Cultural Complexity and Resource Intensification on Kodiak Island, Alaska

Robert E. Kopperl

A dissertation submitted in partial fulfillment of the requirements for the degree of

Doctor of Philosophy

University of Washington

2003

Program Authorized to Offer Degree: Department of Anthropology

UMI Number: 3111093

ProQuest Information and Learning Company
300 North Zeeb Road
P.O. Box 1346
Ann Arbor, MI 48106-1346

In presenting this dissertation in partial fulfillment of the requirements for the Doctoral degree at the University of Washington, I agree that the Library shall make copies freely available for inspection. I further agree that extensive copying of the dissertation is allowable only for scholarly purposes, consistent with "fair use" as prescribed in the U.S. Copyright Law. Requests for copying or reproduction of this dissertation may be referred to Bell and Howell Information and Learning, 300 North Zeeb Road, Ann Arbor, MI 48106-1346, to whom the author has granted "the right to reproduce and sell (a) copies of the manuscript in microform and/or (b) printed copies of the manuscript made from microform."

Signature: ______________________

Date: 12/12/03

University of Washington
Graduate School

This is to certify that I have examined this copy of a doctoral dissertation by

Robert E. Kopperl

and have found that it is complete and satisfactory in all respects, and that any and all revisions required by the final examining committee have been made.

Chair of Supervisory Committee:

Julie K. Stein

Reading Committee:

Virginia L. Butler

J. Benjamin Fitzhugh

Donald K. Grayson

Julie K. Stein

Date: 11/24/03

University of Washington

Abstract

Cultural Complexity and Resource Intensification on Kodiak Island, Alaska

Robert E. Kopperl

Chair of Supervisory Committee:
Professor Julie K. Stein
Anthropology

Models created by archaeologists to explain the development of cultural complexity on the north Pacific coast frequently pose resource intensification, especially of salmon, as a possible cause. However, whether or not intensification actually occurred or why it might arise in the first place are usually left unexplored. In this dissertation, I use the Kodiak archipelago as a case study to rigorously explore these issues. I use models from optimal foraging theory to develop predictions to test the hypotheses that prehistoric intensification of fish occurred as well as depression of certain prey populations. Additionally, I test the hypothesis that intensification had chronological priority over an increase in cultural complexity.

Data from four prehistoric faunal assemblages, three of which were analyzed for this dissertation, are used to test the hypotheses. Bones from Rice Ridge, Crag Point, Uyak and Settlement Point indicate a shift from a focus on sea mammals during the Ocean Bay period to greater use of marine fish and salmon during the later Kachemak and Koniag periods.

According to my model, resource intensification implies a greater use of prey with low net energetic returns over time. I examine the relative taxonomic abundance of sea mammals, marine fish, salmon, and terrestrial mammals within and between sites. Significant declines in ratios of sea mammals to both marine fish and salmon before the advent of mass-harvesting technology suggests a decline in foraging efficiency and strongly supports the intensification hypothesis as well as the hypothesis that intensification occurred before the increase in cultural complexity that occurred during the Kachemak and Koniag periods.

To test the hypothesis that resource depression of certain prey populations occurred, I use several lines of evidence. Changes in relative skeletal abundance of sea mammal bones suggest hunters were traveling farther afield to access sea mammals during the Ocean Bay period. Cut-marked bones become more abundant over time, inferred as an increase in butchering intensity. Changes in the age structures of sea otter, harbor seals, and Pacific cod inferred from their remains indicate that these populations were being negatively impacted by some agent, possibly human foraging activity or changes in paleoclimate.

Table of Contents

Page

List of Figures

Figure **Page**

List of Tables

Table **Page**

Acknowledgements

I would first like to express my thanks to the owners of the faunal collections that I analyzed for allowing me to bring those bones to the University of Washington and learn from them. Dale and Marie Rice, landowners of the Rice Ridge site, not only encouraged me to incorporate their site into my dissertation but also graciously offered as much information as they could muster about its excavation. The City of Larsen Bay and Mayor Alan Panamaroff gave permission for the use of the Uyak faunal remains. Laura Bell Angel and the United States Fish and Wildlife Service, especially Debbie Corbett, encouraged me to use the Crag Point remains. Megan Partlow was very accommodating by allowing me to use some of her data from Settlement Point in my dissertation and even went back into her database when I had questions.

I would also like to express my gratitude to my dissertation committee. Virginia Butler, Ben Fitzhugh, Don Grayson and Julie Stein provided invaluable guidance. Their knowledge and expertise cover so many areas; it has given me confidence in growth as a researcher. Virginia Butler sparked my passion for fish bones and the ways in which people have used fish both prehistorically and historically. Ben Fitzhugh first introduced me to Kodiak, and encouraged me to find relationships between subsistence and larger social change. Don Grayson sparked my interest in evolutionary ecology and inspired me to be a better scientist. Julie Stein has been a wonderful advisor, mentor and committee chair for as long as I've been in the program – thank you so much for all that you've done – you are the best!

Others have commented on earlier drafts of this dissertation and its preliminary proposal as well. Several of those people have come from Don Grayson's grant writing class – Mike Cannon and Mike Etnier provided especially useful comments in that setting. Amy Steffian provided insight not only on the Uyak site but on my research and how it relates to Alutiiq culture history as well. Finally, several anonymous reviewers of my NSF dissertation improvement grant proposal offered valuable comments.

Essential funding has come from several sources. National Science Foundation Dissertation Improvement Grant #BCS-0226397 provided the bulk of my research funding and allowed the Rice Ridge site to be thoroughly radiocarbon dated. John Yellen at NSF patiently answered all of my questions regarding the grant. Between his help and Don Grayson's grant writing class, the whole process became much less arcane. Additional funds have come from the University of Washington Department of Anthropology, the University of Washington Graduate School, the Alaska Anthropological Association, and the United States Fish and Wildlife Service.

Comparative material was graciously loaned to me by the Thomas Burke Memorial Museum at the University of Washington, facilitated by John Rozdilsky and Ted Pietsch. Mike Etnier loaned me numerous specimens from his personal collection, and introduced me to Jim Thomason and the sea mammal skeletal collections housed at NOAA, Sand Point. Kris Bovy loaned me several skeletons as well. The Alaska Department of Fish and Game office in Kodiak, specifically Larry VanDaele, kindly donated a matching set of bear paws to our department to be skeletonized and used for comparative purposes.

Several of my fellow UW anthropology department graduate students offered invaluable assistance and encouragement. In all things statistical, Mike Cannon, Mike Etnier, and Matt Steele stand out in this regard. My fellow zooarchaeology grad students, especially Kris Bovy, Mike Cannon, Mike Etnier, and Lisa Nagaoka, have been wonderful friends and an invaluable support network. Other students who work in Kodiak are part of this group too: Phoebe Anderson, Jennie Deo and Catherine Foster. At the Burke Museum Archaeology division, Laura Phillips has been very supportive as well.

There are many archaeologists who work in Alaska who deserve my thanks for their help and encouragement. The staff of the Alutiiq Museum and Archaeological Repository in Kodiak especially deserves my gratitude. Patrick Saltonstall, Sven Haakanson, Jr., Libby Eufemio and Amy Steffian have made me feel welcome and encouraged my involvement in their community ever since my first season in Kodiak. Patrick Saltonstall's hospitality is, in a word, unparalleled. Don Clark, Don Dumond and David Yesner have been very giving of their knowledge and encouragement as well. The Alaska Consortium of Zooarchaeologists has been another great resource. Sue Bender, Diane Hansen, Becky Saleeby, and Linda Yarborough in particular have always expressed an interest in my research and encouragement to keep looking at those bones.

The folks at the bioarchaeology lab at Hunter College, New York, were instrumental in facilitating the transfer of the faunal remains to the University of Washington. Tom McGovern, Colin Amundsen, and Clayton Tinsley in particular were a great help.

During the preliminary analysis of the Rice Ridge assemblage, I had the assistance of several undergraduate University of Washington students in the UW-Sichuan University Exchange Program on Challenges to the Environment coordinated by Steve Harrell. Ross Nadal and Jonathan Chin sorted thousands of little fish bones with enthusiasm, curiosity and a lot of good humour.

Finally, I could not have finished this project, or started it for that matter, without the support and love of my family, especially my parents, Susan and Sheldon Kopperl, and my brother, Ben Kopperl. Sharmaine Guyll and her family have given me their encouragement and put things in perspective as well, in the most wonderful way.

Dedication

To my parents, Susan and Sheldon Kopperl.

Chapter 1: Introduction

Resource Intensification and Complex Coastal Hunter-Gatherers

Many hunter-gatherer groups living on the Pacific coast of North America, from California to the Aleutian Islands, exhibited characteristics at the time of European contact that set them apart from most other non-agricultural Native Americans. These distinguishing characteristics include densely populated settlements, increased sedentism, elaborate ceremonial institutions, warfare, slavery, social ranking, complex labor organization, and a reliance on technology aimed at intensive harvest and storage of certain animals (Arnold 1996). Attempting to explain the development of cultural complexity in this coastal setting has led anthropologists to invoke several causal variables, including population pressure (e.g., Cohen 1981; Keeley 1988), sedentism (Rosenberg 1998), food storage (Schalk 1977; Testart 1982) and labor organization (Arnold 1993). The most influential models attempting to account for the cultural complexity of coastal foragers rely directly or indirectly upon the intensification of harvesting pressure by humans on certain vertebrates, most frequently salmon or sea mammals, as a primary explanation for this phenomenon (e.g., Ames 1981; Arnold 1992; Matson and Coupland 1995; Yesner 1987).

Resource Intensification has been defined as an increase of energy invested by a social group in the harvest of a particular food resource in order to extract more of that resource (Boserup 1965; Beaton 1991). Such intensification is often linked to significant changes in harvesting and storage technology, settlement patterns, and labor organization (Fitzhugh 2001), and is frequently believed to be the result of periodic fluctuations in resource availability (Hayden 1981).

Resource intensification may in turn arise from the phenomenon of *resource depression*, or the decrease in capture rates of prey as a result of the behavior of predators (Charnov et al. 1976; Stephens and Krebs 1986). The effects of resource depression have been documented archaeologically in many parts of North America (e.g., Borque 1995; Broughton 1995, 1997, 2002a; Butler 2000; Cannon 2001; Kay 1994).

Despite many cultural complexity models for the north Pacific that afford resource intensification some causal role, there have been few detailed attempts to demonstrate that such intensification did occur, and no attempts to demonstrate the possible causes of any such intensification. It follows that changes in subsistence behavior implied by intensification-based explanations of cultural complexity have not been tested against either the record of changing animal utilization or the development of the characteristics of cultural complexity on the north Pacific coast. In this dissertation, I develop a resource depression model drawn from optimal foraging theory. I use the model to test the hypothesis that intensified use of small-bodied prey such as fish occurred at the expense of overall foraging efficiency. I also test the hypothesis that this intensification was driven by decreasing encounters with larger-bodied sea mammals. These hypotheses are tested using data from several archaeofaunal assemblages from the Kodiak archipelago that span approximately

6000 years. The role of intensification in the prehistoric development of cultural complexity in the Kodiak archipelago, Alaska, is further explored, situated within the context of a model of emergent cultural complexity that has already been developed (Fitzhugh 2003).

The remainder of this chapter reviews previous models of cultural complexity developed for the north Pacific coast, focusing on the role of resource intensification. The culture historical sequence developed for the region is reviewed, along with the model developed specifically for the Kodiak region. In Chapter 2, I detail the theoretical underpinnings of the resource depression model. Prey choice, patch choice, and central-place forager models from optimal foraging theory are reviewed along with archaeological and ethnographic applications of these models that seek to explain changes in prehistoric hunting and gathering. In Chapter 3, I establish the hypotheses that explain resource intensification in terms of resource depression and the implications this may have on the development of cultural complexity in the Kodiak region. Archaeological expectations inferred from these hypotheses are also examined. In Chapter 4, I review the archaeological sites and associated faunal assemblages that will be used to test the hypotheses detailed in Chapter 3, as well as the general protocol used for analysis of the faunal remains. In Chapter 5, I evaluate the relative taxonomic abundances of different prey to see if patch choice and prey choice within patches change in a way that is consistent with resource intensification. In Chapter 6, I examine skeletal part abundances and the prevalence of butchery marks on faunal specimens as a reflection of transportation costs and intensity of butchering. Also examined are the age structures of certain prey types as indications of impacts that foragers had on prey populations. In Chapter 7, I discuss the results of the analyses and conclude the dissertation with a review of future research goals.

The Role of Resource Intensification in the Development of Cultural Complexity

Archaeological models attempting to explain cultural complexity on the north Pacific coast (Fig. 1.1) often cite labor- and technology- intensive harvests of certain high-abundance (e.g., salmon) or high-return (e.g., sea mammals) animal species by Native Americans at initial European contact. From historical observations and the presence of archaeological faunal remains and artifacts that may support notions of intensification, a causal role has been given to resource intensification in the development of cultural complexity. The justification for the use of intensification in such a role is often implicitly ethnohistoric, relying more upon the sizeable ethnographic literature available for the region than on inferences from archaeological data. The evolution of complex hunter-gatherers is undeniably a complex process, therefore single causal mechanisms, such as resource intensification, are insufficient in explaining the development of cultural complexity amongst these groups (Fitzhugh 2003:5).

Some cultural complexity models, most notably those for the Northwest Coast (e.g., Coupland 1988; Fladmark 1975), regard the development of intensive salmon harvesting as an initial impetus for complexity and continued intensification as a cause for the social phenomena observed in the ethnographic record, an evolutionary trajectory resulting in a "developed Northwest Coast pattern" (Matson and Coupland 1995:247). Frequently tied to these intensification models is the consequent development of processing and storage technology needed to take advantage of the variable nature of salmon runs and other fish resources in a more efficient manner (Croes and Hackenberger 1988; Schalk 1977). Other models, particularly those developed for coastal California, recognize sea mammals such as seals, sea lions, and whales as playing just as important a role as salmon in the development of cultural complexity (e.g., Colten and Arnold 1998; Hildebrandt and Jones 1992; Porcasi and Fujita 2000).

In these models, increasing human population densities are followed by resource intensification, in turn requiring new forms of labor organization, subsistence technology, and further stratification of social systems. Environmental triggers are used to model this sequence, such as a sudden fluctuation in an environmental parameter like an extended El Niño event (Arnold 1993; Colten and Arnold 1998) or the stabilization of sea level (Fladmark 1975). Changes in labor organization, social hierarchies, and political motivations may indeed be caused in part by intensification of abundant, low-ranking resources. Why intensification should arise in the first place, however, is speculated upon but usually left unexplored.

Salmon Intensification and Cultural Complexity

The focus on salmon utilization in models of cultural complexity is understandable for many reasons. As a source of food, seasonal runs of salmon, trout, and other anadromous fish present a spatially-concentrated, predictable, productive resource that can be stored and consumed during the remainder of the year when they are not available in the rivers. Before modern commercial harvesting in the north Pacific, members of the salmonid family were available from the tributaries of San Francisco Bay in California across the north Pacific Rim to Japan. For example, salmon populations that spawn in the Columbia-Snake, Fraser, Skeena, Stikine and Copper River systems on the Northwest Coast, the Karluk and Ayakulik Rivers on Kodiak Island, and numerous lake-fed river systems on the Alaska Peninsula were historically the most productive salmon rivers in the world (Groot and Margolis 1991). These rivers were heavily utilized by humans prehistorically as well, as evidenced by dense archaeological sites along the banks and at the mouths of each river (e.g., Amorosi 1987; Hoffman et al. 2000). However, even smaller drainages almost always supported some sort of salmon run along the north Pacific, and could have proven valuable to any hunter-gatherer population living along the coast.

Anthropologists often cite the nature of salmon populations as defendable resources to explain why salmon was so centrally important in an environment with many other abundant food resources, and how a reliance on such a resource might cause an increase in cultural complexity (e.g. Coupland 1988). Following Dyson-Hudson and Smith (1978), territoriality and economic defendability on at least a seasonal basis can be expected for salmon runs if the energetic benefits of remaining at and defending a salmon habitat outweigh the costs of its defense, potential risks of remaining in the area, and missed opportunities foraging elsewhere. When a resource is predictable and dense, such as is usually the case with salmon populations, compared to other relatively less predictable and productive resources in the region, territorial and defensive utilization of that resource is an expected outcome (Dyson-Hudson and Smith 1978:26). Archaeologists have made this assumption when explaining the high degree of sedentism, apparent territoriality and cultural complexity among Native Americans living along the north Pacific coast.

Both fisheries scientists and anthropologists have acknowledged for some time that salmon runs vary in terms of productivity, annual timing and consistency both across space and through time. Despite recent advances in the reconstruction of salmon population dynamics with a time depth of hundreds and even thousands of years (Finney et al. 2000, 2002), the interrelationship between salmon, people, and their environment is still not clear (e.g., Hewes 1973; National Research Council 1996). Variability in the aspects of salmon runs that make them potentially defendable resources, such as productivity and predictability during spawning season, has been used to explain spatial variability in labor organization, social stratification, use of storage, and cultural complexity along the Northwest Coast (e.g., Schalk 1977).

Intensification of salmon harvesting must be examined in light of other potential resources whose use may be intensified, as well as other foraging options that would be implemented by hunter-gatherers prior to the development of intensification. Despite the importance of salmon to Native Americans living on the north Pacific coast for thousands of years as inferred by the quantity of salmon remains found at archaeological sites (e.g., Amorosi 1987; Cannon 1991; Matson 1976) other fish resources were utilized intensively as well, especially later in prehistory (Cannon 1995; Croes and Hackenberger 1988; Fitzhugh 1996, 2003; Hanson 1995; Kopperl 2001; Monks 1987). Shellfish beds provided another type of prey that were abundant yet required a relatively large amount of energy to supply enough calories and protein to make the effort to feed large populations worthwhile (e.g., Erlandson 1988). Sea mammals on the other hand have been identified as a primary target that would have provided high energetic returns for the efforts of coastal hunter-gatherers, and apparently played a large role in a diverse economy that they maintained before intensified use of salmon (e.g., Hildebrandt and Jones 1992). A model that takes into account the foraging options of coastal hunter-gatherers over time and across resource types must be used to explain the development of intensification on the coast. Models derived from foraging theory, detailed in Chapter 2, can place intensification of salmon in a broader foraging context that explicitly examines different subsistence options. One important place to test these models is the Kodiak archipelago, Alaska.

Complex Hunter-Gatherers on Kodiak Island, Alaska

The Kodiak archipelago has often been seen as adjacent to, but not a part of, the Northwest Coast culture area (Suttles 1990). However, archaeological and ethnographic evidence demonstrates a continuum between the two areas in both environment and culture. Kodiak juxtaposes a paucity of terrestrial animal resources (Rausch 1969) and a relatively harsh climate (Wilson and Overland 1986) with a wealth of sea mammal resources (Wynne 1997), some of the world's most productive salmon streams (Roppel 1986) and offshore fisheries (Mueter and Norcross 2002), productive shellfish beds (Wilimovsky et al. 1988), and well-documented culture historical sequences (Table 1.1). Deposits from many of the archaeological sites contain the entire range of fauna found in the archipelago today. Early sites contain a variety of sea mammal and fish remains while later sites contain a predominance of fish, most notably salmon and Pacific cod (Amorosi 1987; Clark 1979:218-222; Partlow 2000; Yesner 1989). These observations have led to the assertion of an intensification of salmon fishing during later prehistory. The sequences also demonstrate the development of sedentary, populous communities exhibiting characteristics associated with cultural complexity (Fitzhugh 2002; Fitzhugh and Crowell 1988), making this region well-suited to test models of the evolution of cultural complexity, resource intensification, and resource depression.

