (f.) isotopic compositions of bone collagen for domestic dogs grouped by temporal period. Dot plots represent individual values; box plots show summary distributions of temporal periods.

5.3.3 Dogs and Human Interaction

Figure 5.7 presents a plot of carbon and nitrogen compositions for dogs sampled for the current study and humans, with values compiled from all published data for human isotopic values within the study area, as well as two values obtained in the course of the current project (Arcas 1994a; Arcas 1999; Chisholm 1986; Schwarcz et al.

2014 in Hepburn 2016) and figure 5.8 presents a plot of carbon and nitrogen

compositions for dogs and humans grouped by Coastal and Interior regions. While there is variation in both dog and human samples, considerable overlap occurs for dog samples (DgRr-1, DgRs-2, and DhRp-17) and human samples (DgRr-1, DgR3-2, DgRs-2, DgRs-1, DhRx-16) from the Gulf of Georgia or Coastal region. Variability increases for both dog and human values from sites in the Mid-Fraser Region or Interior, which has been discussed in previous sections for dog samples and is detailed by Chisholm and colleagues, as well as in Hepburn (2016) and Schwarcz et al.'s (2014) analyses. For both regional pairings, human values occupy higher trophic positioning than dogs from similar locations. This is discussed further in the next section.



Figure 5.7 Bivariate scatterplot of carbon and nitrogen isotopic compositions for dogs and humans. Triangles represent humans, circles represent dogs. Green ellipse shows human distribution, blue ellipse shows dog distribution. Asamples from Boston Bar were analyzed as part of the current study.

As discussed previously, the various roles occupied by dogs in their interactions with humans ranged from village watch dogs, companions, hunting and pack dogs, and as village cleaners via consuming human feces.



Figure 5.8 Bivariate scatterplot of carbon and nitrogen isotopic compositions for dogs and humans grouped by region. Triangles represent humans, circles represent dogs.

Their ubiquity in practical, economic, spiritual, and ancestral roles served in prehistoric communities is similarly paralleled in dog remain ubiquity in archaeological sites. Among the sites sampled for the current study, domestic dogs were often the most highly represented mammal in their faunal assemblages; dogs make up 61% of identified mammal remains at DgRs-2, 15.4% at DgRr-1, 16.7% at DhRp-17, and are ubiquitous at other sites. Domestic dogs are found in a number of contexts; articulated in primary burials, with skulls placed upright, associated with human burials, and generally with no evidence of butchering (Bernick 1989; Arcas 1994b; Crellin and Heffner 2000; Ewonus in Antiquus 2001; Prentiss et al. 2014). At DgRs-2, 10 domestic dog skulls were found in the same stratigraphic layer, with maxillae teeth pointing down onto the surface and postcranial remains notably absent. The authors suggest "the remains had a ceremonial significance and were placed in specific positions when this area of the site was first occupied" (Arcas 1994b:33). Interestingly, 83% of these skulls were identified as remains of the Coast Salish wool dog (Crockford 1997:100-101).

While the differential treatment and intentionality of dog burials isn't transposed onto variability in their isotopic signatures, it does lend to the overall significance of the relationship between humans and domestic dogs. Dog ubiquity at all sites sampled highlights how significant a component they were to communities in the past. As ecological counterparts constituted through relations and involvement with one another, domestic dog relations with humans and other faunal species are contingent on human behavior and action. Their isotopic signatures demonstrate the consumptive property of this relationship, where dog, salmon, fish, deer and human engage in repeated action. As Marino (2015) notes, relational and animistic beliefs are indeed expressed materially through daily practices of hunting, consumption, deposition, and burial. While not all things are persons, anything can be. Not all things are persons all of the time, but "reveal themselves as animate through their engagements with other beings" (Losey 2010:19).

Ethnographically, dogs sometimes occupied roles typically reserved for humans. Cryer (2007:229) noted that among Hul'q'umi'num Coast Salish, ancestral names were only bestowed to individuals worthy of them, with some dogs recorded as earning this distinction. A man in debt to his wife's family could ceremonially marry a bride to return some of his acquired names to her relatives, a common occurrence that his 'bride' was a favorite dog (Switzer 1992:24). Dogs are human analogues in death as well, which is partially why sacrifices were uncommon ethnographically. Shamans

could harness dangerous powers from a dog corpse because they were the functional equivalent of human remains (Amoss 1984; Crellin 1994: 54-55).

Human-dog relations and the Canine Surrogacy Approach (CSA)

The canine surrogacy approach (CSA) as previously detailed (see Section 2.2.2), is based on the premise that dogs likely provisioned with food from humans, fed with scraps from human meals, self-provisioning at settlement margins or eating human feces could have shared an isotopically similar diet with contemporaneous humans (Guiry 2012; 2013). Their commensal relationship is ultimately posited to be paralleled isotopically. This becomes especially attractive when archaeological human remains are absent or are unavailable for isotopic sampling and subsequent paleodietary reconstruction. While it has been demonstrated that stable carbon and nitrogen isotope data from associated human and dog bone collagen from a variety of sites found that dogs generally track humans independent of cultural, temporal, or geographical context, Guiry (2012; 2013) cautions that human diets are not universally similar there is a need for CSA authors to explicitly consider the different ways in which dogs can be used to provide information on human dietary practices and the factors which can influence human – dog proxy relationships.

Variation between dog and human isotope values include the common observation that dog remains may consistently produce lower δ^{15} N values (Allitt et al. 2008; Cannon et al. 1999; Hogue 2003; Katzenberg 2006:266; Katzenberg et al. 2010:185; Kusaka et al. 2008), relative to humans, however data compiled by the author demonstrates the reverse. Under some circumstances, dogs have very close to, or slightly elevated, δ^{15} N values relative to their human keepers and there appears to

be little consistency in the relative relationship of δ^{13} C values between dogs and humans (2012:356).

Comparing the dog values of the current study to human values presented in Figures 5.7 and 5.8, while both δ^{13} C and δ^{15} N values track reasonably well with human values, there are some consistent variations across samples. Mean δ^{13} C and δ^{15} N for dogs (-14.4±1.9‰ and 15.1±2.1‰) were depleted relative to Fraser Delta human means (Hepburn 2016: Appendices B and C; δ^{13} C = -13.8‰ and δ^{15} N = 17.8‰) and enriched in carbon (-16.4‰) but depleted in nitrogen (18.2‰) relative to means for humans from the Interior. Looking at specific sites, dogs from Gulf of Georgia sites have mean δ^{13} C values that parallel human values for the Fraser Delta (DgRs-2 = - $13.2\pm0.5\%$ for dogs versus -13.5±0.6‰ for humans; DgRs-30 = -13.2±1.4‰ for dogs versus $-13.5 \pm 0.6\%$ for humans, and DgRr-1 = $-13.6 \pm 1.4\%$ for dogs versus $-13.7 \pm 1.3\%$ for humans). Following previously published data on dog and human isotope values. dog δ^{15} N values are consistently lower; this has been cited as potentially due to metabolic or physiological differences between humans and dogs, the practice of coprophagy by dogs, or through the intentional provisioning of dog by humans (e.g., Allitt et al. 2008; Cannon et al. 1999; Hogue 2003; Katzenberg 2006:266; Katzenberg et al. 2010:185; Kusaka et al. 2008).

The comparison between δ^{13} C and $d\delta^{15}$ N values for dogs recovered from archaeological sites situated along the Fraser and humans from similarly placed sites, supports the supports the hypothesis presented in research question 4 that, while low resolution comparisons may be made between dog and human diet, higher resolution, spatially and temporally specific information may not render as well and undoubtedly,

differences will be observed between dog and human counterparts. The spatial variation observed in the current study as well as the presence of two domestic dogs with terrestrially oriented isotopic signatures for both δ^{13} C and δ^{15} N highlight the potential disparities posed in transposing isotopic signatures to humans from dog remains. In the absence of archaeologically available human remains, however, isotope values derived from dogs can offer generalized analogues to their human counterparts and as ethical, political, and legal issues prevent the ability to analyze human diet directly, CSA applications can at least offer some evidence toward understanding paleodietary practices.

6 Conclusions and Overview

This study's primary aim was to examine resource relationships and foodways in the Late Period (ca. 3000 to 200 cal BP) from seven archaeological sites situated in two different regions of the Fraser River drainage—the Coast and the Interior, among domestic dogs and other fauna. It makes original contributions in the identification of isotopically determined dietary patterns that are both locally oriented and persist over millennia. By looking beyond individual sites representing individual moments in time, this study successfully examines diet and dietary relationships between animals and people at a variety of scales (Cannon 2001; McKechnie 2013; Moss 2012). From a view of ecological communities as holistic in their inclusion and integration of humans and non-human species, the isotopic investigations presented offer an understanding of the past that brings coherence while accounting for variability in the archaeological record. This study tracks these ecological relationships by analyzing carbon, nitrogen, and sulphur isotopes of several species of fauna recovered from archaeological habitation sites in order to assess ancient foodways and dietary practices. The fauna analyzed for the current study occupied regionally specific niches, practiced different subsistence strategies, and played multi-faceted roles in their resource relationships. Using stable isotope analysis, I demonstrated that we can observe how an ecological community and its dietary inter-relationships are expressed in the basic chemistry of its members, whether human, plant, or animal. The following sections will summarize the major findings and their archaeological implications as well as offer a critical assessment of the limitations as well as future research directions and potential applications.

6.1 Major findings and archaeological implications

6.1.1 Locally variable resource relationships

Chapter 4 of this dissertation analyzes fauna from five archaeological sites situated along the Fraser River using multi-isotope analysis (C, N, and S). With the goal of identifying how relationships between resources and species are characterized isotopically within the Fraser River watershed, this chapter addresses the third research question of the overall project in asking if there is spatial, intra- and interspecies variability that we can assess and define beyond simply providing a baseline for human isotopic data. Isotopic variability was indeed identified across sites for individual species (intra-species and inter-site variability) and across species (interspecies variability) with significant dietary differences between terrestrial and aquatic resources at all sites where both resource groups were represented. For all resource relationships examined in the current study and the relationships with the individuals and groups that occupied the archaeological sites these animals came to an end at, interactions are locally oriented, regionally specific, and consistent in their variability. The current study supports and builds upon recent scholarship that recognizes the spatially restricted ecological interactions occurring in the past and sees the necessity in incorporating regionally determined archaeological inquiry at a fundamental level of integration and engagement; as this study demonstrates, an ideal means is through analyzing isotopic signatures of ecological community members, both human and nonhuman, recovered from archaeological sites.

Wild canids, in particular wolves, were among animals with the lowest δ^{15} N values, across all sites. This is attributed to their potential consumption of moose over

other ungulates and prey. That δ^{15} N values for wolves are consistently low is compelling in its apparent contradiction to the wolf's ecological role as a top predator and their presumably elevated δ^{15} N values. As all wolf specimens are from one site, these isotopic signatures indicate a spatially oriented diet that reflects the localized predator-prey relationship existing within the environs of EeRl-4. Regional differences were similarly demonstrated for deer samples from coastal versus interior archaeological sites, where isotopic signatures for deer from Coastal sites and Interior sites were significantly different. Large inter-regional ranges for both δ^{13} C and δ^{15} N values have been previously reported for deer from other regions (Cormie and Schwarcz 1994, 1996; Drucker et al. 2011; Stevens et al. 2006) and likely represent both dietary and mobility differences in the paleoecological relationships of these individuals with their environments. As with the wolves sampled in the current study, the variability of deer diet and habitat is reflected in their isotopic composition and signatures, highlighting the contributions this study particularly and isotopic analysis more generally have in identifying, delineating, and appreciating the locally-oriented relationships between animals and between animals and people that existed in the past. If we can identify local groups of animals and resources in the past or at least identify them to regions, then a greater understanding of regional exchange and movement of resources among groups may be visible and interpretable in the archaeological record through stable isotope analysis.

Paralleling variability in wild canid and deer species, variation in aquatic fauna both within and between species was also observed. While salmon, as a seasonally abundant, storable resource often cited as the basis for British Columbia subsistence

economies (e.g., Donald 2003; Drucker 1965) are ubiquitous in archaeological assemblages in British Columbia, remains are often grouped in broad taxonomic categories due to difficulty in distinguishing species based solely on skeletal morphology. More recently, however, salmon species have been the focus of speciesspecific identification through metric, genetic, and isotopic means (Cannon 1988; Cannon and Yang 2006; Huber et al. 2011; Orchard and Szpak 2011). The current study demonstrates significant differences between salmon species from regionally distinct archaeological sites and the deviation among all salmonids from a completely marine based isotopic signature. This supports the premise that locally determined isotopic signatures, likely tied to salmon life histories and the time spent travelling the Fraser to the Gulf of Georgia or Mid-Fraser regions reflect considerable diversity in the interactions between species and their environments. Resource relationships reflected in salmon, canid, and deer populations then *all* demonstrate the substantial insight isotopic analysis offers in recognizing the local relationships between animals through time generally and in identifying archaeological variability in British Columbia specifically.

6.1.2 Dog diet variability and consistency

Chapter 5 of the current study focused on the multi-isotope analysis of domestic dogs from six archaeological sites situated along the Fraser River with the goals of assessing dietary variability using a multi-scalar approach, evaluating whether dog diet and human diet is similar, and how this reflects the deep human-dog relationships that existed in the past. Isotope values for dogs were generally consistent and dog diet did not differ significantly throughout the Late Period. Contrasting a singular narrative of

unidirectional growth, elaboration, and specialization of subsistence economies (Moss 2012), data presented for dog diet and by extension, domestic dogs' relationships with people in British Columbia through time, indicate remarkable continuity over millennial time scales and across diverse regional landscapes. This identification of spatially and temporally consistent archaeological patterning is anthropologically significant as it provides a basis for interpreting aspects of human lifeways within the Fraser watershed over the 'long-term,' especially since the actions that generated these observed patterns can be reliably presumed to have occurred within the sphere of everyday, lived interspecies relationships. These findings also support the concept of a holistic ecology accurately reflected in the isotopic signatures of animal remains; one that was integrative of human and non-human community members and while regionally variable, was persistent and consistent through several thousand years into the past.

6.1.3 Sulphur isotope analysis in British Columbia archaeology

This research is the first sulphur isotope analysis of archaeologically-based fauna in British Columbia and marks the first time that sulphur isotope analysis has been carried out on a large collection of faunal remains in the region. δ^{34} S values were successfully obtained for 100 archaeological samples across nine species, including domesticated dogs, from six archaeological sites – the only such study for North America to incorporate a large assemblage across several taxa (see Chilton et al. 2001; Nehlich and Richards 2009; Privat et al. 2007). This study offers an initial insight into sulphur uptake mechanisms and variation in British Columbia as they relate to archaeological material. All terrestrial fauna has δ^{34} S values ranging between 0 and -

10‰, which, while certainly more negative than other ³⁴S values reported for fauna from other regions, parallels the bedrock geology in the study area. Sulphur isotope values are partitioned similarly between terrestrial and aquatic resource groups as δ^{13} C and δ^{15} N values are, with terrestrial fauna having variable but almost consistently negative values and aquatic fauna demonstrating a regionally variable and speciesspecific incorporation of freshwater and marine signals across species. The sulphur isotope values obtained for salmonid and sockeye taxa provide insight into anadromous species values from archaeological sites along the Fraser River. As expected, these sulphur values parallel the locally oriented variability for all fauna observed in δ^{13} C and δ^{15} N values and underpin the fact that fundamental to the understanding of past ecological communities and analyzing them isotopically is the development of regionally specific baseline data. Beyond this initial aim, the understanding of biological ecologies that formed an ancient and variable "isoscape" will be a principal contribution to framing archaeological inquiry into the human-animal-plant relationships enduring in the past.