Archaeologists have been developing the culture historical sequence for the Kodiak archipelago since Aleš Hrdlicka's work in the 1930s. His scheme was a simple division of Kodiak prehistory into occupation by the "Koniag", the cultural ancestors of the present-day Alutiit, and an earlier "Pre-Koniag" population that he claimed was displaced by the Koniag (Heizer 1956; Hrdlicka 1944). Archaeologists today generally agree on a sequence with three major chronological divisions, each with two subdivisions (Table 1.1). The three periods reflect a growing population of humans that first colonized the archipelago sometime before 7500 calendar years B.P. Many archaeologists believe that this sequence represents an *in situ* development of the culturally-complex maritime-adapted Alutiit encountered in the mid-1700s by Russian explorers and fur traders, with influences on their social and material culture coming from interactions with Native Americans from coastal southeast Alaska, the Bering Sea region, and the Aleutian Islands (Clark 1984a; Steffian 2001).

Ocean Bay

The Ocean Bay period, roughly spanning the time from colonization before 7500 years B.P. to about 3500 B.P., marks a growing population of humans across the archipelago occupying ideal places for obtaining resources such as sea mammals, marine fish, salmon, and birds. Populations for much of the period probably consisted of small but growing residentially-mobile groups inferred from the small size and thin deposits that characterize most Ocean Bay sites (Clark 1979; Fitzhugh 2002, 2003).

These early inhabitants of the archipelago most likely arrived fully adapted to the maritime environment of Kodiak. Watercraft and the ability to pilot them would have been a prerequisite for successful colonization (e.g., Ames 2002). Also, known positions of Ocean Bay sites in the archipelago show a focus on locations where hunter-gatherers could access sea mammal haul-outs and rookeries and marine fish habitats along the coast, as well as some sites that were located along major salmon streams (Fitzhugh 2002) and lagoon environments (Steffian et al. 2002). Finally, the artifact and faunal assemblages from Ocean Bay period sites indicate both the technology to take advantage of marine resources, in the form of bone harpoon pieces and marine fishing gear, and the successful results of their foraging efforts in the form of marine mammal, bird, and fish bones that dominate the very rare Ocean Bay site with faunal preservation (Hausler-Knecht 1993).

The Ocean Bay period is subdivided into two phases, Ocean Bay I and II, based on a reliance on ground slate technology after about 4500 B.P. that coincides with the beginning of the Ocean Bay II phase. The earlier Ocean Bay I phase is marked by an almost exclusive reliance on chipped stone tool technology in the form of bifacial projectile points and knives, and microblades that have been hypothesized as being embedded in slotted bone points (Fitzhugh 2002, 2003; Steffian et al. 2002). Later phases, from Ocean Bay II onward, show a significant reduction in chipped stone tool use based on very small proportions of chipped tools and debitage in relation to ground slate tools (Clark 1979, 1982). Also, the first evidence of semi-subterranean houses and substantial tent rings occur during the Ocean Bay II phase (Hausler-Knecht 1993; Amy Steffian, personal communication 2003). Despite major differences in artifact content and structural evidence between the two phases, Ocean Bay I and II sites are frequently characterized by thin red ochre-stained occupation floors, lack of shell midden deposits, and little indication of tools necessary to exploit large numbers of fish (e.g., weir sites, net weights).

The first Ocean Bay sites to be investigated on the archipelago were the Roadcut site on Sitkalidak Island and the Chert and Slate sites on Afognak Island (Clark 1979). These sites are typical for the time period, consisting of thin deposits with little or no organic preservation. The Tanginak Spring site (KOD-481) is an exceptional Ocean Bay I site that contains some of the oldest dated deposits in the archipelago as well as almost a meter and a half of house floor and midden deposits, although organic preservation is limited to a few calcined bone specimens (Fitzhugh 1996, 2003). The Rice Ridge site (KOD-363) is also an exceptional site, spanning both Ocean Bay I and II phases, because of its organic preservation and large faunal assemblage that was recovered during excavation, and is outlined in greater detail in Chapter 4 (Hausler-Knecht 1991, 1993).

Kachemak

The Kachemak period, from about 3500-1000 radiocarbon years B.P., marks a transition from dispersed settlements of mobile hunter-gatherers to aggregations of numerous households into villages that were probably occupied for most of the year and inhabited for many years. The period is divided into two phases, the Early Kachemak or Old Kiavak phase (3500-2500 B.P.), and the Late Kachemak or Three Saints phase (2500-1000 B.P.). First defined for the Kenai Peninsula to the north of the Kodiak archipelago by de Laguna (1934), the period shows a general shift by prehistoric people on the Alaska Peninsula, Kodiak archipelago, and Kenai Peninsula towards an economy more reliant on intensive salmon fishing and shellfish collection.

Late Kachemak components from archaeological sites in the Kodiak archipelago are characterized by clusters of semi-subterranean structural depressions, square or rectangular in nature and consisting of one room and often an entrance tunnel. The numbers of house pits in Kachemak sites range from only one or two houses plus associated pit features to villages with many house structures dug in and around extensive shell midden deposits (Clark 1970, 1997; Steffian 1992a). Sites that have been interpreted as being functionally-specific, such as salmon processing camps, first appear during the Kachemak period. Although there is a growing body of evidence that humans were making use of upriver environments late in the Ocean Bay period, it is not until about 3500 B.P. that structures first appear in riverine environments away from the coast, presumably placed in locations that took advantage of salmon runs (Clark 1979; Saltonstall et al. 2001).

Greater effort spent harvesting and processing salmon is also evident in most Kachemak artifact assemblages (Clark 1984a). Semi-lunar ground slate knives, or *ulus*, have the ideal shape and raw material for quick and effective salmon processing, and first appear during the Early Kachemak phase. Notched flat beach cobbles also make their first appearance during this phase. At Kachemak sites situated along some rivers they tend to dominate artifact assemblages, and are surmised by most archaeologists to have been used to weigh down nets for fishing and possibly for hunting birds as well (Saltonstall et al. 2001). Ground stone plummets first appear, inferred to be weights for long-line fishing along the coast. At shell midden sites in which Kachemak bone tool assemblages have been recovered, the suite of ground bone hunting and fishing tools used during the Ocean Bay period is joined by new types. One of the most significant introductions was the toggling harpoon head, which may have provided some advantage for sea mammal hunting over barbed harpoons which were fixed to shafts (Fitzhugh 2001). Rounding out the changes in hunting and fishing technology was the addition of a variety of ground slate points that were smaller than Ocean Bay II bayonets (Clark 1984a). Some of these were probably used in conjunction with both toggling and fixed bone harpoon heads as end blades.

Material culture associated with Kachemak ceremonial life is seen as a reflection of a significant increase in social complexity during this period. Items of personal adornment such as labrets first appear during the Early Kachemak phase and by the Late Kachemak phase take a variety of forms and are made from different raw materials. A large proportion of labrets and other small decorative objects during the Kachemak and subsequent Koniag period are made from high-quality coal whose nearest source is the eastern coast of the Alaska Peninsula (Steffian 1992b; Steffian and Saltonstall 2001). The appearance of these exotic raw materials as well as artifact styles reminiscent of the Norton culture from the Bering Sea region (Dumond 1987) suggests regular trade and travel to and from mainland Alaska. An increase in the size of pecked stone lamps from ones weighing a few kilograms found in some Ocean Bay sites to massive Late Kachemak lamps weighing over 40 kilograms decorated with anthropomorphic, zoomorphic, and abstract designs are inferred as an indication that households that were growing in size and degree of sedentism (Clark 1984a; Fitzhugh 2003:52). Finally, elaborate mortuary practices are found in Later Kachemak burials, including cut and drilled human bones, artificial carved ivory eyes, and secondary burials (Heizer 1956; Simon 1992). The contents and locations of Kachemak sites reflect a population growing in size and social complexity, with an expanding toolkit and settlement patterns that took advantage of both the wide suite of coastal prey resources and concentrated salmon runs along rivers.

Koniag

The Koniag period is the third and final major division of Alutiiq prehistory. Most culture historical schemes place the beginning of this period at 1000-800 radiocarbon years B.P., with an Early Koniag phase that ends around 600 B.P. and a Developed Koniag phase from 600 B.P. until contact with Russian explorers and fur traders in the mid-1700s (Clark 1984a). Recent research at sites with both Kachemak and Koniag components shows a continuum in many aspects of prehistoric Alutiiq life (e.g., Jordan and Knecht 1988; Knecht and Jordan 1985), but many significant differences between the Late Kachemak and Early Koniag phase have been discerned as well.

Koniag settlement patterns show a continued increase in the use of riverine environments. Villages along the coast continue to grow in terms of the number and size of structures, and for the first time very large villages appear along the banks of the largest rivers in the archipelago as well as at outer coast locations. Individual households, however, become more varied in terms of area (Fitzhugh 1996, 2003; Jordan and Knecht 1988; Knecht 1995; Maschner and Hoffman 2003). Some Koniag houses are similar in size to typical Kachemak house proportions, while many Koniag houses are several times larger in area with upwards of eight side rooms or alcoves leading away from a large central room. The appearance of burnt and broken rock piles that may represent the remains of sweat baths are frequently found in Koniag side rooms. Along with clay-lined pits frequently dug both inside and outside of Kachemak houses, Koniag storage features also included large slate slab or wood plank boxes kept inside the house around a central hearth (Clark 1984a; Saltonstall 1997).

Koniag artifact assemblages contain many of the same artifact types as those from the Kachemak period with some additions. The appearance of heavy grooved splitting adzes has been interpreted by some archaeologists as an influence from the northwest coast of North America (Clark 1984). Regardless of its origin, it most likely indicates an increased focus on woodworking, which would have corresponded with the initial appearance of Sitka spruce forests on the northern islands of the Kodiak archipelago (Tennison 2000). Coarse gravel-tempered pottery is not uncommon in Koniag sites along the southern coast of Kodiak Island (Clark 1966, 1974a). Slate pebbles with incised anthropomorphic designs appear briefly, often in large numbers, and then disappear during the Early Koniag phase (Donta 1993; Saltonstall 1997). Other artifacts, such as ground slate points and *ulus* and bone hunting and fishing tools, have temporally-diagnostic forms between the periods but essentially reflect continued economic emphasis on sea mammal hunting, near-shore fishing, and intensive harvesting of salmon.

The elaborate ceremonial culture of the Kachemak period is not as apparent during the Koniag period, similar to the trend in the prehistory of the Gulf of Georgia region of the Northwest Coast between the Marpole and San Juan phases (Ames and Maschner 1999; Matson and Coupland 1995; Stein 2000). However, the presence of labrets of various raw materials and styles continues into the Koniag period and may be indicative of a trend towards increasing social inequality (Steffian and Saltonstall 2001). Also, these status indicators and other artifact types made of wood have been recovered from sites post-dating 1000 B.P., although few have been recovered from the archaeological record of all but the most well-preserved sites (Knecht 1995).

The social organization and economic focus of households and villages during the Koniag phase appears to be a continuation of the Kachemak phase. Population estimates by Fitzhugh (2002, 2003:210-217) based on the number of radiocarbon dated components across Kodiak as well as on house and site area estimates at sites around Sitkalidak Island point to increasing absolute population and population density. During this time, the Alutiit probably participated in some form of warfare both between villages on the archipelago and against neighbors as far away as southeast Alaska (e.g., Holmberg 1985; Knecht 1995). Whaling is evident from large lances and other whaling gear in Koniag artifact assemblages and from early observations by Russian colonists of well-organized hunting parties that pursued several species of whale with aconite poison-tipped darts and became a key aspect of Alutiiq social organization (Crowell 1994). Sea mammal hunting and fishing of both salmon and marine fish most likely continued to provide the foundation of prehistoric Alutiiq diet, unlike coastal Alaskan cultures north of the Bering Strait where whales both large and small would have been the most profitable prey and their remains and the tools to hunt them dominate archaeological assemblages for the past 2000 years (McCartney 1995).

Euroamerican Contact

Colonization by Russia, and later the United States of America, brought both change and continuity to many aspects of Alutiiq life. At the time of initial Russian Contact in the mid-18th Century, the Kodiak archipelago had one of the densest human populations north of California (Clark 1984b). This changed rapidly with the onset of introduced diseases and the dispersal of most adult Alutiiq men to work depots, or *artels*, to harvest sea otter for Russian fur traders around the Gulf of Alaska and as far away as coastal California (Crowell 1997; Lightfoot et al. 1991) and the Kurile Islands (Shubin 1994). The trajectory of Alutiiq social and economic development changed drastically after Russian contact and even further with the sale of Alaska to the United States. However, despite the introduction of non-native processed foods in the grocery stores and non-native animal populations in the bush outside the towns and villages, fishing for salmon, cod, halibut and other fish species remains the most important economic activity and these fish provide a significant portion of the Alutiiq diet. The choice of harbor seals as prey continues as well, despite the changes in hunting technology provided by firearms and motorized boats (Mishler 2001).

Kodiak Island: A Case Study on Prehistoric Resource Intensification

Partlow (2000) has explicitly tested the hypothesis that a shift towards salmon intensification occurred concurrently with changes in household organization evident at the transition from the Late Kachemak phase to the Early Koniag phase, around 1000-800 B.P. Changes in house structure and composition are apparent across the archipelago at this time (Jordan and Knecht 1988; Knecht 1995). Her research, however, was the first to look for a shift in subsistence that might be related to one line of evidence for the appearance of cultural complexity. By examining faunal assemblages from sites spanning the Kachemak-Koniag transition in terms of taxonomic diversity and evenness, Partlow demonstrates a shift at this transition into the Early Koniag phase towards less diverse, salmon-focused fishing concurrent with increases in household storage capacity and salmon skeletal element composition of faunal assemblages consistent with salmon processed for storage.

Unlike Partlow's narrower temporal and analytic focus, Fitzhugh (1996, 2003) provides a very broad model of emergent cultural complexity for the Kodiak archipelago that offers resource intensification as an independent variable arising in part from resource depression. The model uses behavioral ecological principles as an underlying theoretical foundation, explaining individual behaviors and motivations as a response to a composite socioecological environment (Fitzhugh 2003:102-103). Against a backdrop of the highly seasonal and dynamic environment of Kodiak, hunter-gatherers must make an array of individual economic decisions that have long-term implications for the development of complex social relations of the population as a whole.

In this scheme, intensification implies an increased effort by a population to solve subsistence problems, namely to increase caloric yields from the environment. Intensification can take the form of *labor intensification*, in which more effort is directed towards harvesting a particular prey. *Technological intensification*, on the other hand, addresses the same problem by innovation of tools or processes that allow more efficient use of certain prey, thereby making them more profitable and potentially more sought-after than previously higher-ranked prey (Fitzhugh 2001). Intensification in either form is one option available to hunter-gatherer populations at several stages outlined in Fitzhugh's model.

The first stage of the model corresponds to the initial colonization and settlement of the Kodiak archipelago by humans (Fitzhugh 2003:106-111). With a low population density across the islands, families could take full advantage of the wide array of resources available on the archipelago. In the non-winter months of the annual cycle, subsistence is focused on large-bodied prey offering the highest net energetic returns, while the stormy winter months require more limited mobility and consequently a wider diet breadth incorporating less profitable but conveniently located resources such as shellfish and small marine fish. During this stage, food storage is not a significantly useful strategy as mobility during much of the year and inadequate labor input prevent investment in such features. Intensification of either labor or technology is not necessary as long as territorial expansion is still possible for the growing population. This stage corresponds with the Ocean Bay I phase of Kodiak culture history.

The shift to the second stage of the model is triggered by communities becoming circumscribed once the human population of the archipelago fills in and begins utilizing all of the most productive prey habitats. Crowding begins to affect both hunter-gatherers and their environment. The result of this circumscription is increased harvest pressure placed upon high ranking, slow-reproducing prey such as sea mammals. Labor intensification in the form of greater energy spent in pursuit of prey offering lower net energetic returns is one strategy that may be used to adapt to changing prey availability, along with food sharing which reduces short-term variability in harvest returns. This stage corresponds to the Ocean Bay II phase, in which growing human populations across the island were apparently settling in many strategic locations to take advantage of both sea mammals and prey whose harvest and/or processing were more labor-intensive given the available technology (Fitzhugh 2003:111-115).

When crowding of available settlement locations and pressure on prey reaches a point in which decreasing mobility, subsistence returns and foraging efficiency create a "density-dependent equilibrium state" (Fitzhugh 2003:115), the third stage of the model is enacted. A new set of strategies may be used by hunter-gatherers to address these subsistence problems, perhaps most prominently technological intensification. Innovation of new technologies to increase efficiency of harvesting or processing previously low-return prey is risky on an individual level but expected to succeed on a population-wide level over time under these conditions (see Fitzhugh 2001). More efficient utilization of small prey such as salmon *en masse* requires storage technology and a large labor pool to profitably handle a resource that is only seasonally abundant and can spoil easily. The social contexts of economic activities, such as the sexual division of labor, are in turn affected by the shift in focus to mass-harvesting of prey such as salmon. An increase in cultural complexity, in this case greater horizontal differentiation of social groups within a community, is expected. The *increase* in foraging efficiency that occurs from technological intensification may result in further increases in human population, but fissioning of social groups is no longer a viable option. Population growth under these conditions results in increased residential group size and settlement permanence, along with greater competition within and between groups over resources. This stage in Fitzhugh's model corresponds to the Kachemak period on Kodiak, which exhibits significant village formation, mass-harvesting technology, and elaboration of many artifact types.

The patchy, predictable resources that become a more efficient subsistence option in the third stage may develop into a focus for competition and defense, corresponding to the fourth stage of Fitzhugh's model (2003:121-129). Populations of large game that underwent depression in the early stages of the model may rebound when foraging efforts shift towards prey that can be mass-harvested efficiently (Ben

Fitzhugh, personal communication 2003). Hunting of large game may, at this stage, be energetically suboptimal compared with other subsistence pursuits and quite risky, yet reproductively advantageous for some individuals (see also Hawkes 1993; Hildebrandt and McGuire 2002). Individuals in positions of control over defendable, predictable resources such as salmon runs, as well as those engaging in "show-off" behavior by hunting large sea mammals, produce surpluses that garner prestige and offset the costs of those activities. Social inequality emerges as a response to this risky socioecological environment in which there is differential access to the most productive or prestigious resources. Those with less access tolerate subordination as "the best option from a limited set of alternatives" (Fitzhugh 2003:130). Greater cultural complexity in terms of an increase in the vertical, or hierarchical, differentiation of social groups is apparent at this stage of Fitzhugh's model, corresponding to the Later Kachemak phase and Koniag period on the Kodiak archipelago.

Fitzhugh's model outlines the dynamic environmental setting and cultural responses in which resource intensification and growing cultural complexity can be expected. Two different kinds of intensification have been defined in this model. Both are responses to subsistence shortages and result in increased caloric yield, but the first kind, labor intensification, also results in a decrease in foraging efficiency as more effort is focused on lower-return prey. The second kind, technological intensification, focuses effort towards innovations in harvest or processing methods and tools that may *increase* foraging efficiency.

Fitzhugh tests his model with data from an archaeological survey of Sitkalidak Island, part of the Kodiak archipelago, and finds general support for the model. This support includes evidence for technological intensification commencing with the Kachemak period, including artifacts associated with mass-harvesting of fish. The subsistence aspects of his model, however, remain less developed and untested, including whether or not labor intensification occurred as predicted in the model.

In the next two chapters I outline a model that explicitly offers hypotheses concerning the relationship between decreasing abundances of high-ranked prey and widening diet breadth that will allow further evaluation of models of cultural complexity that posit a causal role for intensification. A set of hypotheses can be derived from optimal foraging theory that predicts how coastal hunter-gatherer foraging behavior will change given a decline in high-ranked resource abundance. This theoretically-informed methodology can, with proper attention paid to empirical testing, compliment and build upon on the models mentioned above (Grayson 2001; Grayson and Cannon 1999; O'Connell 1995).