The sulphur isotope data for domestic dogs demonstrated that species other than salmon were contributors to dog diet, a distinction that would not be isotopically visible if limited to carbon and nitrogen isotopic analyses. Species including eulachon, flatfish such as flounder, and herring, have all been cited as potential contributors to dog diet, supported by previous scholarship and the current study. Sulphur isotope values demonstrate temporally and spatially consistency across sites and time periods during the Late Period, though several dogs display values more closely aligned with terrestrial isotopic signatures. With some of the lowest sulphur values for dogs being

obtained from Coastal sites in the Gulf of Georgia region, a locality where marine food sources for dogs are expected and are certainly the trend in the majority of the data, there are differences deserve to be explored. The contribution of these new data and the analysis of the patterning occurring both spatially and temporally will hopefully open the doors to similar isotopic research projects in the near future.

6.2 Limitations

This study used existing archaeological collections and sampled zooarchaeological specimens from sites with particularly robust collections of dog remains. Although the dog bone samples were generally well represented at these sites, non-dog samples were not as easily acquired given previous archaeological methodologies in zooarchaeological collection, quantification, identification, and storage. In the case of samples selected from collections where the original excavations occurred decades ago, faunal remains were often unidentified, stored in bulk quantities, and frequently unsorted. Given the importance of accurate faunal identification with reasonably good archaeological provenience - especially for sites corresponding to, or within close proximity, of the sites that were chosen for analysis because they had plentiful dog remains, samples for some species are fairly small in comparison to others with larger samples sizes and a wider breadth of species diversity.

Similarly affecting the species recovered and represented in the archaeological record, differential preservation and recovery methods employed in earlier projects inevitably exclude food materials that either do not preserve in archaeological deposits, including most plant materials, or have not been recovered due to methodological parameters such as mesh screening size. Herring is a notable example where

substantial quantities have been recovered from sites where bulk augering analysis and screen sizes smaller than 1/8" have been used over the standard ¼" screen size. For fish species especially, the absence of certain taxa in faunal assemblages due to recovery methods and project constraints, is very likely, with more recent projects utilizing smaller mesh observing a shift in the relative abundance of taxa present in the deposits (McKechnie 2013; Partlow 2006; Stewart, et al. 2003).

Two species that were identified as likely or at least potential prey choices in this study (moose for wolves and non-salmonid aquatic species, such as eulachon or flounder for dogs) were not well represented in the samples. To assess ecological communities and develop a comprehensive isotopic interpretation of past foodways, as many potential members as possible must be represented. Modern samples, while not as appropriate relative to archaeological material, can offer an intermediary in stable isotope analyses and is, in fact, often utilized when archaeological material is simply unavailable.

6.3 Future research directions and potential applications

The question of variability is a persistent one in archaeological investigations in British Columbia and along the Northwest Coast, and while zooarchaeological, lithic, demographic, and settlement-oriented evidence all lend to this inquiry on variability, stable isotope analysis offers direct insight into humans and non-human counterparts on individual and community-oriented scales. This dissertation provided significant understanding into the variable and regionally specific interactions and foodways occurring between animals, animals and dogs, and dogs and humans. The application of

sulphur isotope analysis to determine contributions of marine versus riverine resources into dog diet and potentially human diet is an exciting research direction and application. Identifying different scales of isotopic incorporation via analysis of bone collagen and tooth enamel from the same individual would allow for increased resolution and understanding in the dietary and location-based life histories of all fauna but especially dogs. Similarly, the development of regionally specific ecological isoscapes or baselines in which we can discuss patterns of variability and consistency across species groups, will be integral to analyzing these prehistoric relationships accurately and thoughtfully.

6.4 Concluding Remarks

This dissertation sought to examine how the stable isotope analysis of dog remains and other fauna can inform us about pre-contact human-animal relationships. Through the multi-isotope analysis of 244 samples from seven sites situated along the Fraser River, paleoecological variability as well as temporal consistency was demonstrated for dogs, deer, salmonid species, and the other terrestrial fauna successfully sampled and analyzed. By focusing on the processes of and relations between humans and resources within their ecological communities, this dissertation discussed data derived from isotopic analysis using an ecological approach that situates practitioners in the context of an active engagement with the constituents of their surroundings. I hope that in offering an isotopic assessment of the prehistoric relationships and foodways existing in the past, as a tangible mediation of past and present, that these networks of humans and non-humans become visible, unburdened by "any central hero subjects-human, worldview, mind-we can envisage a brigade of

actors... acting together" (Olsen 2010:145). Complex relationships between human and animal as represented in archaeological contexts can thus gain appreciable insight and understanding through the thoughtful application of stable isotope analyses and the appreciation of locally contingent and mediated interactions.

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Lab	Species	Element	Site No.	Sample	%Collagen	%C	%N	%S	¹³ C	¹³ C	¹⁵ N	¹⁵ N	³⁴ S AVG	³⁴ S	C:N	C:S	N:S
No.				wt (mg)					AVG	st.dev	AVG	st.dev		st.dev	Ratio	Ratio	Ratio
9724	Dom. Dog	radius	DgRr-1	24.25	3.60	42.57	14.79		-14.58	0.13	14.85	0.18	•	•	3.36		•
9725	Deer	shaft	DgRr-1	17.20	3.39	41.66	14.64	•	-23.32	0.00	4.52	0.02			3.32		
9727	Deer	vert	DgRr-1	44.20	5.06	42.05	15.15	•	-21.97	0.02	7.87	0.01			3.24	•	•
9728	Sturgeon	scutes	DgRr-1	7.20	1.04	34.87	12.29	•	-11.64	0.14	15.14	0.05			3.31		
9729	Sturgeon	scutes	DgRr-1	15.96	1.18	21.06	6.72	•	-12.94	0.06	15.55	0.35			3.53	•	•
9730	Beaver	vert	DgRr-1	32.61	5.66	37.31	12.86	•	-21.61	0.01	4.82	0.02			3.26		
9731	Salmon	vert	DgRr-1	18.50	3.20	40.63	14.68	•	-15.41	0.07	10.95	0.01	•		3.23		•
9732	Salmon	vert	DgRr-1	24.72	3.98	41.67	15.04	•	-15.57	0.06	11.82	0.01			3.23		
9746	Salmon	vert	DgRr-1	•	0.00	40.94	14.57	•	-15.36	0.06	12.64	0.11			3.28	•	•
9747	Salmon	vert	DgRr-1	21.61	3.66	41.29	14.80		-15.39	0.01	11.38	0.12		•	3.26	•	•
9750	Sturgeon	scutes	DgRr-1	9.50	4.65	41.13	13.74		-11.91	0.04	15.01	0.02	•	•	3.49	•	•
9753	Salmon	Vert	DgRr-1	12.90	3.27	40.37	14.26	•	-15.58	0.10	12.24	0.06		•	3.31	•	
9764	Salmon	Vertebra	DgRr-1	32.54	6.57	40.55	14.66	•	-15.29	0.06	11.53	0.04		•	3.23	•	•
9994	Dom. Dog	cranium	DgRr-1	56.05	8.10	41.65	15.20		-13.78	0.01	15.55	0.00	12.93	0.30	3.30	•	
9995	Dom. Dog	vertebra	DgRr-1	62.80	12.49	41.62	15.75	0.23	-12.57	0.00	16.74	0.02	10.37	1.77	3.29	483.0	156.7
9996	Dom. Dog	ulna	DgRr-1	58.90	9.15	41.62	15.92	0.22	-11.86	0.00	16.84	0.03	10.56	0.77	3.27	505.0	165.7
9997	Dom. Dog	vertebra	DgRr-1	27.98	6.26	41.13	14.80	0.22	-14.52	0.01	15.21	0.00	12.50	0.30	3.33	510.7	157.6
9998	Dom. Dog	tibia	DgRr-1	41.96	7.48	41.12	15.24	0.20	-13.08	0.01	15.81	0.04	11.64	0.01	3.32	548.8	174.5
9999	Dom. Dog	vertebra	DgRr-1	32.77	6.43	40.60	14.99	0.20	-13.63	0.09	15.25	0.00	10.66	1.07	3.28	541.9	171.6
10000	Dom. Dog	femur	DgRr-1	47.00	10.04	42.28	15.99	•	-11.81	0.01	16.79	0.04		•	3.28		•
10001	Dom. Dog	vertebra	DgRr-1	64.10	12.30	41.97	15.20	0.24	-14.02	0.01	15.67	0.03	10.67	0.69	3.38	466.9	145.0
10002	Dom. Dog	femur	DgRr-1	62.20	11.01	41.52	15.45	0.23	-12.52	0.04	15.98	0.02	11.16	0.82	3.26	481.9	153.7
10003	Dom. Dog	ulna	DgRr-1	28.00	5.03	41.28	15.38	0.25	-14.42	0.01	16.12	0.04	13.22	•	3.33	440.8	140.8
10004	Dom. Dog	tibia	DgRr-1	52.60	8.77	41.90	15.28	0.23	-13.59	0.01	15.54	0.06	12.61	0.05	3.30	486.3	152.1
10005	Dom. Dog	femur	DgRr-1	49.80	10.23	43.28	15.04	•	-13.84	1.60	16.22	0.18	•		3.52	•	•
10006	Dom. Dog	metatarsal	DgRr-1	67.50	7.90	41.58	15.69	0.23	-12.70	0.03	16.51	0.04	11.88	0.14	3.28	493.3	159.6
		11															
10007	Dom. Dog	tibia	DgRr-1	77.00	9.87	41.27	15.38	0.23	-12.39	0.04	16.27	0.10	11.08	0.15	3.29	489.7	156.5
10008	Dom. Dog	femur frag	DgRr-1	31.40	4.79	41.13	15.23	0.23	-12.94	0.03	15.94	0.05	11.09	•	3.36	477.4	151.6
10009	Dom. Dog	tibia	DgRr-1	46.30	6.33	41.54	15.36	•	-13.49	0.02	16.21	0.04	•		3.36	•	•