Table 1.1: Culture Historical Phases and Radiocarbon Age Ranges for the Kodiak Archipelago, Alaska

Phase	Approx. Dates	Primary References
Late (Developed) Koniag	400 BP - Contact	Clark 1974a, 1974b; Donta 1993, Jordan and Knecht 1988; Knecht 1995; Saltonstall 1997
Early Koniag	1000/800 - 400 BP	Clark 1974a, 1974b; Donta 1993, Jordan and Knecht 1988; Knecht 1995; Saltonstall 1997
Late Kachemak (Three Saints)	2500 - 1000/800 BP	Clark 1974b; Dumond and Scott 1991; Jordan and Knecht 1988; Hrdlicka 1944; Heizer 1956; Steffian 1992a
Early Kachemak (Old Kiavak)	3500 – 2500 BP	Clark 1997; Saltonstall et al. 2001; Steffian et al. 1998
Ocean Bay II	4500 – 3500 BP	Clark 1979; Fitzhugh 2003; Hausler-Knecht 1991, 1993
Ocean Bay I	>6600 - 4500 BP	Clark 1979; Fitzhugh 2003; Hausler-Knecht 1991, 1993

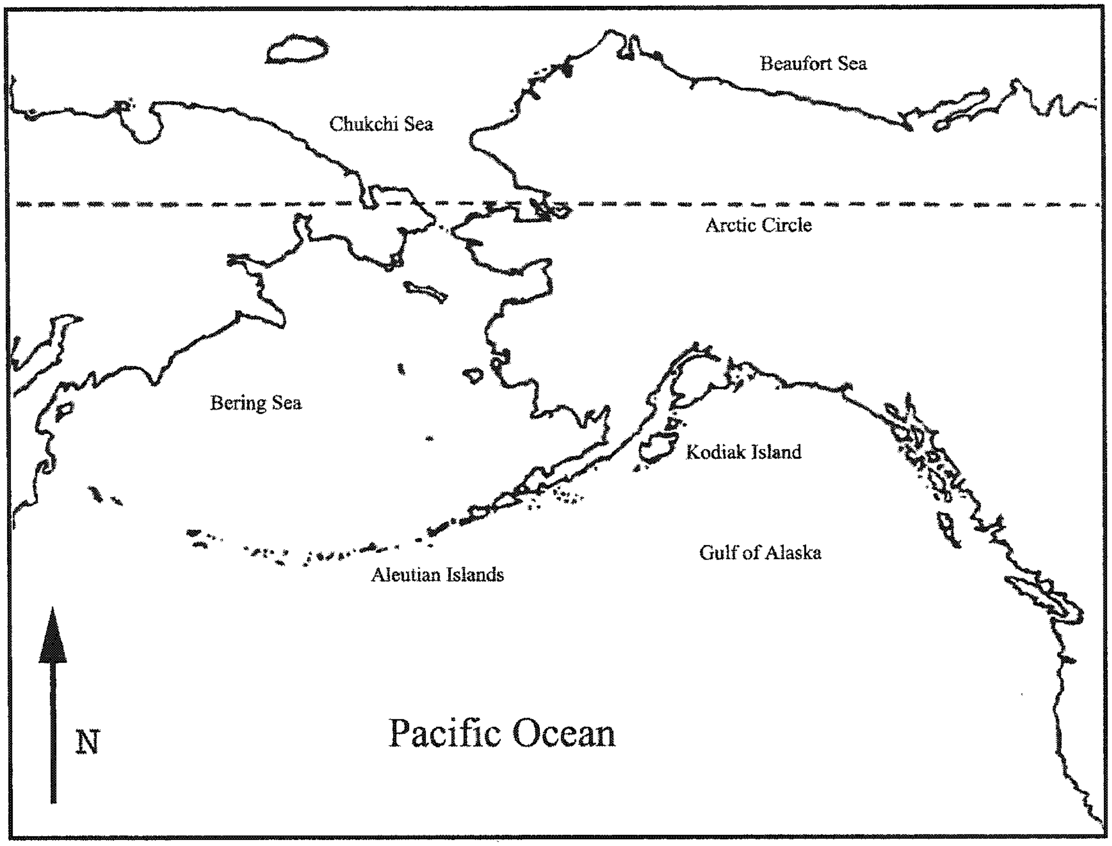


Figure 1.1: The Gulf of Alaska Region

Chapter 2:

Evolutionary Ecological Modeling of Resource Intensification

Optimal foraging theory, a subset of evolutionary ecology, has the potential to explain the diversity of foraging behavior among humans (Boone and Smith 1998; Broughton and O'Connell 1999; Kelly 1995, 1996), as well as more rigorously investigate resource depression and intensification (Grayson 2001). The mathematical models derived from foraging theory are ideal for predicting foraging behavior given certain known parameters, and quantitatively assessing the real-world outcomes of such predictions. This chapter describes several of these models and how they may be used to evaluate long-term trends in prehistoric hunter-gatherer subsistence on Kodiak Island.

Foraging theory was developed in the latter half of the twentieth century when biologists sought to explain variation in foraging-related traits of living organisms in terms of how such design influences reproductive fitness (Mills and Beatty 1979; Stephens and Krebs 1986). Models derived from optimal foraging theory make the fundamental assumption that the foraging behaviors of living organisms have been shaped by natural selection over the course of generations to maximize some reproductive fitness-related currency (Krebs and Davies 1993; Smith and Winterhalder 1992; Stephens and Krebs 1986; Winterhalder 1981). By making this assumption, optimality models allow the researcher to predict, among other things, what decisions will be made by a forager regarding the prey that will be exploited in a particular spatial clump of resources, or patch, and how long those resources will be exploited before moving on to a different patch (Kaplan and Hill 1992). Using these mathematical decision rules, optimal foraging theory provides the means for creating testable resource depression and intensification hypotheses that predict foraging behavior.

Anthropologists have adopted several of these models from zoology to explain foraging behavior among human hunter-gatherers. Ethnographic studies of subsistence practices of living hunter-gatherer communities have repeatedly shown that the basic models of foraging theory are effective in their predictive and explanatory power. For example, the prey choices made by the Aché of Paraguay (e.g., Hawkes et al. 1982; Hill et al. 1987) and various hunter-gatherer groups in Venezuela and Ecuador (Hames and Vickers 1982) clearly follow the basic prey choice model developed by biologists. Similarly, models developed to predict time allocation by foragers towards particular hunting and gathering pursuits have been used with success to explain foraging behavior by diverse groups, from the Inuit of arctic Canada (Smith 1991) to the Alyawara of Australia (O'Connell and Hawkes 1981, 1984). Real-time observation of the energetic efforts, risks, and benefits of different foraging options available to modern hunter-gatherer communities allows ethnographic studies that directly incorporate foraging theory models into explanations of subsistence behavior.

Some of the most interesting results of optimal foraging research are the instances in which the foraging behavior by hunter-gatherers does *not* fit the predictions of the models. Foraging behavior observed at the ethnographic time scale is often not "optimal" in the sense of maximizing net energetic returns, but may be explained in terms of other fitness-related concepts such as costly signaling and reproductive costs of risky subsistence pursuits (e.g., Hurtado et al. 1985; Kaplan and Hill 1992:176; Kelly 1995; Smith and Bliege Bird 2000; Sosis 2000). In these cases, anthropologists are able to re-tool their models in such a way that makes them more complex and realistic (Winterhalder and Smith 1992:16-17).

Archaeological applications of foraging theory that attempt to explain changes in prehistoric subsistence patterns quickly followed the study of contemporary hunter-gatherers in the context of evolutionary ecology. Although much of this effort has been centered in the Great Basin and desert Southwest of North America (e.g., Bayham 1979; Bettinger 1991b; Broughton and Grayson 1993; Cannon 2001), models from foraging theory have been used in a wide variety of spatial and temporal settings, from explaining the focus on reindeer hunting by Paleolithic hunters in France (Grayson et al. 2001) to moa extinctions in New Zealand (Nagaoka 2000, 2002) to resource depression along the California Coast (Broughton 2002b) and Columbia River on the Northwest Coast (Butler 2000). As in ethnographic case studies, adapting prey and patch choice models to archaeological research problems has been shown to be very effective.

The Prey Choice Model and Diet Breadth

The prey choice, or diet breadth, model is the most general model of foraging theory. It predicts which food items a forager will exploit and which the forager will ignore. Like other foraging models, the prey choice model consists of *decision, currency,* and *constraint* components. The decision component refers to the foraging decision that needs to be explained; in this case whether to pursue a particular prey type upon encounter or continue searching for other prey, which are considered mutually exclusive activities in this model. The currency component defines what is to be maximized, minimized, or maintained at a stable level. Maximizing net energetic returns, in terms of caloric gains and costs, and minimizing risk are frequently used currencies in foraging models. Net energetic return is the most commonly used currency in prey choice models (Stephens and Krebs 1986). Constraints comprise the remainder of the assumptions built into the model. In the case of prey choice, prey items are assumed to be encountered randomly and in proportion to their abundance in a homogenous (non-patchy) environment, and in sequential order. Along with mutually exclusive search and handling times, other constraining assumptions include the forager's complete knowledge of prey distribution, abundance, and energetic return rates, as well as the absence of any sort of impact the forager might have on prey abundances or distributions (Charnov 1976; Kaplan and Hill 1992; MacArthur and Pianka 1966; Stephens and Krebs 1986).

Mathematically, the prey choice model can be conceptualized as an equation that solves for a diet breadth that offers maximum net energetic returns:

$$R_{max} = (E/T)_{max}$$

where R_{max} is the maximum rate of energetic acquisition from foraging, E is the total net energetic returns from a particular diet breadth which entails both the energetic food value of prey types and the energetic costs of pursuing, processing, and consuming the prey types, and T is total foraging time involved in utilizing that range of resources. According to the model, a forager will add prey items to its diet in sequential descending order of their profitability until R_{max} is reached. In other words, within a foraging area, the most profitable prey type is the one which offers the highest *net* energetic return rate upon encounter (i.e., not from its abundance within the environment) and will always be pursued when it is encountered. Lower-ranked prey types will be included in this diet sequentially in decreasing order until adding additional prey types begins to *lower* the overall rate of energy acquisition.

Prey ranking is based on the profitability of the prey type, which includes both the food value gained by consuming a prey type as well as the energetic costs involved in including the prey type in the diet. In situations where foraging behavior can be observed, measuring the average caloric value of various prey types and estimating the energetic effort put forth by foragers handling such prey is relatively easy. From direct observation, anthropologists have been able to rank prey options of living hunter-gatherer communities and closely predict diet breadth using the prey choice model. For example, O'Connell and Hawkes (1981) show that Alyawara foragers would regularly ignore abundant but low-ranking resources such as seeds in favor of more profitable prey. In this case and most others, however, researchers recognize that several of the assumptions of the prey choice model are usually not met.

The assumption that prey types are distributed evenly across an environment in which a forager operates and are encountered proportionally based on their abundances is referred to as the *fine-grained search assumption* (Stephens and Krebs 1986). The violation of this assumption in many scenarios by human hunter-gatherers is perhaps the most frequently cited reason for the inapplicability of the prey choice model by itself when explaining foraging behavior. Resources are often spatially-aggregated, or patchy, across the landscape in which a forager must make decisions about where to allocate time and energy towards hunting and gathering. Additionally, a forager operating within a particular patch will likely experience a reduction over time in encounter rates with prey types included in their diet. This may be caused in part by an actual reduction in abundances of this prey from the activities of foragers, behavioral adaptations by prey to avoid predators, or non-anthropogenic changes in prey habitat that would result in lower encounter rates. Because of these common violations of the assumptions integral to the prey choice model, anthropologists often incorporate another model from foraging theory, the patch choice model, into their explanations. This model takes into account the spatial variability of prey distribution and the dynamic nature of energetic returns within a specific resource patch.

The Patch Choice Model and Time Allocation

The patch choice model as it was originally conceived predicts which resource patches a forager will include in its diet by incorporating a similar equation and constraining assumptions found in the prey choice model (MacArthur and Pianka 1966). Patches are ranked by a similar method to that done for prey types in the prey choice model. Foragers will add resource patches to their foraging round in order of decreasing net energetic returns until the inclusion of the next lower-ranking patch decreases overall foraging efficiency. As in the case of the prey choice model, this particular conceptualization of the patch choice model assumes that the activities of the forager in no way impacts encounter rates with prey as a patch is being utilized.

The addition of the *marginal value theorem* to the patch choice model allows us to take into account the effects of resource depression when predicting which patches will be utilized by a forager, and for how long before patch use changes (Charnov 1976). The marginal value theorem is shown graphically in Fig. 2.1. The gain curve represents cumulative energy acquired from a particular resource patch over time. In this case, the rate of energy acquisition gradually decreases over time, which is a realistic conceptualization of many real-world foraging scenarios in which relatively slow-reproducing prey abundance is impacted by hunting or gathering activities. As a forager continues to operate in a patch, net energetic returns decrease over time in a negatively accelerating manner (Charnov 1976; Kaplan and Hill 1992; Stephens and Krebs 1986).

Exactly when foragers end their residence time in a particular resource patch depends upon the expected search effort required to encounter another resource patch in a forager's patch breadth. In Fig. 2.1 the two lines that are tangent to the gain curve predict how long the forager will remain in the current patch. Patch A entails lower search or travel costs to encounter than Patch B, and its point tangent with the gain curve, representing the optimal time to leave the current patch, is closer to the origin. This implies that a forager will have a shorter residence time, represented by T1, in the current patch when he or she expects profitable patches nearby to be relatively easy to come across. On the other hand, the marginal value theorem predicts that a forager will remain in a depleted patch longer when the expected costs involved for searching and traveling to another patch increase, represented by T2.

Following the marginal value theorem, resource depression within a patch may cause a forager to shift to other patches. If the costs involved in moving to a different patch are too high, the depleted patch will continue to be utilized at the expense of foraging efficiency. Such a decrease in efficiency would be caused in part by an increase in the use of less profitable prey types within the patch. In an environment with numerous rich habitats, a forager would most likely shift patch use shortly after a decline in foraging efficiency (Stephens and Krebs 1986). Given enough time, partially-depleted resource patches of high-ranking prey might rebound, in which case they would be utilized once again. Although it is an improvement over the simple prey and patch choice models used in isolation, the marginal value theorem still tends to be unrealistic in most human foraging situations in which hunters and gatherers operate out of a central place. Visiting one or more patches while hunting, gathering, and/or fishing would incur travel costs when the foragers bring back food to a central location, along with the costs involved in traveling from patch to patch.

Central Place Foraging

Models developed to explain patch and residence time choices of central place foragers can be incorporated into resource depression models to take into account the realistic assumption that hunter-gatherers will bring food back to a centralized location. The central place foraging model conceived by Schoener (1979) considers a forager waiting at a central place for prey to be encountered. The model predicts that greater distances traveled by the forager in pursuit of prey will result in narrower diet breadth focused on more profitable prey.

Orians and Pearson's (1979) model expands on this scenario and takes into account the costs incurred during travel between resource patches and a central place, as well as additional costs once the forager begins collecting prey if he or she decides to continue searching for prey with an increased load. Capturing relatively large prey, such as a Steller sea lion by a human hunter for example, might encumber the hunter (or hunting party) to a point where the optimal decision would be to return to the central place with only one (or part of one) prey item. Conversely, a forager would be able to collect multiple smaller prey items with steadily increasing travel costs and handling costs towards subsequent prey encounters, such as human harvesting of small marine fish with a spear or hook and line.

The multiple prey-loading scenario in Orians and Pearson's (1979) model is similar to the marginal value theorem, predicting that as distance from a central place increases, foraging returns are maximized by remaining in a resource patch for a longer period of time (Fig. 2.2). On the other hand, among patches that are equidistant from a central place, those that provide greater energetic returns per unit of time spent foraging within them will allow slightly greater loads to be taken on, but less time spent within the patch (Fig. 2.3). When taking into account travel and search costs, incurred before prey are even encountered within a patch, Orians and Pearson (1979) demonstrate that effective patch quality is decreased, lessening the energy obtained and favoring longer optimal residence time (Fig. 2.4). In general, central place foraging models predict that as hunter-gatherers travel farther from a central place, they will be more selective about what they bring back, both in terms of prey types and portions of chosen prey. This has been demonstrated empirically with human hunter-gatherers both ethnographically (e.g., Hames and Vickers 1982) and archaeologically (Cannon 2003; Jones and Madsen 1989; Metcalfe and Barlow 1992).

Central place foraging also explicitly assumes that foragers will have some impact on encounter rates with prey because of their hunting and/or gathering activities. Hamilton and Watt (1970) model resource depletion together with central place foraging by predicting first that foraging will initially occur close to a central location chosen by a forager. Repeated foraging within a local radius will deplete prey, which in turn will cause an increasing foraging radius. The depleted zone will follow this expanding foraging radius, causing foragers to travel farther and farther from their central place. The rate at which this occurs is dependent upon the population density of the foragers. Archaeological applications of resource depression models, however, recognize that depleted resource patches may rebound, depending upon the reproductive nature of the prey types and the extent of their depletion (e.g., Broughton 1997; Butler 2000).

Operationalizing Foraging Models for Prehistoric Hunter-Gatherers

One main goal of resource depression models is measuring forging efficiency within and between resource patches by human hunter-gatherers, and to examine whether or not any detectable declines in efficiency can be explained by harvest pressure placed on those prey. Unlike ethnographic applications of foraging models (e.g., Hames and Vickers 1982; Hawkes et al. 1982; Kaplan and Hill 1992; O'Connell and Hawkes 1981; Smith 1991), which allow direct observation of diet breadth and associated pursuit, processing, transport and consumption costs at the scale of ecological time, archaeological applications of foraging models must translate these concepts in a manner that allows testing of hypotheses with data spanning a much larger scale of time (Grayson and Cannon 1999; Grayson and Delpech 1998; Madsen and Schmitt 1998; see also Lyman 2003). Diet breadth is a common measure of foraging efficiency within a patch. The prey choice model described above implies that as additional prey types are added to a forager's diet, resource intensification occurs and foraging efficiency declines. Unfortunately, the use of taxonomic richness from faunal assemblages to measure prehistoric diet breadth can be problematic for archaeologists. A broad diet may or may not be less efficient than a narrow one, depending on the relative differences in energetic returns among taxa and the relative abundance of the higher-ranking taxa. Knowledge of these factors is often not available from faunal assemblages that represent the aggregation of foraging behavior frequently spanning long periods of time.

In areas where there are few animal taxa available, changes in foraging efficiency must be measured using proportions of taxa in the diet instead of absolute numbers of taxa. For example, on Kodiak Island the entire range of fauna, both large and small, that were available to prehistoric hunter-gatherers has been utilized since the earliest culture-historical phases, including mammals, fish and birds (Clark 1984a; Hausler-Knecht 1991). Therefore, even if foraging efficiency changed over time, diet breadth in the strict sense (i.e., the number of prey types utilized) may not have changed much over the past 6-7000 years in the Kodiak archipelago.

Resource depression models have been developed in such a way that they avoid the problems inherent in standard diet breadth models when interpreting archaeological data by examining changes in the proportion of presumably high-ranking taxa in faunal assemblages. Two taxa are required to create an index, preferably well-separated in energetic returns. A decline in the ratio of high-ranked to low-ranked taxa may indicate declining human foraging efficiency, controlling for other factors that may change the abundance of the higher-ranking taxon or the net energetic returns of harvesting the lower-ranking taxon (see Broughton 2002a). These factors include climatic change, habitat alterations, or technological factors affecting net energetic returns of harvesting certain prey types (Broughton 1995; Cannon 2001; Nagaoka 1998, 2002).

A proxy of prey rank that has been frequently used is prey body size, which can be inferred from zooarchaeological remains (e.g., Broughton 1994b; Cannon 2001; Simms 1987). With the exception of very large animals such as whales, body size appears to provide a reasonable ordinal-scale indicator of energetic returns of particular prey types (Bayham 1979; Broughton 1994b; Nagaoka 2001). From this conceptualization, faunal assemblages dominated by larger-bodied taxa indicate more efficient foraging. Foraging efficiency indices, such as Broughton's (1995, 1997) artiodactyl and sturgeon indices, can be monitored across time from prehistoric faunal assemblages to the hypothesis that resource intensification occurred.

Resource depression models also require a measure of harvest pressure placed upon high-ranked prey that is independent of the foraging efficiency indices described above. Examining the age-structures of the archaeological remains of targeted prey is one such measure. If the correlation between ranking and body size generally holds true, then we expect large-bodied prey to be harvested most intensively when available. These large bodied K-selected prey types, such as sea mammals in a coastal environment or artiodactyls in an arid interior environment, tend to have longer life cycles and reproduce at a much slower rate than smaller-bodied r-selected prey such as smaller mammals and fish.

Assuming equal costs involved in harvesting infant, juvenile, and adult members of the prey population within a patch, a forager will tend to target older, larger members of the population in order to maximize returns. For example, harbor seals (*Phoca vitulina*) along the coast of the Kodiak archipelago spend most of their time hunting in solitude in near-shore marine environments, and females give birth to pups at sea which are weaned within a few weeks. Aggregations of many individuals are rare and age classes occur in these haul-outs in proportion to their population in general (Reeves et al. 2002; Wynne 1997). Foraging models predict that human hunters would tend to target larger adult individuals when encountered either alone or in groups. Other sea mammals such as porpoises and sea otters have similar age class distributions in which adult individuals present the greatest net energetic returns and occur in such abundance compared with infants and juveniles that they would be harvested most intensively.

The behavior of some prey types creates a different prediction regarding targeted age classes. For example, sea lions and fur seals (Family Otariidae) are the most vulnerable to hunters when they aggregate at specific, predictable places on land to rest and reproduce (e.g., Hildebrandt and Jones 2002; Lyman 1995). The age-class composition at these rookeries is skewed heavily towards infants, juveniles, and females (which also tend to be smaller in these sexually dimorphic species). Because adult males are the largest-bodied sex and age class of the species in these spatial aggregations but their pursuit is the most risky and their abundance is relatively low compared to females and young, a greater proportion of the other members of the population will be targeted.

Empirically, the resource depression model predicts that as high-ranked prey types are utilized more intensively, the age structure of their remains found at archaeological sites will change accordingly (Broughton 2002a). For species such as sea otters, harbor seals and porpoises, in which encounters are in open water (or haul-outs in the case of seals) with individuals or small groups with a relatively even proportion of adults, juveniles and infants, resource depression will cause a *decrease* in the mean and maximum age of individuals over time as more and more animals are captured before fulfilling their complete reproductive potential (Caughley 1977). Less intra-species competition for resources and an increased recruitment rate of younger individuals will be reflected in captured prey and therefore their skeletal remains in faunal assemblages as well. In the situation of taxa that use rookeries, where most otariid seals and sea-lions are assumed to be encountered, the opposite is predicted to occur. Selective targeting of younger individuals will cause an *increase* in the mean and maximum ages of prey captured and their skeletal remains.

Other measures used by resource depression models examine the butchery and transport of individual high-ranking prey items over time. The ways in which hunter-gatherers go about processing and transporting a carcass from a kill site to a central place can be predicted in terms similar to prediction of prey and patch use. These choices have been conceptualized elsewhere in terms of optimal foraging across carcasses based on the utility of certain portions in terms of meat and other useful components such as bone marrow and grease (e.g., Bettinger 1991a; Binford 1978, 1981; Grayson 1989). Consistent with the central place foraging model of Orians and Pearson (1979), the resource depression model predicts field processing of carcasses will be greatly affected by the costs involved in transporting prey back to a central place in such a way that maximizes net energetic returns. This processing involves removing lower-utility portions of the carcass at the site of the kill before transport. Capture of prey close to a central place will entail relatively lower transport costs resulting in less selectivity of the parts of the carcass brought back to the central place. In general, greater distances entail higher transport costs, resulting in more intensive field processing of carcasses and selectivity towards higher-utility parts of the carcasses for transport back to the central place (Metcalfe and Barlow 1992).

Other Considerations

Technological innovations may affect the efficiency with which foragers harvest certain resources. Energetic returns of some prey types may be dependent upon prey density, in which prey rank for a particular prey species changes depending upon how many individuals are caught in a single foraging bout (Madsen and Schmitt 1998; Madsen et al. 1998). Mass harvesting technology increases the profitability of taxa such as anadromous or schooling fish, resulting in an increase of their rank when compared to larger-bodied prey. An obvious example of this is the weir and net fishing technologies developed on the north Pacific coast to exploit salmon runs. Another type of technology, storage and food preservation innovations such as drying racks, allow the surplus acquired from mass-harvesting to be used throughout the year (Schalk 1977; Testart 1982). Intensification, *sensu* Beaton (1991), implies a decrease in foraging efficiency relative to earlier foraging efforts. Therefore, the development of technology that would increase the profitability of certain resources does not imply intensification but rather the opposite. The development of such technology must be controlled for in testing any resource depression model used to explain how changes in prey selection may co-vary with foraging efficiency.

Finally, even if the predictions of the resource depression model are met in a particular situation, other explanations such as climate change may account for decreasing foraging efficiency or changes in the age structures of prey species. Changes in climate and habitat may affect prey populations in such a way that lowers their abundance and encounter rates with human foragers. This would result in foraging decisions analogous to a resource depression situation, but not caused by the hunting and gathering activities of those foragers. Because of this potential conflation, use of the resource depression model requires comparison of changes in foraging efficiency and prey population age structures with climatic fluctuations in the prey environment on as many scales as possible.

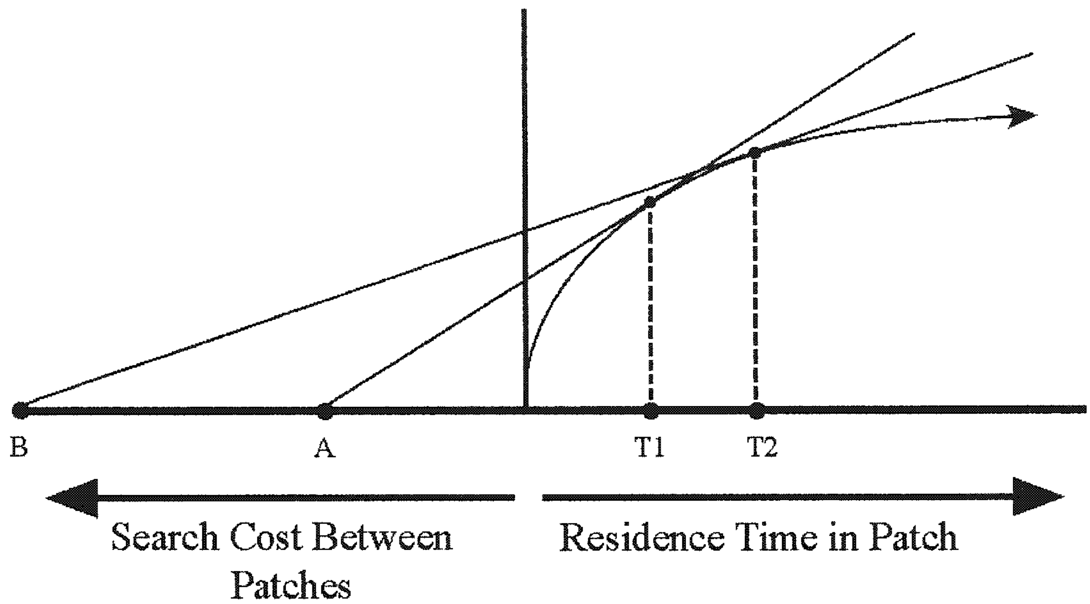


Fig. 2.1 Marginal Value Theorem (adapted from Kaplan and Hill 1992:181)

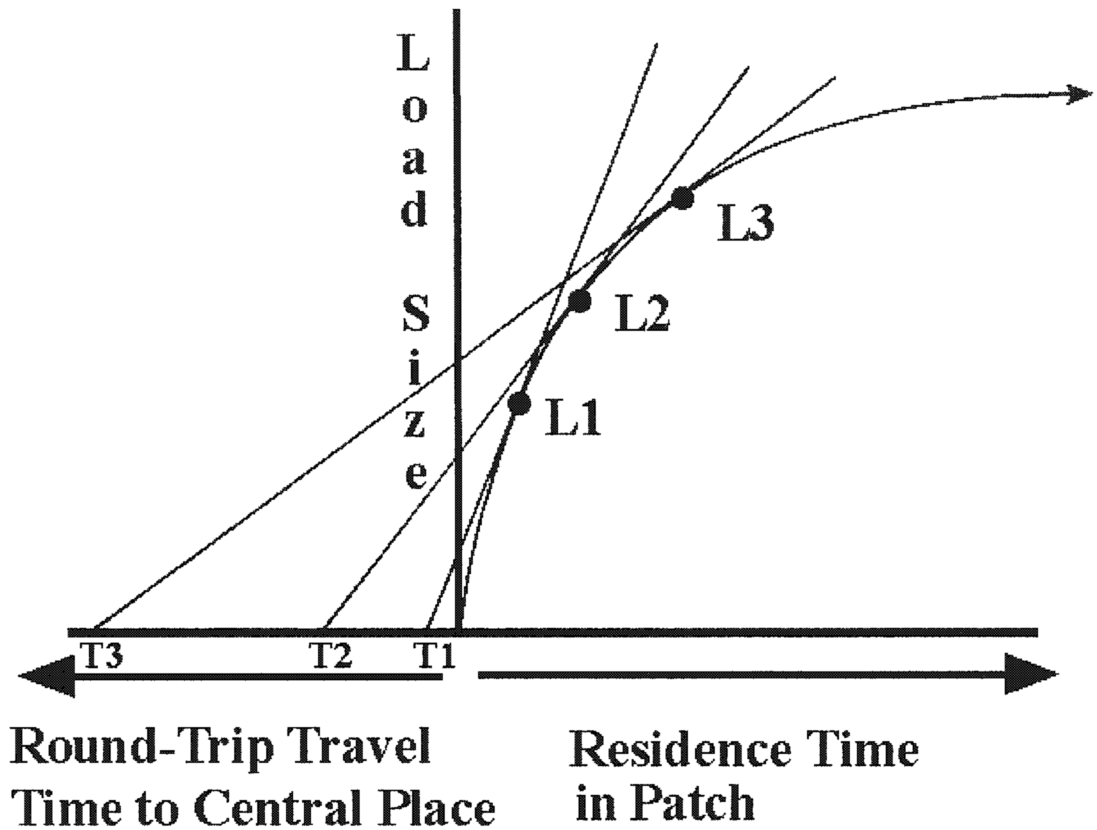


Fig. 2.2 Optimal Load Size Compared to Travel Costs
(adapted from Orians and Pearson 1979:163)

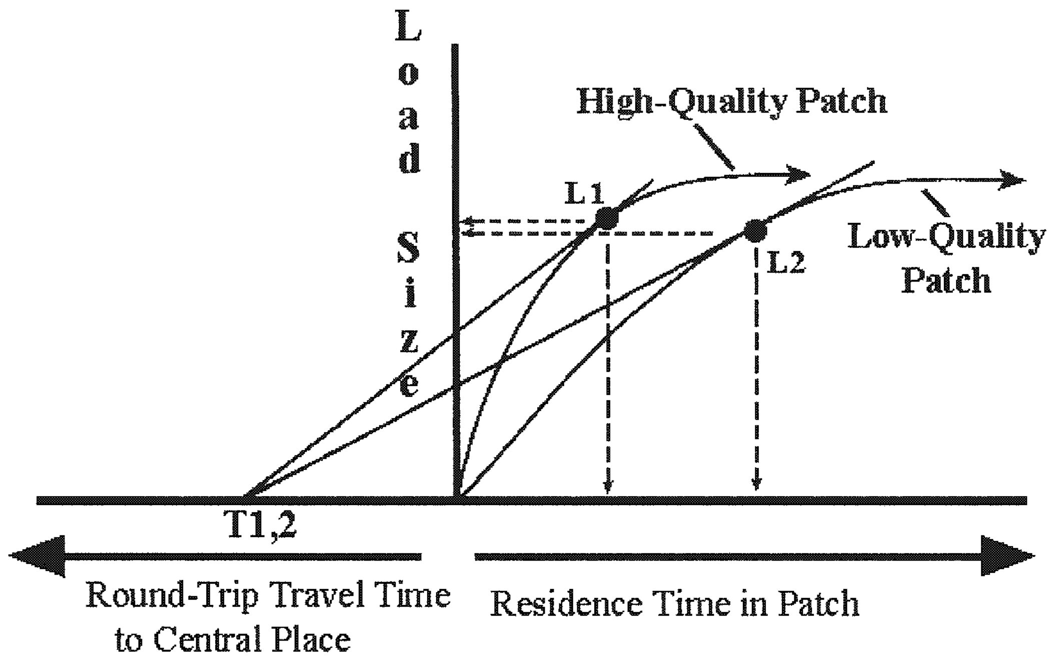


Fig. 2.3 Optimal Load Size and Residence Time Compared to Patch Quality (adapted from Orians and Pearson 1979:163)

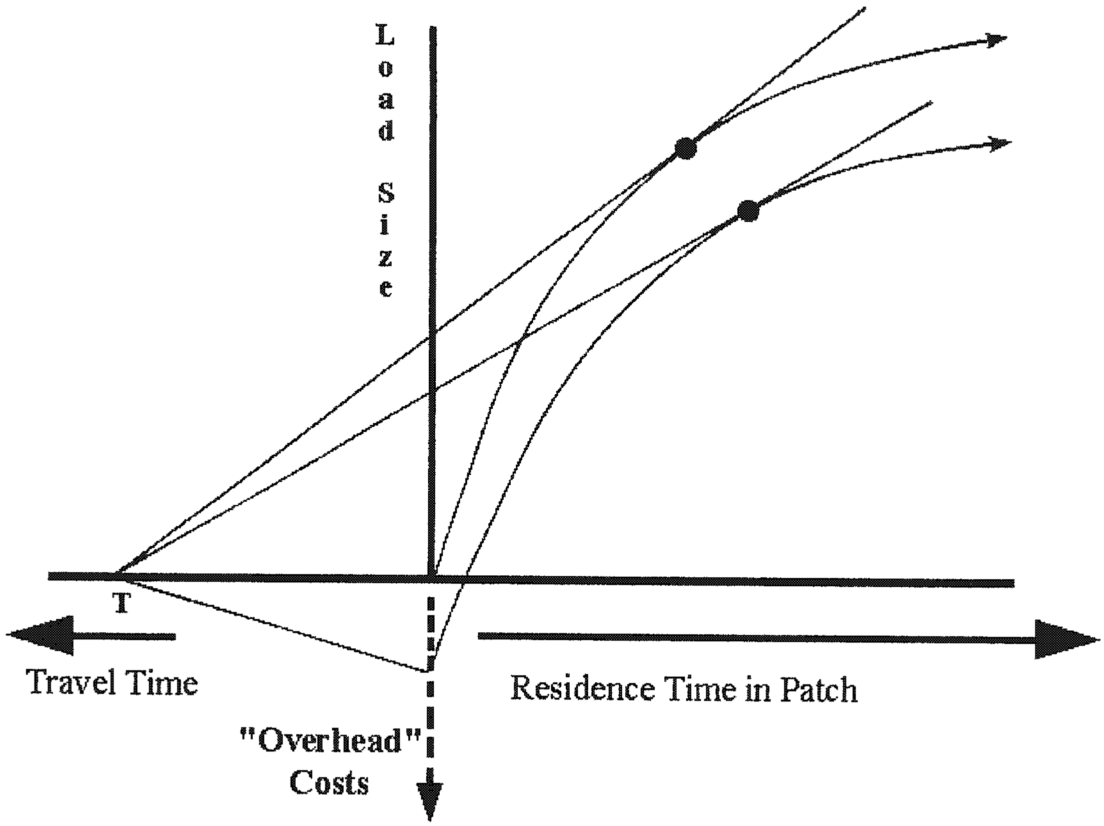


Fig. 2.4 Optimal Load Size and Residence Time Incorporating Travel and Search Costs (adapted from Orians and Pearson 1979:164)

Chapter 3:

Testing the Resource Depression Model - Hypotheses and Expectations

The Kodiak archipelago provides an ideal setting to investigate the role of resource intensification in the development of prehistoric cultural complexity and possible explanations for how this intensification might arise. This chapter first describes the Kodiak archipelago in terms of its natural environment, and then establishes several hypotheses about resource intensification, resource depression, and the role of intensification as a causal agent of cultural complexity. The means of testing these hypotheses are discussed in turn.

The Kodiak Archipelago Environment

Physical Environment

Kodiak is a product of the long-term action of plate tectonics on a continental scale, and short-term localized tectonic activity resulting in an archipelago consisting of several large islands and numerous small islets and sea stacks. The larger islands include Kodiak, Afognak, Raspberry, Sitkalidak, Shuyak, Marmot, Spruce, Tugidak, and Sitkinak Islands, which comprise most of the roughly 13,000 square kilometer land area of the archipelago. The subduction of the Pacific plate underneath the North American plate along the Aleutian trench has brought together several terranes, forming the archipelago (Jacob 1986). Seismic activity along the length of the Aleutian trench from ongoing subduction has further pushed, pulled, elevated and dropped the landscape of Kodiak. The steep terrain, rocky coasts and numerous indented bays that characterize the archipelago are a result of this action as well as scouring from Pleistocene glaciation (Karlstrom and Ball 1969). These varied environments provide numerous animal habitats.

South-central Gulf of Alaska is characterized by stormy, wet and relatively temperate weather that creates a lush environment along the length of its coast. Two semi-permanent weather systems provide the Kodiak archipelago with significant precipitation, usually in the form of rain. The Aleutian low pressure system is centered close to Kodiak during the winter months, while the east Pacific high pressure system is centered farther south into the Gulf of Alaska. The resulting influence of these systems is reliable precipitation and moderate temperatures year-round, with winter temperatures at sea level only occasionally dropping below 0° Celsius long enough to freeze fresh water or the heads of bays (Wilson and Overland 1986). The maritime weather and long daylight hours during the spring and summer allow thick vegetation growth near sea level and along river drainages.

Vegetation

Most of the archipelago's vegetation can be characterized as tundra, lacking tree species and dominated by grasses, sedges, and moss and is found in both upland locations and closer to sea level in moist, poorly-drained areas (Viereck et al. 1992). The high-brush ecosystem is also common on the archipelago, usually consisting of low grasses and ferns amid thickets of alder (*Alnus* spp.), willow (*Salix* spp.), salmonberry (*Rubus spectabilis*) and devil's club (*Oplopanax horridus*). This ecosystem occurs in transitional areas between beach and forest, beach and tundra, and forests and upland tundra (Viereck and Little 1994). A third major vegetation type in the archipelago is the coastal Sitka spruce/hemlock forest. This type is found primarily on the islands north of Kodiak, including Afognak, Spruce, Marmot and Shuyak Islands, as well as lowland drainages and flat areas along the northern margin of Kodiak Island. Within the archipelago, this forest type consists of Sitka spruce (*Picea sitchensis*) as the only large tree species, accompanied by alders, willow, devil's club and abundant berries and ferns.

Although vegetation similar in composition to that of the modern tundra community probably established itself on the archipelago shortly after retreat of glaciers at the end of the Holocene from Beringia and possibly refugia within glaciated regions on Kodiak (Heusser 1983; Hopkins and Smith 1981; Nelson and Jordan 1986), the forest ecosystem is a relative newcomer. Pollen evidence suggests that white spruce (*Picea glauca*) spread as close to the archipelago as Cook Inlet to the north by about 8000 B.P. (Anderson and Brubaker 1993). However, Sitka spruce appears to have spread from southeast coastal Alaska as the pioneering tree species of the coastal rainforest and reached the archipelago only within the past 1000 years (Griggs 1934; Tennessen 2000). If this is the case, then the Alutiit would have had to rely on driftwood as a source of fuel, large structural timber and raw material for wooden objects until the middle of the Koniag period (Deo 2003).