Appendix A: Isotopic and Elemental Information for Sampled Fauna

10010	Dom. Dog	tibia	DgRr-1	25.00	4.69	41.13	15.11	0.25	-12.86	0.05	15.73	0.01	7.44	1.41	3.35	439.2	138.3
10011	Dom. Dog	innominate	DgRr-1	71.80	7.97	41.48	14.98	•	-14.53	0.02	15.13	0.02	•	•	3.30	•	•
10012	Dom. Dog	mandible	DgRr-1	36.50	6.22	41.30	15.23		-11.30	0.07	15.93	0.07			3.33	•	
10013	Dom. Dog	mandible	DgRr-1	63.70	9.22	41.37	14.96	0.24	-13.98	0.00	15.16	0.10	8.73	0.54	3.29	470.0	145.7
10014	Dom. Dog	metacarpal	DgRr-1	54.20	11.71	41.26	15.52	0.23	-13.36	0.03	16.72	0.04	11.96	0.80	3.32	478.9	154.5
		V															
10015	Dom. Dog	innominate	DgRr-1	53.40	10.60	41.64	14.81	•	-13.25	0.08	15.03	0.19			3.30		
10017	Dom. Dog	mandible	DgRr-1	33.00	7.04	40.24	14.68		-14.21	0.03	15.19	0.03			3.34		
10018	Dom. Dog	mandible	DgRr-1	45.00	6.65	40.70	15.19		-14.13	0.06	16.24	0.02		•	3.37	•	
10019	Dom. Dog	tibia frag	DgRr-1	45.50	7.08	39.19	14.66		-14.15	0.08	15.92	0.04			3.31		
10020	Dom. Dog	femur frag	DgRr-1	18.00	3.72	41.39	15.07		-14.37	0.02	15.72	0.01		•	3.35	•	
10021	Dom. Dog	radius	DgRr-1	31.00	6.57	42.20	15.79	0.22	-13.80	0.02	16.47	0.01	12.58	0.12	3.35	512.0	164.3
10022	Dom. Dog	ulna	DgRr-1	59.20	11.28	41.92	14.91	0.22	-14.82	0.01	14.99	0.07	13.90	0.27	3.29	520.5	158.7
10023	Dom. Dog	ulna	DgRr-1	99.00	13.01	43.11	15.84	•	-12.90	0.02	15.96	0.06	•	•	3.29		•
10024	Dom. Dog	ulna	DgRr-1	28.20	7.03	41.27	15.44	0.21	-13.66	0.01	16.37	0.03	12.56	0.04	3.35	524.7	168.3
10025	Dom. Dog	radius	DgRr-1	48.00	7.33	41.62	15.10	•	-13.17	0.04	15.34	0.05	•	•	3.28		•
10026	Dom. Dog	calcaneus	DgRr-1	30.20	6.94	40.71	15.18	•	-14.36	0.03	16.04	0.02		•	3.34	•	•
10027	Dom Dog	metacarnal	DoBr-1	45.60	10.22	40.56	15.00		-14 54	0.05	15 35	0.03			3.28		
10027	Dom. Dog	metacarpar	Dgiti-1	+0.00	10.22	40.00	10.00	•	-14.04	0.00	10.00	0.00			0.20	·	
10028	Dom. Dog	calcaneus	DgRr-1	67.00	10.77	41.54	15.13	0.22	-14.28	0.05	15.58	0.00	13.87	0.27	3.30	515.8	161.1
10029	Dom Dog	mandible	DaBr-1	25.00	4.85	41.69	15 28		-12 39	0.02	16.03	0.14			3 37		
10030	Dom Dog	vertebra	DaRr-1	37.50	7 16	42 72	15.20	0.23	-12.35	0.05	16.33	0.01	. 12 59	0.03	3.30	495.8	
10031	Dom Dog	vertebra	DgRr-1	28.00	4 75	41 94	15.88	0.20	-13.39	0.02	17.06	0.02	12.00	0.00	3.34	100.0	107.1
10032	Dom Dog	vertebra	DgRr-1	27.50	5 14	41.82	15.07	0.24	-13 37	0.05	15 53	0.01	. 1 57	1.53	3 35	465.2	143.7
10033	Dom Dog	vertebra	DgRr-1	65.80	13.62	42.85	12 20	0.27	-19.06	0.09	9.37	0.02	-10.19	3.78	3.33	431.7	105.4
10034	Dom. Dog	vertebra	DaRr-1	55.90	12.70	42.62	16.09	0.24	-11.96	0.02	17.01	0.06	11.91	0.43	3.28	474.0	153.5
10035	Dom Dog	vertebra	DaRr-1	36.70	7.43	41 73	14 85		-14 84	0.00	15.16	0.03		0.10	3.34		
10036	Dom Dog	vertebra	DaRr-1	21.00	4 79	41 41	14 91	•	-15.34	0.01	15.66	0.08	•		3.47		
10037	Dom, Dog	vertebra	DaRr-1	31.50	4.98	42.58	15.04		-15.07	0.16	15.68	0.07			3.45		
10038	Dom. Dog	vertebra	DaRr-1	32.80	6.99	43.22	15.19	•	-14.62	0.04	15.93	0.06			3.48		
10039	Dom. Dog	humerus	DaRr-1	43.50	6.35	42.74	14.80		-14.89	0.13	15.30	0.03			3.52		
10040	Dom Dog	humerus	DaRr-1	27.70	5.34	41.95	14.67	•	-14.48	0.02	15.25	0.07	•		3.51		•
10040	Dom. Dog	nameras	- Ugra	21.10	0.04	1.00	14.07		14.40	0.02	10.20	0.01	•		0.01	•	