Terrestrial Mammals

Despite a lack of trees, the tundra and high-brush ecosystems provide food for several native terrestrial mammal species, as well as an important nutritional component for Alutiiq subsistence. Six mammal species are generally agreed to have inhabited Kodiak Island prior to Russian colonization: brown bear (*Ursus arctos*), red fox (*Vulpes vulpes*), northern river otter (*Lontra canadensis*), ermine (*Mustela erminea),* tundra vole (*Microtus oeconomus*) and the little brown bat (*Myotis lucifugus*) (Rausch 1969; USFWS 1987) (Table 3.1). The low mammalian species richness can be attributed to island biogeography, since very similar ecosystems on mainland Alaska host a much greater diversity of mammalian fauna (Murie 1959; Rausch 1969). The Alutiit made use of several terrestrial mammal species for food and clothing. Brown bear, red fox, and river otter remains have been found in prehistoric faunal assemblages (e.g., Clark 1974a, 1997; Partlow 2000; Yesner 1989) and were recorded ethnohistorically as sources of both meat and raw material (e.g., Davydov 1977; Holmberg 1985). The ermine is found occasionally in prehistoric sites but is well-documented in ethnohistoric observations to have been used for its fur in parka construction (Crowell and Laktonen 2001). Tundra voles are found in faunal assemblages as well but were probably intrusive inhabitants of archaeological sites.

Although all of these species can be found today throughout the archipelago, it is the brown bear, red fox and northern river otter that offer significant energetic returns from hunting on land. The brown bear is one of the largest North American land mammals by weight, upwards of 700 kg, and is usually encountered as a solitary male or a mother with cubs. Foxes and northern land otters also tend to be encountered individually or in small family groups and were a source of furs during Russian colonization (Khlebnikov 1994). I assume in this dissertation that the costs associated with travel across tundra and steep topography, as well as the danger involved in putting one's self above a brown bear in the food chain, make the hunting of mammals on land for food a relatively low-profit activity.

Other mammal species have been introduced to the archipelago by humans at various times. To offset the paucity of terrestrial game and furbearers, Russian and Euroamerican colonists introduced mule deer, reindeer (caribou), elk, mountain goat and American beaver, while red squirrel, muskrat, snowshoe hare and possibly arctic ground squirrel represent recent unintentional introductions (USFWS 1987). Additionally, domesticated dogs have accompanied the Alutiit for thousands of years, inferred from their presence in archaeofaunal assemblages dating back to the Ocean Bay period (Allen 1939; Haag 1948; Hausler-Knecht 1991; Heizer 1956). Although domesticatd dogs could have provided a food source for the Alutiit, ethnohistoric observations across Pacific coastal Alaska make no mention of this practice (e.g., Davydov 1977; Holmberg 1985; Khlebnikov 1994; Veniaminov 1984). If future analyses of prehistoric faunal assemblages from Kodiak yield large numbers of dog bones indicating butchery and possible consumption by humans, then the dietary options of people living at that time might be different enough to warrant their inclusion into subsistence models.

Marine Mammals

The marine habitats surrounding the islands of the Kodiak archipelago provide a very different and varied suite of faunal resources than the terrestrial habitats found inland (Table 3.1). Marine mammals are commonly encountered as individuals or in aggregations along most every stretch of beach and rocky coast of the archipelago (NOAA 1997), and the abundance of their remains found in the earliest faunal assemblages in the area suggest that this has been the case for many millennia (e.g., Clark 1984a; Hausler-Knecht 1991). The relatively large body size of sea mammals, which offer hide, bone, sinew and gut as raw material in addition to meat and blubber, makes them attractive prey within an attractive patch type that also provides abundant marine fish resources.

Given hunting technology developed specifically for capturing sea mammals and the means of transportation to reach them (see below), sea mammal habitats were sought out. Ethnographic observations of Alutiiq subsistence attests to the historical importance of the Steller sea lion (*Eumetopius jubatus*) and harbor seal (*Phoca vitulina*) hunts throughout the year with the exception of late spring and summer, when commercial salmon harvesting takes place. With the introduction of purse seiners in the early 20th century, hunting excursions occurring during fishing trips could provide much larger loads of sea lion and seal meat, making them the most widely shared subsistence food in Alutiiq villages (Mishler 2001:163-164).

The otariid family of eared seals is represented in the archipelago by two species, the Steller sea lion and the northern fur seal. The Steller sea lion is the largest pinniped inhabiting the Kodiak archipelago, averaging 680 kg for adult males and 270 kg for adult females, with some males attaining weights of almost 1100 kg (Reeves et al. 2002; Wynne 1997). They commonly aggregate year-round at haul-outs on rocky points of land and offshore sea stacks and islands scattered across the archipelago, except during late summer when they congregate at rookeries on Marmot, Chirikof, and Barren Islands (NOAA 1997). The northern fur seal averages about one-third the weight of the Steller sea lion and today is only found migrating through the area en route to and from rookeries on the Pribilof Islands in the Bering Sea and the Commander and Bogoslof Islands along the Aleutian chain (Reeves et al. 2002). Unlike Steller sea lions, which are found in both the archaeological and ethnographic record on Kodiak, northern fur seals appear archaeologically in the southeastern portion of the archipelago (Clark 1974a, 1986) but are not known to have been hunted historically by the Alutiit.

The change in archaeological visibility of otariid seals may be due to shifts in the distribution of their rookeries and therefore their availability to human residents of the north Pacific coast. Historic commercial hunting of northern fur seals, for example, has drastically altered their migration and breeding habits to the extent of obscuring their prehistoric distribution across the north Pacific (Etnier 2002). Debate between Lyman (1989, 1991, 1995) and Hildebrandt and Jones (1992, 2002; see also Jones and Hildebrandt 1995) highlights the behavioral complexity of these species of pinnipeds and the implications that their behaviors have on their availability to hunter-gatherers and the technology required to successfully harvest them.

Harbor seals are the single species of “earless”seals (Family Phocidae) that inhabit the waters surrounding Kodiak today. They are commonly found individually or in small groups in bays or hauled out on isolated beaches year-round across the archipelago (NOAA 1997). Much smaller than sea lions, adult harbor seals are also not as sexually dimorphic in terms of body size. Adult weights average about 115 kg (Wynne 1997). Like sea lions, they have been a focus of Alutiiq subsistence ethnohistorically (e.g., Davydov 1977, Holmberg 1985) and in the present (Mishler 2001), and are common archaeologically as well (Clark 1984a). Historically, the same tools and techniques have been used to hunt both sea lions and harbor seals, and frequently a planned hunt for one species winds up including the other as well (Mishler 2001).

Sea otter (*Enhydra lutris*) are small (adults weigh about 30 kg) marine mammals that live in many of the near-shore habitats of the archipelago, and were popular targets of hunting both prehistorically and historically. They were hunted to near extinction by Russian-led hunting parties and subsequent American exploitation for their extremely valuable pelts, whose fur is the densest of any other mammal (Wynne 1997). Although the Alutiit today do not hunt sea otter for either food or fur (Mishler 2001; Teakon Simeonoff, personal communication 1997), there is some archaeological evidence that they were targeted heavily during the Ocean Bay period (Hausler-Knecht 1991).

Two species of porpoise, harbor (*Phocoena phocoena*) and Dall’s (*Phoecoenoides dalli*), inhabit the archipelago year-round in small groups, although

Dall's porpoises tend to prefer deeper water while harbor porpoises frequent shallower near-shore habitats (Reeves et al. 2002). Dall's porpoise on average weigh about 140 kg while harbor porpoises average about half that weight (Wynne 1997). Both were hunted by the Alutiit historically (e.g., Davydov 1977:225) and prehistorically (Clark 1974a, 1997). The Pacific whitesided dolphin (*Lagenorhynchus obliquidens*) is also found seasonally in offshore waters above the continental shelf (Wynne 1997) and occasionally in deep channels near the archipelago (Reeves et al. 2002).

Whale utilization by the Alutiit has been the subject of much study. Seven species of baleen whale and five species of toothed cetaceans larger than porpoises, ranging from the 1200 kg Stejneger's beaked whale (*Mesoplodon stejnegeri*) to the 90,000 kg blue whale (*Balaenoptera musculus*), have been recorded in the vicinity of Kodiak archipelago (Reeves et al. 2002; Wynne 1997). Some of these species are frequently observed from beaches in shallow water or occasionally found as beached carcasses. Cetacean remains are found in some of the earliest known faunal assemblages from the archipelago, dating to the Ocean Bay period (Hausler-Knecht 1991). However, whether these remains represent hunted or scavenged whales is not clear, since their sporadic appearance, frequently in the form of modified artifacts, indicated that butchering took place away from shell midden sites (Mason and Gerlach 1995; Yarborough 1995). Although watercraft were necessary for colonization of the archipelago, and ground bone and slate tool technology allowing efficient hunting of sea mammals was in place during the Ocean Bay period

(Fitzhugh 2001), large harpoon heads and blade inserts that are inferred as whaling equipment do not appear archaeologically until the Koniag period. Crowell (1994; see also Heizer 1943) asserts that this coincided with the development of aconite poison dart hunting techniques.

Although utilization of at least scavenged whale carcasses has been occurring for millennia along the north Pacific coast, many archaeologists propose that a focused whale-hunting economy developed relatively recently in conjunction with the fluorescence of cultural complexity, in which the symbolic and economic benefits of successful whale hunts outweighed the labor costs and bodily risks involved in these pursuits (Fitzhugh 2001; Whitridge 1999; Yarborough 1995; Yarborough and Yarborough 1998). Modifications and butchery marks on the remains of whales, when found in substantial number, further indicate complex butchery and utilization patterns (Monks 2001). Faunal analysis of Crag Point, a Kachemak-period site on Kodiak Island described in greater detail later in this dissertation, yielded the spinous process of a large whale vertebra in which the tip of a ground slate projectile point was embedded (Figures 3.1-3.3). Charcoal samples associated with this specimen date to 2000 radiocarbon years B.P., which suggest the possibility of whale hunting much earlier than the Koniag period.

Fish

Upwelling and distribution of nutrients in the Gulf of Alaska by currents and storms supports abundant and diverse fish populations that have fed humans on the north Pacific coast for thousands of years. Native Americans have utilized these fish in marine and riverine settings, both providing different opportunities and challenges in terms of their harvest. Fishing for marine species in the open ocean, and even protected bays, has the potential of yielding very large individual fish, but also entails the risks of maritime travel and limited cargo potential of boats. Harvesting anadromous fish along the banks and at the mouths of rivers allows concentrated effort on aggregations of individual fish that can be taken en masse with the proper technology, although the availability of these species is usually quite seasonally restricted. Also, the labor costs involved in catching, processing, and possibly storing large volumes of anadromous fish is quite high compared to long-line fishing of marine species, which was the common fishing method by the Alutiit to catch cod, halibut, and other marine fish before the advent of modern commercial net fishing (Mishler 2001).

Table 3.2 lists the species of fish that inhabit the waters surrounding the Kodiak archipelago today. Marine species that have been economically important to the Alutiit historically also appear in great abundance in archaeological sites. These include large-bodied fish such as Pacific cod (*Gadus macrocephalus*), ling cod (*Ophiodon elongatus*), halibut and other flatfish (Order Pleuronectiformes), and rockfish (Family Scorpaenidae), as well as much smaller-bodied Pacific herring (*Clupea harengus pallasi*). Archaeological assemblages indicate prehistoric use of sculpins (Family Cottidae) and smaller greenlings (Family Hexagrammidae) as well (Partlow 2000). Some species, such as halibut, tend to move further offshore during winter and some species such as herring are concentrated in shallow bays to spawn in the spring. Populations of Pacific cod in the northeast Pacific spawn in waters of about 120 meters in depth in the winter before returning to shallower depths averaging about 70 meters in the summer months (Ketchen 1961). These spawning and feeding areas overlap to a large extent off the coast of the Kodiak archipelago (OCSEAP 1986). In general, the availability of marine fish today as a broad prey type in near-shore marine habitats of the Kodiak archipelago is consistent year-round (Kramer and O'Connell 1995; Kramer et al. 1995; Mecklenburg et al. 2002; OCSEAP 1986; Rogers et al. 1986).

Upon their return to the spawning streams from which they came, Pacific salmon, trout and char (Family Salmonidae) briefly cohabitate in the archipelago's bays and estuaries with marine fish before migrating upriver. Although this is the prime time and location for the commercial harvest of salmon (Mishler 2001; Roppel 1986), historic observations shortly after Russian colonization reflect a riverine orientation for Alutiiq salmon fishing (Davydov 1977:231-232; Holmberg 1985:46). Prehistoric expansion of Alutiiq settlement up the Karluk River, for example, indicates a gradual focus on salmon from rivers (Jordan and Knecht 1988). Even earlier settlement along the upper banks of the Buskin River near its source at Buskin Lake appears connected to salmon harvesting as well (Saltonstall et al. 2001). Historically, salmon runs on the Kodiak archipelago generally begin each year with runs of Chinook salmon (*O. tshawytscha*) up the largest streams in the late spring, followed by summer runs of pink (*O. gorbuscha*) and chum (*O. keta*) salmon up most rivers and streams and sockeye salmon (*O. nerka*) up rivers with lake systems. Coho salmon (*O. kisutch*) migrate up Kodiak rivers in late summer through fall (Roppell 1986). Steelhead trout (*O. mykiss*) and smaller dolly varden char (*S. malma*) can sometimes be found in larger streams at other times of the year (Mecklenburg et al. 2002).

Marine and Riverine Resource Patches

For the purpose of this dissertation, I conceptualize the economically important habitats of Kodiak Island in terms of two general resource patches, near-shore marine and riverine. Although terrestrial habitats away from rivers and streams were undoubtedly used for plant collecting and travel, they are not considered for the resource depression model because they would provide only sporadic encounters with bear, fox, and voles. Likewise, the off-shore marine environment was used by the Alutiit as a source of large cetaceans (and possibly smaller sea mammals and fish, too) and as a thoroughfare for travel as far away as the Aleutian Islands and southeast Alaska. As I discussed in Chapter 2, however, body size as a proxy of net energetic returns and prey rank extends only so far before the cost involved in transporting and processing very large animals such as whales begins to seriously compromise net energetic returns and prey ranking from a caloric perspective. The economic utility of whale hunting in the open ocean is further clouded by the lack of whale remains in archaeological sites in the Kodiak archipelago and the uncertainty regarding hunting and scavenging of whale from the remains that are present. Therefore, this resource depression model only considers the near-shore marine and riverine resource patches. Also, this model only considers a few of many subsistence choices within these two patches. Birds and shellfish were a large component of the Alutiiq diet since Ocean Bay times (Hausler-Knecht 1993; Partlow 2000) but are not incorporated in this particular resource depression model.

Marine habitats in the near-shore resource patch include rocky reefs, sea stacks, bays and open water accessible by boat, as well as beach habitats that offer smaller-bodied and less diverse fish and sea mammals that might not require watercraft for access. Marine fish and sea mammal species would be searched for in these habitats, and sea mammals pursued upon encounter. Given the seasonal movements of some sea mammal species and their much lower abundance than fish, hunting and fishing trips from a central occupation site are expected to frequently result in marine fishing, sometimes to the exclusion of sea mammal hunting if none are encountered.

Riverine habitats are exploited from the banks and at the mouths of streams. The concentration of water runoff, and nutrients from spawned-out salmon carcasses, allows thick vegetation growth near streams. This vegetation and the seasonal presence of salmon in turn often attract terrestrial mammals (and raptors) to the immediate vicinity. When salmon are present, however, they would offer the greatest net energetic returns to human hunter-gatherers. Fishing for salmon in this patch may offer an opportunity to hunt land mammals and collect plants as well.

Resource Depression on Kodiak Island

The resource depression model predicts that initial human populations on Kodiak Island focused on resource patches that offered the highest energetic returns for a given technology, with an underlying assumption that population growth and density increased throughout the period of time being examined. Marine resource patches were utilized when sea mammals and large fish were available, using hunting and fishing technology widespread along the north Pacific coast that was aimed at procurement of individual animals (McCartney et al. 1998). Encounter rates with sea mammals and larger marine fish began to decrease from greater harvesting pressure by a growing human population (Charnov 1976; Charnov et al. 1976; Hamilton and Watt 1970). These conditions, an island containing a low population density of hunter-gatherers harvesting sea mammals and fish as well as some riverine resources, corresponds to the Ocean Bay I and II phases on the Kodiak archipelago.

As harvesting pressure and crowding of habitats by humans caused decreasing encounter rates with sea mammals, optimal resource patch-use would shift from nearby sea mammal haul-outs and rookeries to more frequent use of lower-return, higher-cost resource patches such as salmon streams and inland habitats, as well as more distant near-shore sea mammal habitats (Erlandson et al. 1992; Fitzhugh 1996, 2003). Demographic evidence indicating dense human settlement along most all coasts and in diverse habitats of the archipelago first appears in the Late Kachemak phase in the form of clusters of house pits found along many beaches, the mouths of streams, and smaller numbers of house pits inland at the confluences of lakes and streams (Saltonstall et al. 2001). The demographic characteristics of the living communities of high-ranked prey types, and eventually lower-ranked prey types, should reflect depression. In particular, amongst taxa acquired at rookeries where young individuals could be targeted most easily, mean and maximum ages of individuals in the population should have increased over time. Amongst taxa that do not create rookeries, such as sea otters and porpoises as well as fish communities, ages of individuals should have decreased over time. These phenomena should be apparent in the age structure of archaeological faunal assemblages.

Without a change in technology for harvesting salmon that decreased their cost relative to harvesting sea mammals, the body-size proxy for energetic returns suggests that salmon will not increase in proportion in the diet until encounter rates with sea mammals decrease. However, because of their abundance, once added to the diet they would become a very important part of it rather quickly (see Winterhalder and Goland 1997). The development of mass-harvesting technology that further lowers the procurement and processing costs of salmon fishing would increase their importance in the diet even further (Fitzhugh 2001, 2003:115). The first evidence of fishing nets on Kodiak Island is indirect, in the form of notched and grooved stones that initially appear during the Early Kachemak phase. Many archaeologists infer their function as net weights or single line weights. Additional examination of the role of technological change and how this may have affected energetic returns will be discussed below.

If resource intensification occurred and played some causal role in the development of cultural complexity as has been asserted in the models described in Chapter 1, then indications of intensification would appear in the archaeological record at specific times based upon prior social and ecological conditions established in those models. Specifically, Fitzhugh's (1996, 2003) model of the evolution of cultural complexity predicts that *labor intensification*, or a decline in foraging efficiency, will occur when the growing human population density of Kodiak reaches a point in which circumscription of hunting and fishing territories occurs, concurrent with resource depression of high-ranked prey. The shift in subsistence focus towards prey entailing additional energetic costs for capture or processing corresponds with the Ocean Bay II phase. *Technological intensification*, in this case the innovation of mass-harvesting and storage technology that allows more efficient utilization of fish, is predicted to occur when the increasing costs of reduced foraging efficiency, i.e. labor intensification, outweigh the risks of innovation (Fitzhugh 2001).

Technological intensification is predicted to occur during the Kachemak period, and creates demographic and social conditions that foster emergent cultural complexity as greater differentiation of social groups becomes an economic necessity. Further evolution of cultural complexity, in terms of social inequality, is predicted to occur during the Koniag period as competition over certain resources such as salmon runs results in a social climate encouraging both prestige-seeking behavior and tolerated subordination, depending upon individual access to resources.

As described in the previous chapter, this dissertation uses the basic models of optimal foraging theory to test the hypothesis that resource depression and intensification occurred, detailed above. Intensification in this sense corresponds to Fitzhugh's labor intensification, and it is this kind of intensification that I evaluate in the context of his model. This dissertation is not the place to test any models of cultural complexity, but instead to see specifically how one cultural complexity model developed for the same region relates to a more rigorous investigation of resource intensification that uses faunal data reflecting changes in subsistence behavior across several thousand years on the Kodiak archipelago.

Hypotheses

Derived from the resource depression model discussed in Chapter 2 and the environmental setting and cultural complexity model described above, the following hypotheses are tested using archaeofaunal data from the Kodiak archipelago. Table 3.3 presents a summary of the hypotheses with the measures used to test them and the expected outcome of those tests.

(1) If resource intensification of low-return prey occurred, then a greater proportion of these animals would enter the diet of hunter-gatherers on Kodiak relative to higher-ranked, more profitable prey.

(2) If resource depression of high-ranked prey occurred, then reduced encounters would cause foragers to travel farther from settlements for access, butcher captured individuals more intensively, and negatively impact prey population structures.

(3) If resource intensification occurred and played a causal role in the development of cultural complexity as conceptualized in Fitzhugh's model (2003), then foraging efficiency will decrease as human population density on the archipelago increases and encounters with high-ranked prey decrease. The decrease in foraging efficiency will occur prior to the development of either mass-harvesting technology and evidence of sociocultural complexity.

The implications of each of these hypotheses are discussed in turn below.

Archaeological Expectations – Intensification and Taxonomic Abundance

The relative abundances of certain taxa found in faunal assemblages offer a means of empirically testing the hypothesis that resource intensification occurred on the Kodiak archipelago. An index similar to the artiodactyl indices used by Broughton (e.g., 1994b) for San Francisco Bay and Cannon (2001) for southwestern New Mexico will be used to measure changes in the proportions of large-bodied, high-return taxa within and between archaeological sites, which may hypothetically reflect changes in foraging efficiency. Instead of an artiodactyl index that measures the proportion of artiodactyls to smaller-bodied fauna, indices are needed that measure foraging efficiency of hunter-gatherers adapted to the environment of Kodiak.

I have created a sea mammal index that measures foraging efficiency in the near-shore marine patch, where sea mammals are the most profitable prey option compared with marine fish. The sea mammals and fish that inhabit the rocky near-shore coasts of the Kodiak archipelago were most likely taken individually by the Alutiit using harpoons, bayonets, and long-line fishing techniques (Davydov 1977; Holmberg 1985). Despite the great sizes occasionally attained by halibut, the large difference in body size between sea mammals and marine fish (Tables 3.1 and 3.2), their inferred individual collection, and the additional non-caloric value of sea mammals for their skin and bone as raw materials for manufacture of clothing, boat covering, and tools, make the two prey types ideal for use in a marine foraging efficiency index. The number of identified specimens (NISP) of sea mammals from a particular assemblage is divided by the number of sea mammal and marine fish specimens combined:

$$\frac{\sum \text{Sea mammal NISP}}{\sum (\text{Sea mammal NISP} + \text{Marine fish NISP})}$$

Values approaching 1.0 reflect high frequencies of sea mammals compared to marine fish and are interpreted as indicating a relatively more efficient diet than lower values.

Similarly, I have created an index to measure foraging efficiency in riverine patches that were exploited with greater regularity as human population grew and encounter rates with high-ranking marine resources would have decreased. Ethnographic accounts of mass-capture of salmon using nets and weirs are abundant from California to the mouth of the Yukon River (Damas 1984; Kroeber and Barrett 1960; Suttles 1990) and archaeological evidence supports the notion of mass-capture of salmon along rivers for the past few thousand years (Jordan and Knecht 1988; Knecht 1995; Moss et al. 1990; Saltonstall et al. 2001; Saltonstall and Steffian 2002). The land adjacent to salmon-bearing rivers and lakes provided other mammalian resources such as foxes, which would offer a much lower net energetic return than salmon during their spring, summer and fall runs, but were still probably utilized for food (Amorosi 1987; Clark 1984b; Yesner 1989). If salmon are considered the highest-ranked resource in such settings, with or without mass-harvesting tools, and foxes are considered lower-ranking, a salmon index is as follows:

$$\frac{\sum \text{Salmonid NISP}}{\sum (\text{Salmonid} + \text{Fox NISP})}$$

Following the patch choice model, I have created an index that measures foraging efficiency between sets of discrete resource patches as well. The resource depression model predicts that near-shore marine resource patches such as sea mammal haul-outs and rookeries would have provided the highest energetic returns given the amount of energy expended and would have been utilized most intensively by foragers operating from a site located centrally to this and other resource patches. The seasonal nature of most food resources around the Kodiak archipelago requires patches such as salmon streams to be exploited on a more limited basis throughout the year even though they may provide relatively high returns at certain times. As encounter rates with high-ranking prey in the high-ranked marine resource patches declined, more time would be spent making use of lower-ranked riverine patches nearby. An index that compares the proportion of remains of high-ranked prey from near-shore marine patches to those from riverine patches will offer a measure of foraging efficiency between resource patch types that can be compared within and between faunal assemblages:

$$\frac{\sum \text{Sea mammal NISP}}{\sum (\text{Sea mammal NISP} + \text{Salmon NISP})}$$

I predict that this index will decline as net energetic returns from foraging within marine resource patches decreases.

The intensification hypothesis used in this dissertation postulates a decrease in prehistoric foraging efficiency. Controlling for certain factors and assuming faunal assemblages represent similar site functions, seasonal occupations and ecological contexts, these indices reflect foraging efficiency and can be compared over time as Broughton (e.g., 1995, 1997), Butler (2000, 2001) and Cannon (2001) have done to demonstrate resource intensification. Therefore, in locations where sea mammals were the most profitable prey option, I expect the sea mammal index to decrease over time, reflecting a shift within marine resource patches to smaller-bodied taxa such as cod, rockfish, sculpin, and flatfish. Additionally, less-profitable patches such as salmon streams (given consistent harvesting technology over time) will be exploited more frequently, increasing the abundance of salmon over sea mammals. In riverine patches, intensification led to the inclusion into the diet of a greater proportion of non-salmonid resource such as foxes, which would lower the salmonid index. The results of these tests are the subject of Chapter 5.

Archaeological Expectations – Resource Depression

Relative Skeletal Abundance

Depletion of high-ranked taxa in nearby patches may cause a shift not only towards intensified use of lower-ranked prey within those resource patches (e.g., a shift from sea mammals towards marine fish in near-shore patches) and nearby lower-ranked patches (e.g., an increased focus on nearby salmon streams), but also a shift to more distant high-ranked patches that have not undergone resource depression. Therefore, a shift to more distant patches would not necessarily cause an apparent decline in the abundances of high-ranked taxa in faunal assemblages, but may instead hold steady or exhibit an *increase* in the relative abundances of such taxa (Broughton 1995, 2002a; Cannon 2003). However, transport costs of large mammals will increase with greater use of distant patches.

Efforts to reduce transportation costs, such as greater field processing of carcasses and consumption of lower-utility body parts at kill sites instead of central-place settlements is expected as distances to those settlements from kill sites increase (Broughton 1995, 2002a; Metcalfe and Barlow 1992; Nagaoka 2002; O'Connell et al. 1988, 1990). Archaeologically, a decrease in the frequencies of skeletal elements from lower-utility body parts is expected at central place archaeological sites over time as nearby patches are depleted and hunters move farther afield. These lower-ranked body parts include flippers and crania of sea mammals (e.g., Diab 1998; Lyman et al. 1992; Savelle et al. 1996; Savelle and Friesen 1996). I predict that the mean utility of body parts of a particular species in an assemblage, represented by utility values given in published indices applied to the minimum number of elements (MNE) for the species, will decrease over time if transport costs, and presumably distance traveled by hunters, increase.

Travel to distant resource patches, especially those that provide profitable prey or other resources, may not be a viable option on an island with a growing human population increasingly inclined to defend these patches. Circumscription can be counteracted by several means: settling for less-desirable prey or patches, attempting to forcibly access a defended patch, or engaging in trade to meet subsistence needs. By using meat utility as an ordinal proxy measure of distance traveled by hunters, I cannot address here the possibility that some carcass parts found archaeologically were obtained by trade. Also, I cannot infer distances to patches or whether or not those carcasses were from animals procured at contested patches. Therefore, this test simply assumes an increase in the mean utility of a particular species is an indication of increased travel costs and localized resource depression.

Cut-marks

As encounter rates with sea mammals in nearby patches decrease, captured individuals will be processed more intensively. This may be inferred archaeologically from an increase in butchery marks on sea mammal bone fragments. Although experimental research by Egeland (2003) suggests that the absolute number of cut-marks on a particular bone is not related to the thoroughness of butchery but instead factors such as the skill of the butcher, I assume that greater intensity of butchery will lead to an increase in the *proportion* of specimens exhibiting cut-marks, regardless of specific *numbers* of cut-marks. A simple index that measures the number of cut-marked specimens to all specimens of a particular species is calculated for each assemblage to test whether or not increased butchery of sea mammals occurred.

Age Structures

A change in age of resident sea mammals over time should be apparent concurrent with depression of larger-bodied taxa. Wildlife biology research (e.g., Caughley 1977) suggests that selective targeting of individual prey in their prime from a population of slow-reproducing mammals will result in a decrease in the mean and maximum ages of the remaining population. If resource depression of sea mammals such as harbor seal, sea otter and porpoise occurred, then I expect the proportion of sub-adult individuals to increase under harvesting pressure as mean age decreases. A different prediction is made for otariids, however, because they are most vulnerable at rookery locations in which their demographic profile is much different from other mammal populations. In this case, I expect the proportion of sub-adult specimens of sea lions, and fur seals if present, in archaeological faunal assemblages to decrease given their age composition at rookeries and haul-outs. In this dissertation, I make coarse-grained age estimates for sea mammal specimens that distinguish infants, juveniles, and adults, based on epiphyseal fusion and in some cases size and texture of bone.

Age structures of fish remains can also be used to test the resource depression hypothesis. Marine fish such as Pacific cod, halibut, and rockfish do not die after a single breeding season, unlike salmonids, and can attain great ages and continue growing as they age (Moyle and Cech 1996). The mean and maximum dimensions of certain skeletal elements will decrease over time as harvest pressure increases on these species. Several methods have been used to determine fish size and age from certain skeletal elements (e.g., Amorosi 1987; Casteel 1976; Colley 1990; Van Neer et al. 1999). Pacific cod are one of the most heavily exploited marine fish species in the region, and their jaw elements are identifiable to species and quite abundant in most coastal sites in the Kodiak archipelago. Comparison of measurements on the angular, dentary, maxilla and premaxilla (Fig. 3.4), when identified confidently to species, should allow inference of changes in mean and maximum body size over time within and between sites (Broughton 1997; Butler 2001; Zohar et al. 1997; but see also Leach and Davidson 1999, 2001).

Cultural Complexity

The third hypothesis stated in this dissertation tests the proposition that resource intensification played a causal role in the development of cultural complexity on the Kodiak archipelago. Following Fitzhugh's (2003) model, intensification in the sense of decreasing foraging efficiency is predicted to occur during the Ocean Bay II phase as decreasing encounters with high-ranked sea mammals caused a shift in subsistence focus towards lower-ranked, more labor intensive fish resources and more distant sea mammal habitats. Technological intensification in the form of innovation of mass harvesting and storage tools is predicted to occur during the Kachemak period, encouraging a further increase in the utilization of fish resources relative to sea mammals as they become more profitable with the adoption of new technologies.

The model of cultural complexity predicts that decreasing foraging efficiency, which is evaluated in this dissertation in the first hypothesis, will be visible prior to any characteristics of cultural complexity in the archaeological record, and prior to the appearance of mass-harvesting and storage features that suggest technological intensification (Table 3.4). Thus chronological data are required to determine whether or not changes in the faunal record occurred prior to these archaeological phenomena. Although definitions and archaeological correlates of cultural complexity on the north Pacific coast are quite varied, archaeological sites on the Kodiak archipelago are benefited by some useful, often abundant markers. The appearance of remains such as large dwellings that housed extended families (Erlandson et al. 1992; Fitzhugh 2003:210-213; Jordan and Knecht 1988), defensive structures (Fitzhugh 2003:83-84; see also Erlandson and Moss 1999; Moss and Erlandson 1992), evidence of warfare such as armor (Knecht 1995), elaborate burials (Simon 1992) and decorative items of personal adornment (Steffian and Saltonstall

2001), are predicted by this hypothesis to occur after the first indications of resource depression and intensification.

The initial appearance of individual phenomena vary, but in general the latter part of the Late Kachemak and the Koniag period (ca. 1500-300 radiocarbon years BP) in Kodiak's culture history exhibit the entire suite of characteristics attributed to a higher degree of cultural complexity than previous eras (Clark 1984a; Fitzhugh 2002, 2003). Decreases in the foraging efficiency indices described earlier in this chapter should be apparent in faunal assemblages dating to the Ocean Bay period, before the advent of either mass harvest and storage technology or an increase in cultural complexity apparent in the Kachemak and Koniag periods.

Other Factors Affecting Faunal Assemblage Composition

Assuming comparisons are made within and between archaeological sites representing similar seasonal, functional and ecological contexts, data from their faunal assemblages should be appropriate for a diachronic analysis required to test the hypothesis detailed above, but I must also take into account some factors both inherent in and external to most faunal assemblages before making any unequivocal statements regarding changes in foraging behavior or prey population dynamics.

Fragmentation

The degree of fragmentation that has occurred in a faunal assemblage is a factor that will most likely affect quantification of specimens (Butler and Chatters

1994; Lubinski 1996; Lyman 1994). Comparison between assemblages, as well as faunal aggregates within assemblages, undergoing different fragmentation processes may result in differences between the total number of identifiable specimens (NISP) and the number of taxa in an assemblage, which may be misinterpreted as a change in diet breadth (Grayson and Delpech 1998). Before any inferences can be drawn regarding resource depression and changes in foraging efficiency between faunal samples, I must determine if differential fragmentation may explain in part any of the changes seen in relative taxonomic abundance.

Climatic Factors

Resource depression can be invoked as an explanation of shifting taxonomic abundances and changes in prey population parameters, however sea mammals and fish populations are sensitive to climatic fluctuations as well as human foraging activities. Climatic conditions constrain the natural abundances of many species, and foragers decide accordingly which resource patches to exploit and which prey types to harvest. Changes in the relative abundance of certain taxa in faunal assemblages may indicate a shift in the availability of particular species because of climatic changes instead of human-induced resource depression (Grayson et al. 2001). Change in climate that could account for observed changes in taxonomic abundances, therefore, must be examined.

Explanations of fluctuations in the diets of prehistoric foragers on Kodiak Island often ignore climatic factors. The specific effects of climatic fluctuation such as the Little Ice Age on human foraging on Kodiak have only recently been investigated (Finney 2000, 2002; Knecht 1995). The paleoclimatic record for the region must be compared to changes in the relative abundances of high-ranked prey types. Significant correlation between the faunal indices I use here and climatic fluctuations may indicate that human-induced resource depression was not the sole cause of patterns seen in the Kodiak faunal assemblages.

This dissertation uses multiple sources of data to assess the relationship between climatic change and changing abundances of high-ranked taxa. The number of broad-scale climatic interpretations from various sources of data for Alaska and the northeast Pacific has been growing (e.g., Heusser et al. 1985; Mann et al. 1998; Mason and Jordan 1993; Nelson and Jordan 1988; Sabin and Pisias 1996; Wiles and Calkin 1994; Wiles et al. 1995, 1996). However, the temporal and spatial scales of these reconstructions offer different interpretations of the climatic history of the region throughout the Holocene. For example, both syntheses of state-wide pollen core data (Anderson and Brubaker 1993) and specific pollen data from Kodiak (Nelson and Jordan 1988) have been interpreted as a reflection of a generally stable climate for the past few thousand years. Mann et al. (1998) agree with this interpretation but also note these particular sets of pollen data lack fine temporal resolution, and cite neoglacial advances of the past few thousand years on the Kenai Peninsula as a more reliable indicator of late Holocene climatic fluctuations. Isotopic data from archaeological shellfish remains are another potential avenue for Holocene climatic reconstruction, and are in the initial stages of study at the University of Washington (Ben Fitzhugh, personal communication 2002).

Technological Change

The development of technology used to harvest certain density-dependent taxa may change their net energetic return rates, hence increasing their profitability compared to other resources (Madsen and Schmitt 1998). The fishing weir, which channeled, trapped, or in some other way made mass-harvesting possible during season upstream salmon migrations, was the technological innovation on the Northwest Coast that had perhaps the greatest impact on the efficiency of salmon harvesting (Cannon 1996; Kroeber 1960; Schalk 1977). Archaeological evidence ranging from weir remains (e.g., Moss et al. 1990) to grooved pebbles inferred as net sinkers (Clark 1984a) may reflect the ability of foragers to harvest fish in quantity. Although prehistoric evidence of weirs is rare on Kodiak Island (but see Knecht 1995), preserved wooden stakes interpreted as weir remains have been found further east along the north Pacific coast and have been dated to as early as 3000 years ago (Moss et al. 1990). Notched and grooved stones, asserted by archaeologists to be net or line sinkers, are characteristic of the Kachemak phase on Kodiak Island (Clark 1984a). The relationship between innovations in fishing technology and the relative abundances of various taxa present in Kodiak faunal assemblages will be examined using published artifact data (e.g., Clark 1974a, 1974b, 1979, 1997; Jordan and Knecht 1988; Knecht 1995; Steffian 1992a; Steffian et al. 1998) to see if technological change, instead of declining foraging efficiency, might account for shifts from larger-bodied prey to smaller-bodied prey.

Technological innovations that alter transportation costs while foraging requires consideration as well, specifically boats. For the Alutiit, watercraft played a central role in getting them to hunting and fishing locations and back again safely. Historically, two kinds of boats were employed by the Alutiit (Crowell and Laktonen 2001; Zimmerly 2000). The *qayaq*, also called a "baidarka" by Russian colonists, was the lightweight, maneuverable skin-covered ancestor of the modern kayak, and had from one to three hatches. The *angyaq*, or "baidara" was a much larger open skin-covered boat that could hold up to 20 paddlers plus passengers and heavy cargo loads. The watercraft of the Alutiit and their neighbors were so well adapted to the environment of the north Pacific that Russian colonists quickly realized that they could not improve on these designs, and conscripted Alutiiq boat-making techniques along with the people themselves for exploration and fur harvesting (Rousselot 1994).

Although watercraft used by the first inhabitants of Kodiak were probably different from those described ethnohistorically, reconstructing the evolution of boat technology for the archipelago is difficult if not impossible to accomplish empirically. Boats suitable for bringing a colonizing population from the Alaskan mainland to the archipelago would have had to cross Shelikof Strait, which is 50 km wide and reaches 200 m in depth. Although the Kodiak archipelago was covered by glacial ice regularly from the Miocene epoch until the beginning of the Holocene, retreat of these glaciers would have created the water barrier of the strait by 8000 B.P. at the very latest (Hampton et al. 1986; Karlstrom 1969; Péwé 1975). Because of this paleoenvironmental history and early Ocean Bay archaeological sites reflecting a maritime orientation (Clark 1979; Fitzhugh 2003; Hausler-Knecht 1991, 1993; Steffian et al. 1998), proficiency in boat construction and use by the earliest Alutiit seems a safe assumption.

Direct archaeological evidence of boats on Kodiak is very rare, because in most coastal locations preservation of watercraft and related artifacts is poor (but see Gamble 2002). Occasionally post-depositional processes create exceptional conditions that have preserved prehistoric watercraft and watercraft-related artifacts (e.g., Samuels 1991). This is the case at KAR-001, the New Karluk site, which is a series of ten waterlogged Alutiiq housefloors near the village of Karluk on the west side of Kodiak Island. The occupation layers date initially to the Kachemak-Koniag transition about 1000 B.P. until shortly before Russian contact (Jordan and Knecht 1988). Sophisticated wood and skin boat technology is apparent from the hundreds of boat parts recovered during excavation (Knecht 1995).

Although firm evidence of Alutiiq boat use is limited to the past thousand years based on archaeological and ethnohistoric observations and inferences, indirect evidence in the form of subsistence, artifact, and paleoenvironmental data strongly suggest that the Alutiiq economy has been tied to boats since Ocean Bay times. Until the introduction of motorized boats in the mid- to late-19th century (Roppel 1986), water travel was dependent upon the physical efforts of the Alutiit by paddling and rowing kayaks and boats. Although boats increase the potential loads that hunter-gatherers can transport back to a central place by at least an order of magnitude (Ames 2002), encumbrance would still be a concern when hunting or fishing trips were made to distant patches because, even with boats, more energy must be exerted with greater traveling distances. Therefore, I make the assumption that butchering decisions by the Alutiit would still be dictated in large part by the travel costs involved in hunting and fishing in near-shore patches at varying distances from a central location.