10041	Bear	mandible	DgRr-1	54.50	8.85	41.68	10.35		-19.86	0.07	5.90	0.05		•	3.27		•
9715	Beaver	ulna	DgRr-2	20.06	2.90	28.11	14.54		-21.92	0.10	6.51	0.03			3.31	•	•
9716	Deer	scapula	DgRr-2	22.20	3.98	41.80	14.68		-22.45	0.11	5.61	0.16		•	3.33		•
9717	Deer	scapula	DgRr-2	9.00	0.68	22.57	7.37		-21.83	0.19	5.24	0.13	•	•	3.60	•	•
9714	Beaver	ulna	DgRr-6	24.71	2.49	38.74	13.26		-21.63	0.15	4.55	0.23		•	3.41	•	•
10529	Dom. Dog	femoral	DgRs-2	121.40	6.07	40.98	14.86	0.27	-13.48	•	15.62	·	12.22	0.12	3.19	412.8	128.4
		head															
10530	Dom. Dog	mandible	DgRs-2	68.90	12.50	41.02	14.52	0.25	-12.48	•	16.10	•	12.90	0.12	3.27	447.0	135.6
10531	Dom. Dog	mandible	DgRs-2	58.70	10.46	41.31	14.31	0.23	-13.52	•	15.10	•	8.67	0.18	3.15	479.5	142.4
10532	Dom. Dog	cranium	DgRs-2	35.10	4.18	41.82	14.73	0.28	-13.22		15.20	•	8.62	5.31	3.29	398.7	120.4
10533	Dom. Dog	cranium	DgRs-2	79.50	5.99	42.14	14.54	•	-14.16		15.02		12.51	0.19	3.25		
10534	Dom. Dog	cranium	DgRs-2	34.00	6.14	41.83	14.47		-13.40		15.38				3.32		
10535	Dom. Dog	metacarpal	DgRs-2	26.50	5.25	40.11	14.53	•	-13.05	•	15.22	·	•	•	3.33	•	•
10536	Dom. Dog	cranium	DgRs-2	52.40	9.13	38.58	14.85	•	-14.04		14.60	-		•	3.29	•	
10537	Dom. Dog	cranium	DgRs-2	38.40	5.79	41.92	14.87	•	-14.10		14.99	•			3.13		
9894	Dom. Dog	cranium	DgRs-30	124.93	12.54	42.32	14.90	•	-13.09	0.04	15.81	0.02			3.31		
9895	Dom. Dog	cranium	DgRs-30	100.34	14.09	41.73	14.90	•	-13.48	0.02	15.66	0.04			3.27		
9896	Dom. Dog	mandible	DgRs-30	81.84	11.04	41.19	14.85	•	-13.13	0.00	16.21	0.03	•	•	3.23	•	•
9897	Dom. Dog	mandible	DgRs-30	77.58	9.48	40.40	14.35	•	-12.95	0.05	16.13	0.04	•	•	3.28	•	•
9898	Dom. Dog	mandible	DgRs-30	65.30	8.18	42.28	14.87	•	-13.41	0.01	15.76	0.04		•	3.31		
9899	Dom. Dog	mandible	DgRs-30	85.30	10.92	42.01	14.83	•	-13.63	0.01	15.92	0.01		•	3.30		•
9900	Dom. Dog	mandible	DgRs-30	73.10	10.78	41.92	15.12		-13.25	0.02	14.93	0.00			3.23		
9901	Dom. Dog	cranium	DgRs-30	67.73	10.92	42.86	15.27	•	-13.82	0.12	15.25	0.07		•	3.27		
9902	Dom. Dog	mandible	DgRs-30	97.08	14.80	41.73	15.03		-13.26	0.06	16.19	0.01			3.24		
9903	Dom. Dog	ulna	DgRs-30	103.64	14.06	41.25	14.65	•	-13.85	0.34	15.38	0.00	•	•	3.28		•
9904	Dom. Dog	humerus	DgRs-30	41.58	9.58	41.47	14.78		-12.51	0.04	16.18	0.03		•	3.27	•	
9905	Dom. Dog	humerus	DgRs-30	58.56	11.64	41.28	14.45	•	-13.34	0.06	15.59	0.02			3.33		
9906	Dom. Dog	humerus	DgRs-30	63.82	11.84	41.65	14.57		-13.91	0.05	15.23	0.02			3.33		
9907	Dom. Dog	humerus	DgRs-30	45.14	10.98	41.04	14.59	•	-12.44	0.02	15.46	0.04			3.28		
9908	Dom. Dog	humerus	DgRs-30	47.14	11.81	41.50	14.87		-13.51	0.09	15.94	0.02			3.25		
9909	Dom. Dog	humerus	DgRs-30	51.98	11.87	41.30	14.83	•	-13.27	0.04	15.80	0.02		•	3.25		•
9910	Dom. Dog	humerus	DgRs-30	67.33	11.09	42.92	13.64		-15.11	2.66	15.99	0.09	•		3.25	•	•

9911	Dom. Dog	femur	DgRs-30	103.19	10.65	41.35	14.69	•	-13.36	0.02	15.76	0.02	•		3.28	•	•
9912	Dom. Dog	femur	DgRs-30	90.74	10.96	41.45	14.60		-13.05	0.01	16.23	0.01	•		3.31	•	
9913	Dom. Dog	femur	DgRs-30	93.24	9.46	41.77	14.85		-13.91	0.02	15.24	0.05	•	•	3.28	•	•
9914	Dom. Dog	femur	DgRs-30	73.80	10.65	41.61	14.83		-13.82	0.04	15.33	0.14			3.27		
9915	Dom. Dog	femur	DgRs-30	78.74	9.82	41.62	14.84	•	-13.12	0.01	15.60	0.06	•	•	3.27	•	•
9916	Dom. Dog	femur	DgRs-30	59.60	11.16	41.97	14.99		-13.92	0.00	15.75	0.10	•	•	3.27	•	•
9917	Dom. Dog	femur	DgRs-30	68.54	9.30	42.03	15.05	•	-13.44	0.10	15.68	0.00	•	•	3.26	•	•
9918	Dom. Dog	femur	DgRs-30	84.75	11.63	41.40	14.79		-13.60	0.03	15.43	0.02	•		3.26	•	
9919	Dom. Dog	femur	DgRs-30	79.04	12.79	41.35	14.71	•	-13.30	0.01	15.82	0.03	•		3.28		
9920	Dom. Dog	femur frag	DgRs-30	66.20	11.53	40.98	14.65	•	-13.54	0.06	15.76	0.14			3.26		
9921	Dom. Dog	femur frag	DgRs-30	189.50	11.33	41.09	14.60	0.33	-12.24	0.07	16.97	0.02	7.43	0.17	3.28	332.4	101.3
9922	Dom. Dog	femur frag	DgRs-30	65.00	10.28	42.03	14.95		-13.74	0.01	15.84	0.01			3.28	•	
9923	Dom. Dog	femur frag	DgRs-30	55.60	11.39	42.40	14.59	•	-14.83	0.01	15.04	0.02	•		3.39		
9924	Dom. Dog	femur	DgRs-30	123.20	10.83	41.42	14.74	•	-12.91	0.03	16.25	0.03			3.28		
9925	Dom. Dog	femur frag	DgRs-30	126.80	9.23	41.25	14.65	•	-13.29	0.05	14.97	0.04		•	3.28		•
9925	Dom. Dog	femur frag	DgRs-30	126.80	9.23	41.06	14.77	•	-13.12	0.26	14.80	0.02		•	3.24	•	
9926	Dom. Dog	tibia frag	DgRs-30	75.90	14.03	41.63	14.74		-13.73	0.01	14.65	0.22	•	•	3.29	•	•
9927	Dom. Dog	tibia frag	DgRs-30	65.30	11.92	42.01	14.86	•	-13.42	0.18	15.80	0.10		· .	3.30	·	•
9928	Dom. Dog	metatarsal	DgRs-30	71.10	12.45	41.51	14.90	•	-11.93	0.10	15.73	0.20		•	3.25	•	•
		Ш															
9929	Dom. Dog	metatarsal	DgRs-30	118.70	11.37	40.94	14.66	•	-13.16	0.07	15.79	0.24			3.26	·	
		Ш															
9930	Dom. Dog	metatarsal	DgRs-30	104.50	14.47	39.75	13.04		-13.67	0.09	15.29	87.58	•	•	3.59	•	•
		Ш															
9931	Dom. Dog	metatarsal	DgRs-30	121.10	14.43	41.48	14.39	•	-14.09	0.09	14.59	0.91	•	•	3.36	•	•
		II															
9932	Dom. Dog	metatarsal	DgRs-30	77.00	12.96	41.23	14.45	•	-13.55	0.22	15.20	0.20	•		3.33		
		11															
9933	Dom. Dog	metatarsal	DgRs-30	76.00	11.06	41.35	14.62	•	-14.02	0.06	15.60	0.22			3.30		
		IV															
9934	Dom. Dog	metatarsal	DgRs-30	92.40	15.15	40.97	14.80	•	-12.09	0.03	16.25	0.44	•	·	3.23	•	•
		IV															

9935	Dom. Dog	metatarsal	DgRs-30	69.80	13.85	41.16	14.77	•	-13.45	0.17	15.31	0.15	•	•	3.25		•
0000	Dam Dam	IV		00.00	40.00	44.05	14.00		12.04	0.07	15.00	0.40			0.07		
9930	Dom. Dog	IV	DGRS-30	99.00	10.86	41.05	14.00	•	-13.94	0.07	15.09	0.16	•		3.27		
9937	Dom. Dog	metatarsal IV	DgRs-30	83.70	12.64	41.44	14.90		-13.83	0.26	15.14	0.03			3.24		
9938	Dom. Dog	metatarsal IV	DgRs-30	73.40	9.76	41.09	14.65	•	-13.89	0.12	15.27	0.07	•	•	3.27		•
9939	Dom. Dog	metatarsal IV	DgRs-30	83.40	13.52	40.30	14.48	•	-13.97	0.04	15.10	0.10		•	3.25		
9940	Dom. Dog	metatarsal IV	DgRs-30	57.60	9.41	40.34	14.37	•	-13.62	0.10	15.46	0.12	•	•	3.27		
9941	Dom. Dog	metatarsal IV	DgRs-30	49.00	9.53	40.84	14.37	0.27	-14.20	0.11	15.07	0.09	3.29	•	3.31	403.8	121.9
4100	Bald Eagle	humerus	DhRp-17	37.00	8.83	42.17	14.85	0.26	-15.51	0.03	13.63	0.03	9.47	0.21	3.35	441.4	133.3
4101	Lynx	lumbar vert	DhRp-17	9.00	2.76	40.57	14.88	•	-15.47	0.01	13.47	0.02			3.21		
4104	Dom. Dog	metatarsal 3	DhRp-17	29.00	5.97	39.49	13.87	0.22	-14.51	0.03	15.40	0.06	11.27	0.12	3.34	479.1	144.3
4106	Dom. Dog	thoracic vertebra	DhRp-17	24.00	7.72	38.59	12.84	0.20	-14.00	0.10	16.33	0.01	11.57	0.06	3.52	515.1	147.0
4108	Dom. Dog	rib	DhRp-17	11.00	3.05	37.88	12.29	•	-14.16	0.09	16.35	0.02	•	•	3.55	•	•
4117	Dom. Dog	tibia	DhRp-17	50.00	11.26	40.96	13.71	0.25	-13.23	0.05	16.33	0.04	11.69	0.16	3.49	437.3	125.5
4118	Dom. Dog	tibia	DhRp-17	23.00	7.49	40.22	13.74	0.23	-22.97	0.01	8.59	0.05	2.08	0.47	3.45	477.2	139.8
4121	Dom. Dog	humerus	DhRp-17	68.00	10.37	39.45	14.15	0.22	-13.99	0.00	15.34	0.02	13.00	0.15	3.29	489.8	150.7
4122	Deer	phalanx	DhRp-17	50.00	10.89	34.55	12.09		-24.63	0.03	1.83	0.05		•	3.34		
4123	Dom. Dog	thoracic	DnRp-17	16.00	9.58	42.10	14.07	0.23	-13.70	0.05	16.90	0.02	12.09		3.51	488.6	140.0
1121	Dom Dog	rib	DhPn-17	27.00	7.46	40.46	14.01	0.23	-13 58	0.01	16.90	0.03	13 13	0.25	3.40	469.6	130 /
4124	Dom Dog	humerus	DhRp-17	38.00	10.56	39 15	14.01	0.25	-13.55	0.01	17.04	0.05	11.56	0.23	3.40	409.0	131.5
4127	Dom Dog	7th lumbar	DhRp-17	30.00	8.55	41.32	15.07	0.25	-13.66	0.40	16.80	0.00	12.23	0.04	3.20	441.2	138.0
	2 onn 2 og	vert	21110 17	50.00	0.00	11.02	10.07	0.20	10.00	0.00	10.00	3.00		0.21	0.20		
4128	Dom. Dog	mandible	DhRp-17	10.00	3.00	39.68	14.18	0.26	-14.50	0.07	15.83	0.04	10.49	•	3.27	407.4	124.8

4129	Dom. Dog	ribs	DhRp-17	74.00	13.19	41.20	14.31	0.20	-14.67	0.03	20.14	0.02	11.65	0.11	3.37	549.9	163.8
2856	Dom. Dog	metacarpal	EeRI-4	42.00	10.88	42.31	15.68	0.26	-15.47	0.05	13.76	0.14	9.31	2.21	3.15	427.4	135.8
2857	Canid	humerus fragment	EeRI-4	26.00	6.06	42.63	14.43	0.28	-19.87	0.00	3.91	0.09	1.64	0.52	3.45	410.6	119.2
2858	Deer	shaft fragment	EeRI-4	2.00	0.41			0.25					2.50			•	•
2859	Deer	shaft fragment	EeRI-4	28.00	5.98	41.83	16.08	0.26	-21.14	0.07	3.90	0.13	-2.93	1.11	3.05	436.7	143.9
2860	Deer	shaft fragment	EeRI-4	31.00	7.38	43.03	15.44	0.25	-20.38	0.08	4.42	0.09	0.02	1.03	3.25	460.4	141.7
2862	Deer	mandible fragment	EeRI-4	38.00	8.96	41.10	15.33	0.24	-20.41	0.04	5.34	0.08	-2.00	0.38	3.15	451.8	144.5
2863	Mule Deer	3rd phalange	EeRI-4	17.00	4.14	42.24	14.66	0.25	-20.05	0.05	4.55	0.30	1.16	1.95	3.40	459.4	136.7
2864	Mule Deer	scaphoid	EeRI-4	29.00	6.68	41.40	14.23	0.24	-20.48	0.03	3.94	0.03	1.80	0.26	3.40	451.9	133.2
2866	Mule Deer	3rd phalange	EeRI-4	36.00	11.11	42.40	14.97	0.23	-20.67	0.04	5.44	0.12	-2.92	0.88	3.35	492.1	148.9
2867	Mule Deer	vertebral epiphysis	EeRI-4	30.00	6.62	42.83	14.81	0.25	-20.39	0.07	3.00	0.17	-0.33	0.60	3.35	466.6	138.3
2868	Mule Deer	femoral head	EeRI-4	34.00	7.59	42.74	16.28	0.23	-19.81	0.00	3.91	0.10	0.32	0.91	3.10	507.1	165.6
2874	Salmon	vertebra	EeRI-4	5.00	1.42	•		0.35			•	•	12.00	0.79	•	•	•
2876	Salmon	vertebra	EeRI-4	21.00	9.46	42.09	15.93	0.57	-15.79	0.11	11.09	0.16	14.56	0.74	3.10	198.7	64.5
2877	Salmon	vertebra	EeRI-4	16.00	3.27	40.49	14.17	0.53	-15.58	0.00	10.91	0.13	14.07	0.33	3.35	204.8	61.4
2878	Salmon	vertebra	EeRI-4	11.00	4.30	40.97	14.74	0.59	-15.88	0.05	10.24	0.01	14.84	1.11	3.26	185.5	57.2
2879	Salmon	vertebra	EeRI-4	7.00	3.63	41.44	14.38	0.56	-16.22	0.08	9.87	0.03	14.47	0.42	3.37	197.5	58.7
2880	Salmon	vertebra	EeRI-4	12.00	2.42	34.33	12.27	0.38	-16.27	0.02	11.04	0.36	11.31	•	3.27	238.6	73.1
2881	Salmon	vertebra	EeRI-4	1.00	1.82	•	•	0.54	•	•	•	•	14.12	•	•	•	·
2882	Salmon	vertebra	EeRI-4	2.00	0.78	40.48	14.23	0.50	-16.45	0.00	9.81	0.11	14.24	•	3.35	216.7	65.3
2883	Salmon	vertebra	EeRI-4	1.00	1.25	•	•	0.49	•	•	•	•	14.34	•	•	•	·
9708	Sockeye	thoracic Vert	EeRI-4	11.00	6.15	39.08	14.38		-16.27	0.01	9.69	0.21	•		3.17		