Summary

In this chapter, I have established the specific hypotheses and predictions that are the focus of this dissertation. To accomplish this, I conceptualize the patch choices available to Alutiiq foragers in general terms: the near-shore marine patch providing high-return sea mammals and more labor-intensive, lower-return marine fish; and the riverine patch providing seasonal yet productive runs of salmon along with sporadic encounters with terrestrial animals such as foxes. To test the hypothesis that resource intensification occurred, measures of the proportion of high-ranked prey within patches and between patches can be applied to a sequence of comparable faunal assemblages. To test the hypothesis that resource depression of sea mammal populations occurred, I employ three lines of evidence: Carcass transport distance inferred from relative skeletal abundance, butchery intensity inferred from cut-mark proportion on faunal remains, and alteration of demographic profiles of prey inferred from proportions of various age classes of faunal remains.

To test whether or not marine fish were undergoing harvest pressure as well, width measurements of certain skeletal elements of Pacific cod are taken with the expectation that the mean of these measurements will decrease over time if cod body size decreases and harvest pressure increases. Finally, to test the hypothesis that resource intensification played a causal role in a marked increase in cultural complexity, I compare the chronology of the intensification indices discussed here with the timing of archaeological correlates of complexity and technological intensification found in the Kodiak region.

Several factors must be taken into account for confidence to be placed in these tests. First, shifts towards greater use of lower-ranked prey must not coincide with technological innovations that would make the low-ranked prey more profitable, otherwise this is not a decrease in foraging efficiency or resource intensification. Second, changes in fragmentation of faunal remains that could account for perceived changes in the use of different animals must be controlled. Third, climate change coinciding with changes in subsistence must be examined because they may account for changing demographic profiles of particular animal species. Finally, archaeological faunal assemblages that are compared to each other to accomplish the tests must be of sufficient size and comparable to each other in terms of ecological setting and prey availability, site function, and season of use, faunal sample size, and archaeological recovery techniques. The samples used in this dissertation are the subject of the next chapter.

Table 3.1 Non-Introduced mammal species around the Kodiak archipelago today (From Forsell and Gould 1981; Mishler 2001; Murie 1959; Rausch 1969; Reeves et al. 2002; USFWS 1987; Wynne 1997

Taxon	Habitat	Avg. Adult Weight (kg)	Modern Availability
Land Mammals			
Ursus arctos (Brown Bear)	Terrestrial	340-680	Year-Round
Vulpes vulpes (Red Fox)	Terrestrial	3-7	Year-Round
Lontra Canadensis (Northern River Otter)	Terr./Near-Shore	5	Year-Round
Mustela erminea (Ermine)	Terrestrial	0.1-0.2	Year-Round
Microtus oeconomus (Tundra Vole)	Terrestrial	0.006-0.020	Year-Round
Myotus lucifugus (Little Brown Bat)	Terrestrial	0.007-0.009	Year-Round
Pinnipeds, Porpoises and Sea Otters			
Eumetopius jubatus (Steller Sea Lion)	Near-Shore	680 (M), 270 (F)	Rook in Summer
Callorhinus ursinus (Northern Fur Seal)	Pelagic	204 (M), 50 (F)	Fall-Winter
Phoca vitulina (Harbor Seal)	Near-Shore	115	Year-Round
Phocoenoides dalli (Dall's Porpoise)	Near-Shore/Pelagic	140	Year-Round,
Phocoena Phocoena (Harbor Porpoise)	Near-Shore	54	Year-Round
Enhydra lutris (Sea Otter)	Near-Shore	32 (M), 27 (F)	Year-Round
Whales			
Balaenoptera musculus (Blue Whale)	Pelagic	90000	Summer
Balaenoptera physalus (Fin Whale)	Pelagic	41000	Year-Round
Balaenoptera acutorostrata (Minke Whale)	Pelagic	5400 (M), 7200 (F)	Summer
Megaptera novaeangliae (Humpback Whale)	Near-Shore/Pelagic	22600 (M), 31800 (F)	Summer
Eschrichtius robustus (Gray Whale)	Near-Shore/Pelagic	30,000	Spring/Fall
Physeter catodon (Sperm Whale)	Pelagic	36200 (M), 20000 (F)	Year-Round
Berardius bairdii (Baird's Beaked Whale)	Pelagic	9000 (M), 11000 (F)	Year-Round
Ziphius cavirostris (Cuvier's Beaked Whale)	Pelagic	2600 (M), 3000 (F)	Winter/Spring
Mesoplodon stejnegeri (Stejneger's Beaked Whale)	Pelagic	1200	Year-Round
Orcinus orca (Killer Whale)	Near-Shore/Pelagic	7200	Year-Round

Table 3.2 Fish species observed around the Kodiak archipelago today (List from Rogers et al. 1986; see also Mecklenburg et al. 2002; Size and habitat data from Froese and Pauly 2002, Hart 1973, Kramer et al. 1995, Kramer and O'Connell 1995, Love 1996)

Taxon	Common Name	Habitat	Max. Total Length (cm)	Max. Wt. (kg)
Chondrychthes - Cartilaginous Fish				
Squalus acanthias	Spiny Dogfish	Near-Shore Pelagic	130	9
Raja binoculata	Big Skate	Near-Shore Pelagic	240	91
Raja rhina	Longnose Skate	Near-Shore Pelagic	140	
Clupeidae - Herring				
Clupea harengus pallasi	Pacific Herring	Shallows and Bays in Spring	33	<1
Salmonidae - Salmon, Trout and Char				
Oncorhynchus gorbuscha	Pink (Humpy) Salmon	Most Rivers, Spring-Summer	76	6
Oncorhynchus keta	Chum (Dog) Salmon	Most Rivers, Summer	102	15
Oncorhynchus kisutch	Coho (Silver) Salmon	Larger Rivers, Late Sum.-Fall	98	14
Oncorhynchus mykiss	Rainbow/Steelhead Trout	Larger Rivers, Summer	120	25
Oncorhynchus nerka	Sockeye (Red) Salmon	Rivers with Lakes, Early Sum.	84	7
Oncorhynchus tshawytscha	Chinook (King) Salmon	Large Rivers, Summer	135	57
Salvelinus malma	Dolly Varden	Most Rivers, Spring-Fall	91	13
Osmeridae - Smelts				
Hypomesius pretiosus	Surf Smelt	Beaches, Seasonal	22	<1
Mallotus villosus	Capelin	Beaches, Seasonal	22	<1
Thaleichthys pacificus	Eulachon	Large Rivers, Summer	23	<1
Gadidae - Codfishes				
Gadus macrocephalus	Pacific Cod	Near-Shore in Spring /Sum.	100	23
Microgadus proximus	Pacific Tomcod	Near-Shore Pelagic	30	1
Theragra chalcogramma	Walleye Pollock	Near-Shore Pelagic	80	
Zoarcidae - Eelpouts				
Lycodes brevipes	Shortfin Eelpout	Near-Shore Pelagic	30	
Lycodes palearis	Wattled Eelpout	Near-Shore Pelagic	51	
Gasterosteidae - Sticklebacks				
Gasterosteus aculeatus	Threespine Stickleback	Wide-Ranging, Salt/Brackish	10	<1
Aulorhynchidae - Tubesnouts				
Aulorhynchus flavidus	Tubesnout	Kelp-Beds	18	<1
Trichodontidae - Sandfishes				
Trichodon trichodon	Pacific Sandfish	Shallows Near-Shore	30	

Table 3.2, cont. Fish species observed around the Kodiak archipelago today

Bathymasteridae - Ronquils				
Bathymaster caeruleofasciatus	Alaskan Ronquil	Near-Shore Pelagic	30	
Bathymaster signatus	Searcher	Near-Shore Pelagic	30	
Ronquilus jordani	Northern Ronquil	Near-Shore Pelagic	17	
Scorpaenidae - Rockfishes				
Sebastes alutus	Pacific Ocean Perch	Mainly Off-Shore	51	
Sebastes ciliatus	Dusky Rockfish	Near-Shore Rocky Reefs	53	
Sebastes crameri	Darkblotched Rockfish	Mainly Off-Shore	58	
Sebastes melanops	Black Rockfish	Near-Shore Rocky Reefs	63	
Sebastes nigrocinctus	Tiger Rockfish	Near-Shore Rocky Reefs	61	
Anoplopomatidae-Sablefishes				
Anoplopoma fimbria	Sablefish (Black Cod)	Off-Shore	100	57
Hexagrammidae - Greenlings and Lingcod				
Hexagrammos decagrammus	Kelp Greenling	Kelp-Beds and Reefs	53	
Hexagrammos lagocephalus	Rock Greenling	Kelp-Beds and Reefs	61	
Hexagrammos octogrammus	Masked Greenling	Near-Shore Rocky Reefs	28	
Hexagrammos stelleri	Whitespotted Grnling.	Near-Shore Rocky Reefs	41	
Pleurogrammus monopterygius	Atka Mackerel	Near-Shore Pelagic	51	
Ophiodon elongates	Lingcod	Near-Shore Pelagic	152	
Cottidae – Sculpins				
Artedius fenestralis	Padded Sculpin	Near-Shore Rocky Reefs	14	<1
Blepsias bilobus	Crested Sculpin	Near-Shore Rocky Reefs	25	
Blepsias cirrhosus	Silverspotted Sculpin	Shallow Bays	19	<1
Clinocottus acuticeps	Sharpnose Sculpin	Shallow Bays	5	<1
Dasycottus setiger	Spinyhead Sculpin	Near-Shore Pelagic	23	
Enophrys bison	Buffalo Sculpin	Near-Shore Rocky Reefs	30	
Gilbertidia sigalutes	Soft Sculpin	Near-Shore Pelagic	8	<1
Gymnocanthus galeatus	Armorhead Sculpin	Near-Shore Pelagic	36	
Gymnocanthus pistilliger	Threaded Sculpin	Near-Shore Pelagic	23	
Hemilepidotus hemilepidotus	Red Irish Lord	Wide-Spread Near-Shore	51	
Hemilepidotus jordani	Yellow Irish Lord	Near-Shore Pelagic	41	
Hemitripterus bolini	Bigmouth Sculpin	Near-Shore Pelagic	69	
Icelinus borealis	Northern Sculpin	Near-Shore Pelagic	10	<1
Icelus spiniger	Thorny Sculpin	Off-Shore	19	<1
Leptocottus armatus	Pac. Staghorn Sculpin	Wide-Spread Near-Shore	46	
Myoxocephalus jaok	Plain Sculpin	Wide-Spread Near-Shore	53	
M. polyacanthocephalus	Great Sculpin	Wide-Spread Near-Shore	76	
Myoxocephalus scorpius	Shorthorn Sculpin	Wide-Spread Near-Shore	90	
Nautichthys oculofasciatus	Sailfin Sculpin	Wide-Spread Near-Shore	20	
Nautichthys pribilovius	Eyeshade Sculpin	Wide-Spread Near-Shore	6	<1
Oligocottus maculosus	Tidepool Sculpin	Near-Shore Rocky Reefs	9	<1
Psychrolutes paradoxus	Tadpole Sculpin	Near-Shore Pelagic	6	<1
Radulinus asperellus	Slim Sculpin	Near-Shore Pelagic	13	<1

Table 3.2, cont. Fish species observed around the Kodiak archipelago today

Cottidae – Sculpins, cont.				
Synchirus gilli	Manacled Sculpin	Wide-Spread Near-Shore	6	<1
Triglops forficate	Scissortail Sculpin	Near-Shore Pelagic	25	
Triglops macellus	Roughspine Sculpin	Near-Shore Pelagic	20	<1
Triglops pingelii	Ribbed Sculpin	Near-Shore Pelagic	20	<1
Stichaeidae - Warbonnets and Pricklebacks				
Anoplarchus purpurescens	High Cockscomb	Wide-Spread Near-Shore	20	<1
Lumpenella longirostris	Longsnout Prickleback	Near-Shore Pelagic	26	
Lumpenus maculates	Daubed Shanny	Near-Shore Pelagic	16	<1
Lumpenus medius	Stout Eelblenny	Near-Shore Pelagic	28	
Lumpenus sagitta	Snake Prickleback	Near-Shore Pelagic	51	
Poroclinus rothrocki	Whiteb'd Prickleback	Near-Shore Pelagic	25	
Stichaeus punctatus	Arctic Shanny	Near-Shore Pelagic	22	
Pholididae - Gunnels				
Apodichthys flavidus	Penpoint Gunnel	Wide-Spread Near-Shore	46	
Pholis clemensi	Longfin Gunnel	Near-Shore Pelagic	13	
Pholis laeta	Crescent Gunnel	Wide-Spread Near-Shore	25	
Anarhichadidae - Wolf-Fishes				
Anarichas orientalis	Bering Wolffish	Near-Shore Pelagic	124	
Anarrhichthys ocellatus	Wolf-Eel	Near-Shore Rocky Reefs	240	
Zaproridae - Prowfishes				
Zaprora sileneus	Prowfish	Near-Shore Pelagic	88	
Ammodytidae - Sand Lances				
Ammodytes hexapterus	Pacific Sand Lance	Wide-Spread Near-Shore	20	
Agonidae - Poachers				
Agonus acipenserinus	Sturgeon Poacher	Near-Shore Pelagic	30	<1
Anoplagonus inermis	Smooth Alligatorfish	Near-Shore Pelagic	15	<1
Occella dodecadron	Bering Poacher	Near-Shore Pelagic	22	<1
Pallasina barbata	Tubenose Poacher	Near-Shore Pelagic	13	<1
Cyclopteridae - Snailfish				
Aptocyclus ventricosus	Smooth Lumpsucker	Near-Shore Pelagic	27	<1
Liparis callyodon	Spotted Snailfish	Wide-Spread Near-Shore, Intertidal	13	<1
Liparis cyclopus	Ribbon Snailfish	Wide-Spread Near-Shore, Intertidal	11	<1
Liparis dennyi	Marbled Snailfish	Wide-Spread Near-Shore	30	<1
Liparis fucensis	Slipskin Snailfish	Near-Shore Pelagic	18	<1
Liparis mucosus	Slimy Snailfish	Wide-Spread Near-Shore, Intertidal	7	<1

Table 3.2, cont. Fish species observed around the Kodiak archipelago today

Pleuronectidae - Flatfishes				
Atheresthes stomias	Arrowtooth Flounder	Near-Shore, Sandy Bottom	86	8
Glyptocephalus zacharius	Rex Sole	Off-Shore, Sand and Mud Bottom	61	
Hippoglossoides elassodon	Flathead Sole	Wide-Spread Near-Shore, Silt/Mud	56	
Hippoglossus stenolepis	Pacific Halibut	Wide-Spread Near-Shore Summer	267	225
Isopsetta isolepis	Butter Sole	Near-Shore, Mud or Silt Bottom	55	
Lepidopsetta bineata	Rock Sole	Near-Shore, Rocky/Sandy Bottom	61	3
Limanda aspera	Yellowfin Sole	Near-Shore, Sandy Bottom	48	
Microstomus pacificus	Dover Sole	Off-Shore, Sand and Mud Bottom	76	5
Parophrys vetulus	English Sole	Near-Shore, Sandy Bottom	61	
Pleuronectes quadrituberculatus	Alaska Plaice	Off-Shore	60	
Platichthys stellatus	Starry Flounder	Wide-Spread, Near-Shore Brack.	91	9
Psettichthys melanostictus	Sand Sole	Near-Shore, Sandy Bottom	63	2.3

Table 3.3 Summary of Hypotheses and Expectations for Resource Depression Model

Hypothesis 1: If resource intensification occurred then a greater proportion of low-ranked prey entered the diet.

Variable	Measure	
Foraging Efficiency	Relative abundances of high-ranked prey within a patch	
	Marine Patch:	$\frac{\Sigma \text{ Sea Mammal NISP}}{\Sigma \text{ (Sea Mammal + Marine Fish NISP)}}$
	Riverine Patch:	$\frac{\Sigma \text{ Salmon NISP}}{\Sigma \text{ (Salmon + Fox NISP)}}$
	Relative abundance of high-ranked prey between patches	$\frac{\Sigma \text{ Sea Mammal NISP}}{\Sigma \text{ (Sea Mammal + Salmon NISP)}}$

Expectations: These indices will *decrease* as foraging efficiency within and between patches declines

Hypothesis 2: If resource depression occurred, then travel to patches increases and/or butchery intensifies.

Variable	Measure	
Distance to Patch	Relative Skeletal Abundance:	Mean Utility of MNE present in an assemblage

Expectations: Mean utility will *decrease* as travel to patches from a central place increases

Butchery Intensity	Cut-Mark Frequencies:	Proportion of cut-marked specimens in an assemblage

Expectations: Proportion of cutmarked sea mammal specimens will *increase* as encounters with sea mammals become increasingly scarce

Prey Population	Age/Size Structure:	Sea Mammals: Proportion of adult specimens Pacific Cod: Mean width of certain jaw elements

Expectations: Resource depression will cause a decrease in the proportion of adult specimens of non-otariid sea mammals, and a decrease in the mean body size of Pacific cod

Hypotheses 3: If resource intens. described in Hypothesis 1 played a causal role in the development of cultural complexity then the decrease in foraging efficiency must have occurred during the Ocean Bay period prior to either mass-harvest and storage tech. or characteristincs of increased cultural complexity.

Variable	Measure
Timing of Intensification	Relative chronology of intensification and characteristics of cultural complexity and technological intensification

Expectations: Characteristics of intensification listed under the first hypothesis above should become evident prior to the appearance of mass harvesting and storage technology, and archaeological correlates of cultural complexity.

Table 3.4 Archaeological correlates of cultural complexity and technological intensification from the Kodiak region.