9710	Sockeye	thoracic Vert	EeRI-4	8.00	4.21	39.38	14.36	•	-16.14	0.07	9.70	0.08		•	3.20	•	•
9711	Sockeye	thoracic Vert	EeRI-4	6.00	4.11	39.03	14.04		-16.70	0.01	11.00	0.00			3.24		
9712	Sockeye	Pre-caudal Vert	EeRI-4	6.00	3.06	37.52	13.01	•	-17.03	0.09	9.66	0.04	•	•	3.36	•	•
9719	Sockeye	thoracic Vert	EeRI-4	20.00	5.31	40.29	14.92	0.57	-16.06	0.06	9.99	0.03	11.78	0.62	3.15	190.4	60.4
9722	Sockeye	thoracic Vert	EeRI-4	9.00	2.39	39.12	14.46	•	-14.68	0.01	13.22	0.06		•	3.16		
9723	Sockeye	thoracic Vert	EeRI-4	5.00	2.86	39.62	14.54	•	-15.66	0.06	11.08	0.12		•	3.18		
9733	Bighorn Sheep	Tarsal	EeRI-4	14.00	3.45	40.37	14.19		-20.28	0.05	4.14	0.07		•	3.32	•	
9734	Bighorn Sheep	Vertebra	EeRI-4	40.00	10.34	42.62	15.42	•	-19.24	0.02	5.77	0.05		•	3.22		
9735	Mule Deer	Femur	EeRI-4	46.00	7.67	38.54	13.97	•	-21.46	0.02	2.04	0.25		•	3.21		
9736	Mule Deer	Tibia	EeRI-4	49.00	8.38	42.09	14.92		-21.74	0.04	3.61	0.09		•	3.29		
9737	Mule Deer	Radius	EeRI-4	9.00	2.03	36.27	12.83	•	-21.22	0.01	3.09	0.07	•	•	3.30	•	•
9738	Mule Deer	Tibia	EeRI-4	47.00	9.55	42.58	15.38	•	-20.61	0.01	4.02	0.02			3.23		•
9739	Mule Deer	Trapezoid Magnus	EeRI-4	64.00	15.80	42.63	15.47	•	-20.40	0.04	3.52	0.16	•	•	3.21	•	•
9740	Mule Deer	Metatarsal	EeRI-4	45.00	7.01	42.04	14.96		-20.82	0.00	5.88	0.09			3.28	•	•
9741	Mule Deer	Pubis	EeRI-4	29.00	5.85	42.10	15.16	0.20	-19.42	0.03	4.80	0.16	-3.44	0.42	3.24	561.9	173.5
9742	Mule Deer	Ulna	EeRI-4	25.00	5.43	42.05	14.65	0.22	-20.58	0.02	2.60	0.25	-4.54	0.53	3.35	522.1	156.0

9743	Mule	Thoracic	EeRI-4	35.60	6.00	40.54	14.30	•	-20.52	0.16	3.59	0.05	•	•	3.31	•	•
	Deer	Vert															
9744	Mule	Phalange	EeRI-4	49.00	11.06	42.04	15.22		-20.56	0.02	3.03	0.04			3.22	.	
	Deer																
9745	Mule	Tibia	EeRI-4	54.00	10.55	42.34	15.32		-20.73	0.03	4.07	0.01	·		3.22	•	
	Deer																
9748	Mule	Lumbar	EeRI-4	56.00	11.55	42.60	15.51		-19.30	0.01	4.14	0.14		.	3.20	.	
	Deer	Vert															
9749	Mule	Astragalus	EeRI-4	48.00	8.48	42.47	15.21		-20.28	0.04	3.03	0.05	·		3.26	•	
	Deer																
9751	Mule	Pubis	EeRI-4	39.00	7.83	42.04	14.88		-20.51	0.03	3.99	0.07	•		3.30		•
	Deer																
9752	Mule	Lumbar	EeRI-4	33.00	5.36	40.35	14.24	•	-20.50	0.02	4.12	0.09			3.31		•
	Deer	Vert															
9754	Beaver	Caudal	EeRI-4	39.00	7.60	41.81	14.66	0.25	-20.71	0.09	5.33	0.05	-5.24		3.33	455.6	137.0
		Vert															
9755	Beaver	Vertebra	EeRI-4	39.00	7.53	41.52	14.32	0.19	-20.92	0.04	3.52	0.26	-3.77	0.05	3.38	599.1	177.2
9756	Salmon	Thoracic	EeRI-4	16.00	8.00	39.86	13.76	0.50	-16.57	0.04	9.61	0.09	16.10	0.74	3.38	215.0	63.6
		Vert															
9758	Mule	Lumbar	EeRI-4	64.00	10.72	42.16	15.02	•	-20.43	0.05	4.17	0.10	-8.33	0.01	3.28		•
	Deer	Vert															
9761	Mule	Lumbar	EeRI-4	37.00	9.27	41.57	14.49	0.19	-19.78	0.01	3.67	0.09	-1.02	0.20	3.35	584.0	174.6
	Deer	Vert															
9763	Mule	Metatarsal	EeRI-4	42.00	9.35	42.03	14.94	0.18	-20.07	0.02	4.04	0.03	-5.28	0.44	3.28	641.1	195.4
	Deer																
9766	Deer	humerus	EeRI-4	55.00	11.29	42.20	14.52		-22.12	0.02	3.04	0.19			3.39	·	
9767	Deer	premaxilla	EeRI-4	74.00	12.69	43.31	15.24		-20.55	0.03	2.60	0.05	•	•	3.32	•	•
9768	Deer	scaphoid	EeRI-4	28.00	5.16	42.68	14.99		-20.71	0.02	4.20	0.01	•		3.32		•
10046	Wolf	ulna	EeRI-4	14.50	8.90	41.27	14.82		-20.01	0.40	3.08	0.11		•	3.25	•	
10047	Canid	ulna	EeRI-4	21.00	15.67	40.97	14.84	•	-20.45	0.08	3.81	0.01			3.22		
10048	Dom. Dog	fibula	EeRI-4	105.00	11.96	42.17	14.95	0.22	-15.39	0.21	14.51	0.09	12.37	0.06	3.29	511.7	155.6
10049	Canid	tibia	EeRI-4	91.00	17.37	40.85	14.60	0.20	-20.78	0.33	4.21	0.13	-2.28	0.22	3.26	559.2	171.4

10050	Dom. Dog	cervical vertebra	EeRI-4	53.50	10.33	41.19	14.69	0.25	-15.88	0.06	13.53	0.03	13.07	0.01	3.27	448.8	137.3
10051	Dom. Dog	axis	EeRI-4	36.00	10.78	40.84	14.67	0.24	-15.86	0.30	13.47	0.14	13.18	0.22	3.25	454.2	139.9
10052	Dom. Dog	thoracic vert	EeRI-4	26.40	11.05	40.44	14.53	0.23	-15.91	0.05	13.75	0.06	12.77	0.24	3.25	479.8	147.8
10053	Wolf	metatarsal I	EeRI-4	2.00	2.50	39.10	13.54		-20.78	0.10	3.29	0.04			3.37		
10054	Dom. Dog	caudal vert	EeRI-4	31.50	8.20	40.56	14.56	0.22	-15.16	0.02	14.23	0.17	8.24	0.22	3.25	492.1	151.5
10055	Dom. Dog	metatarsal	EeRI-4	84.50	6.79	42.08	15.00	0.20	-15.47	0.11	14.14	0.12	11.34	0.63	3.27	576.1	176.0
10056	Canid	tibia	EeRI-4	84.90	10.13	40.93	14.78	0.24	-20.14	0.08	4.18	0.05	-1.55	0.26	3.23	455.3	140.9
10057	Dom. Dog	calcaneus	EeRI-4	75.50	10.99	41.85	14.96	0.23	-15.00	0.27	14.78	0.01	10.90	0.44	3.26	496.5	152.2
10058	Dom. Dog	calcaneus	EeRI-4	82.50	13.31	41.35	14.95	0.23	-14.75	0.31	14.95	0.13	14.43	0.97	3.23	490.6	152.1
403	Dom. Dog	cranial frags	EeRI-7	6.00	2.71	41.66	12.91	•	-17.97	0.02	14.01	0.12		•	3.47		
404	Dom. Dog	cranial frags	EeRI-7	11.00	5.19	42.80	14.84	0.25	-16.72	0.05	13.50	0.07	9.84	0.32	3.37	466.4	138.6
406	Dom. Dog	cranial frags	EeRI-7	20.00	9.48	43.04	15.13	0.26	-17.54	0.01	12.05	0.10	5.56	2.32	3.32	441.9	133.2
407	Dom. Dog	cranial frags	EeRI-7	6.00	2.94	42.74	14.82	0.23	-16.46	0.08	13.45	0.09	10.35	1.48	3.37	507.0	150.7
408	Dom. Dog	cranial frags	EeRI-7	4.00	1.95	42.14	13.92		-16.85	0.20	13.39	0.06			3.53		
429	Dom. Dog	epiphysial end	EeRI-7	1.00	0.49	43.61	14.16	•	-20.91	0.34	6.15	0.07	•	•	3.60	•	•
430	Dom. Dog	2 bone frags.1 tooth	EeRI-7	10.00	4.72	43.93	14.94	0.27	-15.99	0.08	15.53	0.03	11.60	0.62	3.43	442.5	129.0
431	Dom. Dog	mandible, maxilla, canine	EeRI-7	11.00	4.45	44.11	14.60	0.27	-16.49	0.07	15.25	0.05	9.90	1.75	3.53	444.4	126.1
432	Dom. Dog	shaft	EeRI-7	14.00	7.00	43.66	15.45	0.23	-15.57	0.08	14.78	0.10	11.62	1.09	3.30	506.7	153.7

433	Dom. Dog	ulna	EeRI-7	18.00	8.41	44.10	15.32	0.25	-15.56	0.00	15.95	0.00	9.34	0.74	3.36	480.5	143.1
434	Dom. Dog	humerus	EeRI-7	11.00	5.29	43.82	15.28	0.25	-15.84	0.01	14.81	0.10	10.66	1.40	3.35	477.4	142.7
435	Dom. Dog	mandible	EeRI-7	20.00	9.30	43.97	15.20	0.25	-16.00	0.02	15.24	0.05	9.56	1.39	3.37	479.1	142.0
436	Dom. Dog		EeRI-7	6.00	3.19	42.74	13.46	•	-16.83	0.08	17.06	0.06			3.51	•	•
437	Dom. Dog	carpal or	EeRI-7	28.00	13.21	43.85	15.52	0.24	-14.81	0.08	15.50	0.04	11.96	1.36	3.30	487.7	148.0
		tarsal															
3966	Deer	phalanx	EeRI-7	63.00	12.48	39.74	14.13	•	-21.65	0.00	6.38	0.04			3.29		
3967	Deer	tarsal	EeRI-7	20.00	4.52	41.80	14.59	•	-20.65	0.01	3.95	0.02	•		3.34	•	•
3968	Deer	scapula	EeRI-7	21.00	9.38	40.83	15.49	0.20	-22.35	0.13	4.10	0.03	-3.56	0.58	3.07	558.9	181.8
3973	Deer	ulna	EeRI-7	34.00	9.42	41.66	14.98	0.20	-20.84	0.02	3.21	0.08	-8.77	1.55	3.26	556.0	171.5
3974	Deer	scapula	EeRI-7	13.00	3.99	39.75	12.67		-21.67	0.05	4.56	0.02			3.50		
3976	Deer	ulna	EeRI-7	33.00	12.00	39.93	13.93	•	-19.54	0.01	6.66	0.03	•	•	3.33	•	•
3978	Deer	scapula	EeRI-7	25.00	7.16	38.65	12.64	0.20	-21.42	0.01	4.14	0.07	-0.85	0.09	3.57	529.1	148.4
3979	Deer	astragalus	EeRI-7	45.00	10.74	43.54	14.52	•	-20.78	0.01	3.56	0.00	•	•	3.53	•	•
3981	Hare	tibia	EeRI-7	31.00	7.77	43.24	14.07	0.28	-23.35	0.06	1.81	0.04	-9.34	0.14	3.41	419.7	117.1
3982	Grouse	femur	EeRI-7	35.00	12.11	42.82	13.64	0.30	-18.94	0.06	5.23	0.00	-1.41	0.04	3.49	381.0	104.1
3983	Deer	metapodial	EeRI-7	65.00	15.37	40.97	14.61	•	-20.43	0.04	3.71	0.02			3.28	·	
3984	Deer	phalanx	EeRI-7	18.00	4.31	36.69	11.75	•	-20.82	0.04	4.54	0.01			3.53		
3985	Deer	metatarsal	EeRI-7	41.00	8.91	41.91	13.50	•	-21.37	0.01	4.47	0.02		•	3.55	· .	•
3986	Deer	phalanx	EeRI-7	12.00	2.59	42.70	13.69	0.22	-20.62	0.09	6.15	0.00		•	3.60	518.1	142.4
3987	Hare	mandible	EeRI-7	45.00	9.55	42.21	14.22	•	-20.60	0.05	3.71	0.08	-6.52	0.71	3.48		
3988	Deer	ulna	EeRI-7	53.00	10.93	40.40	15.77	0.19	-19.48	0.09	6.03	0.04	-5.28	0.09	2.99	567.6	189.9
3993	Deer	metacarpal	EeRI-7	58.00	11.24	41.62	14.61	•	-20.42	0.04	3.68	0.07			3.35	·	
3996	Deer	1st phalanx	EeRI-7	50.00	10.25	42.49	13.65	0.20	-20.89	0.04	3.95	0.00	-0.72	0.01	3.60	567.1	156.2
3997	Bird	humerus	EeRI-7	11.00	10.78	42.69	12.92		-21.34	0.01	7.15	0.01			3.50		
3999	Deer	1st phalanx	EeRI-7	64.00	13.73	41.81	14.24	0.20	-20.52	0.56	4.05	0.08	-2.98	0.49	3.45	572.3	167.1
4000	Lynx	1st phalanx	EeRI-7	39.00	14.34	42.33	14.31	0.23	-21.10	0.35	4.80	0.00	-3.85	0.27	3.49	502.2	145.5
21540	Dom. Dog	metatarsals - 2	EeRI-7	6.40	1.84	•	•	•	-15.62	•	15.79	•		•	3.47	•	

21541	Dom. Dog	spinous process frag	EeRI-7	8.60	2.86				-17.94		11.23				3.39		
21542	Dom. Dog	rib frag	EeRI-7	10.20	2.84	•	•	•	-16.63	•	13.31	•	•	•	3.34	•	•
21543	Dom. Dog	bone	EeRI-7	10.80	3.21	•	•	•	-16.28	•	12.68	•	•	•	3.24	•	•
21544	Dom. Dog	bone	EeRI-7	5.30	1.49	•	•	•	-15.92	•	13.68	•	•	•	3.28	•	•
21545	Dom. Dog	cranial	EeRI-7	10.40	3.33	•			-15.85		12.92				3.24		•
		frags															
21546	Dom. Dog	mandible	EeRI-7	0.30	0.09	•	•	•	-16.04	•	13.09	•	•	•	3.24	•	•
2108	human	femur	Boston	0.58	0.20	41.84	15.03	0.24	-14.75	0.10	18.74	0.01	8.76	1.32	3.25	465.4	143.3
			Bar														
2109	human	femur	Boston	0.56	0.10	35.33	12.68	0.18	-14.48	0.05	19.31	0.17	10.43	0.98	3.25	538.9	165.9
			Bar														