	Ocean Bay I (7500-4500 BP)	**Ocean Bay II** (4500-3500 BP)	**Early Kachemak** (3500-2500 BP)	**Late Kachemak** (2500-800 BP)	**Early Koniag** (800-400 BP)	**Developed Koniag** (400 BP - Contact)
Settlement Patterns Indicative of Population						
Settlement Size	Solitary	Solitary	Solitary	Village	Village	Village
House Size	Tents?	Simple Semi-Sub.	Simple Semi-Sub.	Simple Semi-Sub.	Multi-room Semi-Sub.	Multi-room Semi-Sub.
Possible Indicators of Political Conflict						
Defensive Structures (Refuge Rocks)	?	?	?	Small	Small	Large, Common
Artifacts interpreted as armor	?	?	?	?	Present	Present
Possible Indications of Trade						
Lthic Raw Materials	Some exotic (for proj. points)	Local	Local	Exotic (Decorative)	Exotic (Decorative)	Exotic (Decorative)
Ceremonial/Decorative Features						
Mortuary Practices	?	Simple	Simple	Elaborate	Elaborate	Elaborate
Labrets	?	?	Rare	Common, Few Motifs	Common, Indiv. Styles	Common, Indiv. Styles
Incised Slate Tablets	None	None	None	None	Common	Rare
Features of Technological Intensification						
Stone Tools Assocaited with Net Technology	None	None	Net Sinkers Rare	Net Sinkers Common	Net Sinkers Absent	Net Sinkers Absent
Storage	?	?	Clay-Lined Pits	Clay-Lined Pits, Slate Boxes	Clay-Lined Pits, Slate Boxes,	Clay-Lined Pits, Slate Boxes, Pottery
Stone Weirs associated with Riverine sites	None	None	None	None	Present	Present

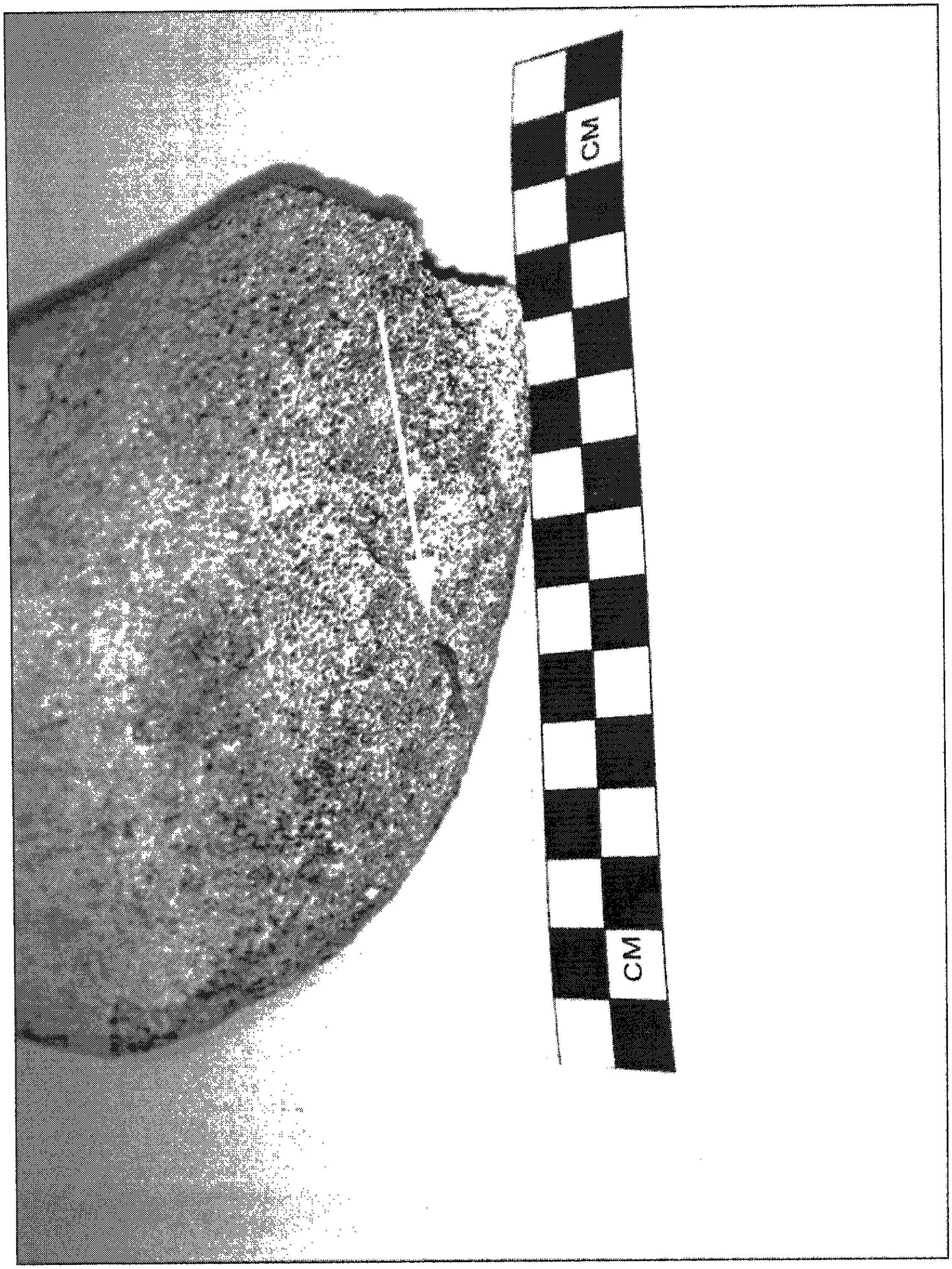


Fig. 3.1 Spinous process of whale vertebra with embedded slate projectile point, oblique view of superior margin of process (photo by author)

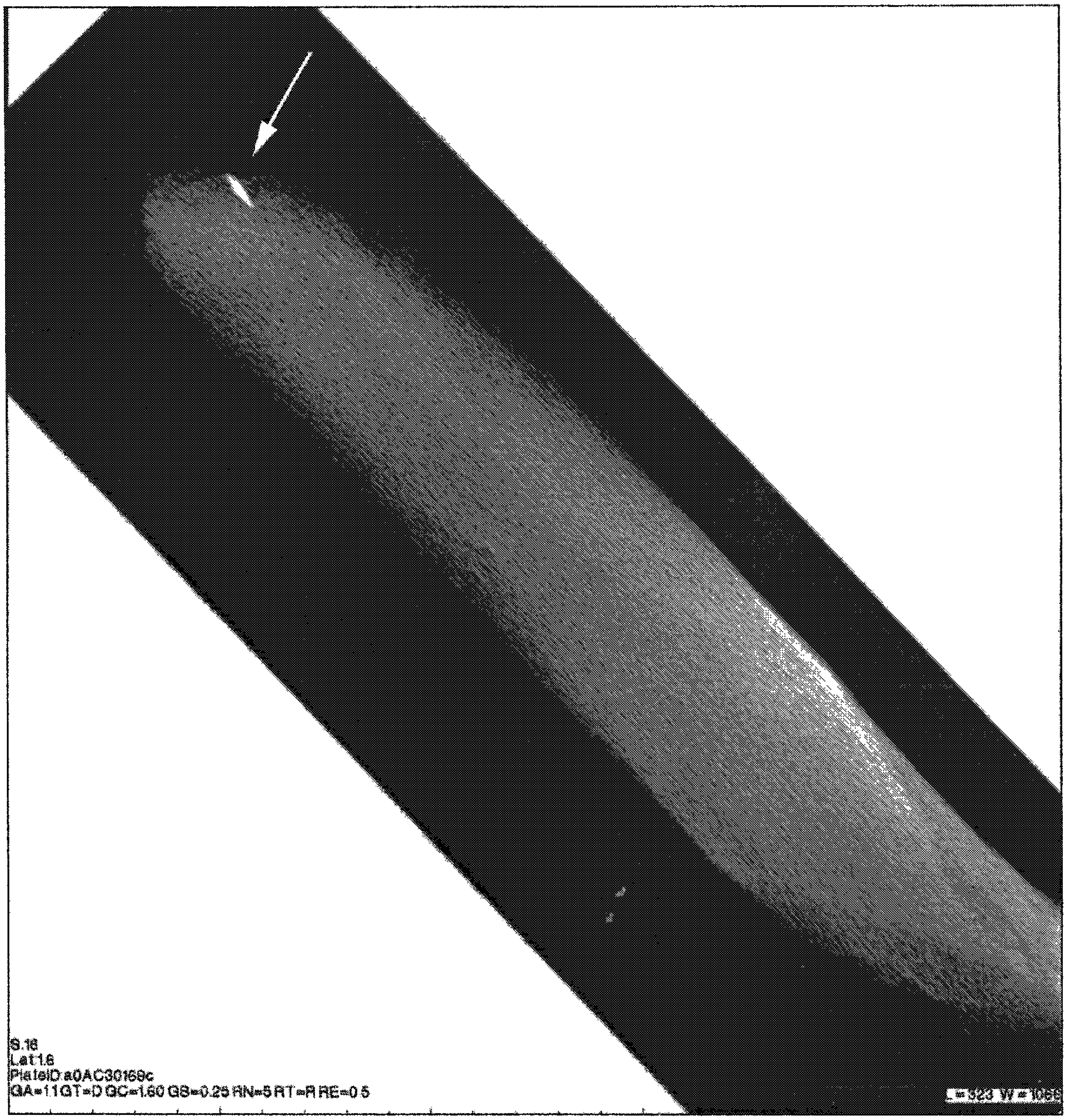


Fig. 3.2 X-Ray image of whale vertebra with embedded slate projectile point (indicated by arrow), oblique anterior view (image provided by UW Medical Center-Roosevelt, Radiology Department)

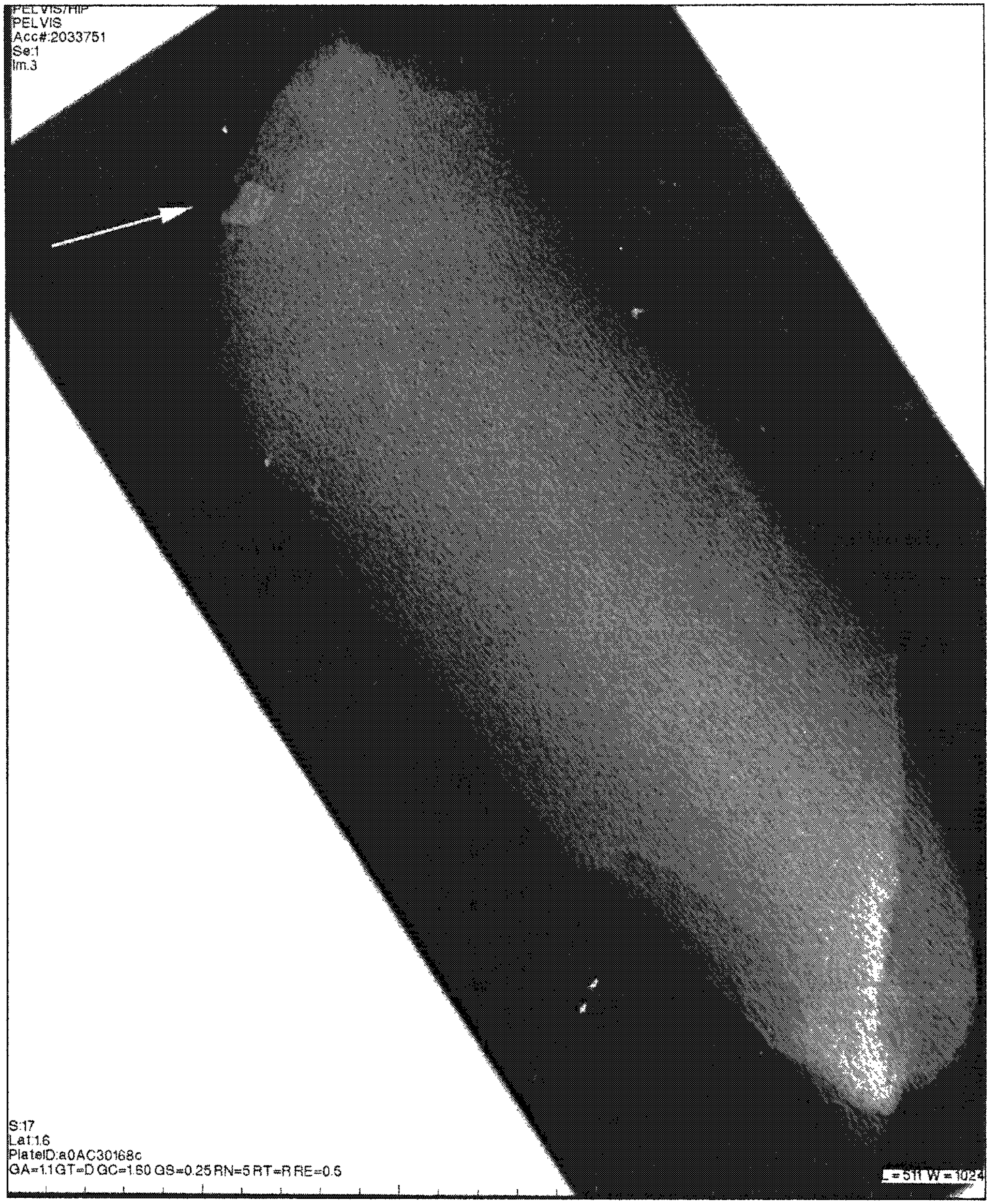


Fig. 3.3 Same specimen as Figure 3.2, lateral view (image provided by UW Medical Center-Roosevelt, Radiology Department)

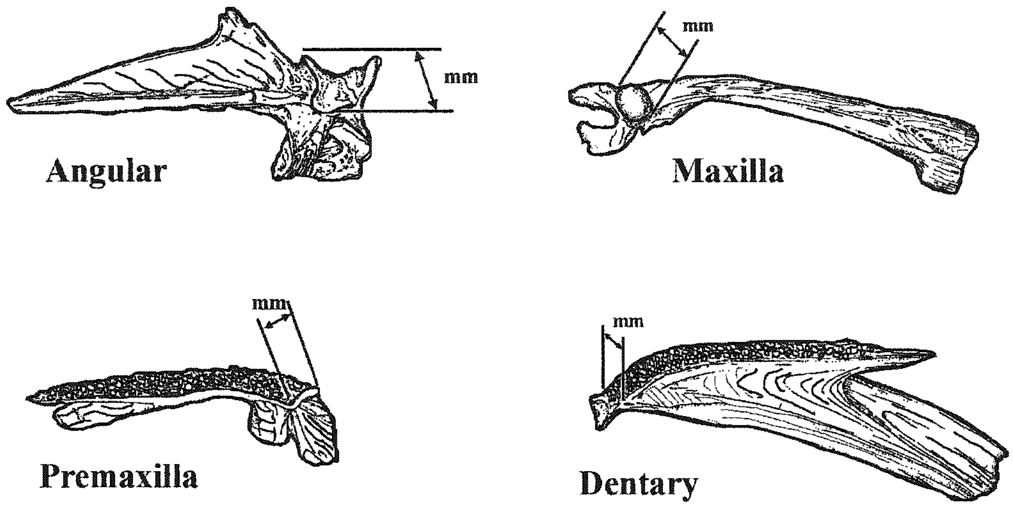


Fig. 3.4 Measurements taken on four jaw elements of Pacific Cod (*G. macrocephalus)* (Drawings adapted from Cannon 1987)

Chapter 4:

Kodiak Archaeological Sites and Their Faunal Remains

The hypotheses outlined in Chapter 3 can be tested empirically using archaeological faunal assemblages that consistently meet certain conditions. These conditions include an ample time-depth either within or between sites to discern the broad-scale diet breadth changes hypothesized here. Also, the assemblages should be large enough to draw statistically valid conclusions. Finally, the sites from which these assemblages come should reflect consistent patterns of foraging behavior and similar access to marine and riverine resource patches instead of special-use or seasonally-restricted sites. This chapter summarizes four sites on the Kodiak archipelago that meet these criteria whose fauna have been analyzed for this dissertation (Fig. 4.1). The specific methods of analysis of these assemblages are also summarized.

Ideally, this dissertation would use data from faunal assemblages recovered from one site representing the entire span of Alutiiq prehistory, since this sequence reflects a population growing in size and social complexity and eventually turning towards intensive harvesting of salmon to support itself. The appropriate data, however, are not available in their entirety for several reasons. Foremost is the issue of organic preservation. The weathered volcanic ash that is the primary component of much of the archipelago's soil is not conducive for the survival of bone in archaeological sites. Shellfish remains counteract this acidity and generally provide good preservation conditions. Shellfish were apparently not consumed and deposited in enough quantity to form shell middens until about 2500 B.P., in Late Kachemak villages along the coast. Therefore, Ocean Bay and Early Kachemak sites are fewer in number and rarely have large samples of preserved bone. The Rice Ridge site is an exception and provides an opportunity to test subsistence hypotheses starting at a relatively early point in Kodiak's prehistory. The deposits at Rice Ridge do not postdate the end of the Ocean Bay II phase around 3800 B.P. (Table 4.1), so more recent assemblages should also be used. The other three sites examined in this dissertation, Crag Point, Uyak and Settlement Point, do not cover the Kachemak and Koniag periods evenly or completely (Table 4.2), but offer discrete samples of both midden and house-floor deposits from settings that would have provided foragers with similar patch and prey choices as were offered at Rice Ridge.

Assemblages used in this analysis would also ideally come from well-defined sequences within the same site, which would allow more confidence when having to make the assumptions of consistent site function, seasonality, and microhabitat conditions. Because the time span I am interested is longer than the occupation of any one site, I must be explicit about these assumptions because I compare assemblages from several spatially-distinct sites. Even assemblages within a single site may represent different uses of the local area, seasonal occupations, or microhabitat changes. For these reasons, I have chosen sites which have been interpreted as villages or semi-permanent sites in which the aggregations of faunal remains represent most or all of the annual subsistence cycle based on artifact and structural data and the presence of coarse seasonal indicators such as salmon, herring, and infant sea mammal remains. Although I have chosen sites in similar general ecological settings there is the possibility that their local prey availability may have been somewhat different. For the purposes of this dissertation, I assume that if such inconsistencies existed they did not have an effect on differences in foraging behavior that I infer from the assemblages.

Although I assume that site function associated with each assemblage remained consistent, I do recognize a dichotomy between the two disposal contexts of most of the assemblages recovered from these sites: housefloor units incorporated into what have been interpreted as living surfaces and midden units which are associated with large numbers of shellfish remains and lack the characteristics of housefloors such as hearths and structural features. I assume that disposal behavior by the human occupants of the sites differed between these contexts based upon ethonhistoric accounts (e.g., Davydov 1977) and prior zooarchaeological research (Partlow 2000), and the assemblages are expected differ accordingly in terms of relative taxonomic and skeletal abundance of prey. Including both floor and midden assemblages into a single diachronic comparison may reveal more about differences between disposal context than broader subsistence issues over time, therefore their analyses are kept separate with the exception of changes in Pacific cod element sizes, where I assume that Pacific cod would not be disposed of differentially between the two contexts based on size.

Rice Ridge (KOD-363)

The Rice Ridge site represents a large occupation spanning the Ocean Bay I and II phases and contains one of the largest well-preserved faunal assemblages dating to this early time. The deposits consist of alternating house floor and midden strata with abundant stone and bone tools, animal bones, and shell. Charcoal collected and submitted for radiocarbon dating during the 1988-1990 field seasons of excavation yielded three dates: one from the basal cultural deposit (6080±90 radiocarbon years B.P.) and two from the terminal cultural deposit (3850±80 and 3860±90 radiocarbon years B.P.) (Hausler-Knecht 1993, Mills 1994).

Twenty-two additional charcoal samples were recovered from bulk sample bags stored at the Alutiiq Museum in Kodiak, Alaska in September, 2002, and submitted to Beta Analytic (see below). These new dates were obtained in order to clarify the depositional context of the faunal assemblages and allow more refined temporal comparisons of this material. The dates are presented in Table 4.1.

The thick deposits sit atop a ridge of land that extended into Chiniak Bay in the lee of a small near-shore island at the time it was occupied (Fig. 4.2). Today, however, the site is located several hundred meters inland from the present coastline because of tectonic uplift that has been occurring along the eastern edge of Kodiak Island. Nearby resources (within about a 5 km radius) available today include small salmon streams with runs of pink salmon, seal and sea lion haul-out areas, both rocky and sandy near-shore environments providing marine fish and sea mammals, and a variety of littoral environments with abundant shellfish beds and marine birds. At a greater distance are a large sea lion rookery at Cape Chiniak to the east and larger rivers such as the Olds River at the head of Kalsin Bay to the west of the site, which provides significant runs of pink, coho, and chum salmon (NOAA 1997). Physiographic changes in the local environment caused by various geomorphological processes undoubtedly changed the microhabitats of available prey types near Rice Ridge and the other sites used in this dissertation (e.g., Gilpin 1995). The lack of resolution of the faunal assemblages for discerning specific hunting and fishing trips, however, prevents this analysis from detecting such microhabitat change.

During the 1988-1990 field seasons, numerous 2m x 2m excavation units were dug across the site under the direction of Philomena Hausler, an anthropology graduate student at Harvard University. A 2 x 3 unit block (4m x 6m) was centered on the ridge and extended northward from an initial 2m x 2m test unit. These units contained an average of 2.5 meters of cultural deposits within at least eleven strata with abundant artifacts, faunal remains, and charcoal. Artifacts and faunal remains were recovered by hand during excavation as well as from ¼" mesh screens (Hausler-Knecht 1991). This dissertation focuses on fauna from four of these units, Squares 2, 3, 5 and 6, which form a contiguous 4m x 4m block (Fig. 4.2).

Stratigraphy of the excavation units had to be inferred from copies of field forms archived at the Alutiiq Museum in Kodiak and narrative descriptions of the deposits written on the faunal bags, as well as personal communications in 2001 and 2002 with Donald Clark, who was one of the excavators of the site, and Dale and Marie Rice, the landowners. Field notes of the principal investigator and maps and profile drawings of the site were not available. On one hand, each bag of faunal remains has a very precise recorded provenience including depth below datum and color, texture, and content characteristics of the deposit from which each came. On the other hand there is an almost total absence of synthetic information about site stratigraphy as a whole. Because of this, the Rice Ridge fauna have been aggregated into eleven sequential stratigraphic units, designated A through K, but the stratigraphic profiles I have created are schematic and tentative (Figs. 4.3-4.6).

Table 4.3 summarizes the stratigraphy of the deposits examined here. The eruption of Novarupta on the Alaskan Peninsula on June 6, 1912 blanketed most of northern Kodiak Island with 30-60 cm of "Katmai" ash (Griggs 1922), which formed a protective cap over the archaeological deposits at Rice Ridge. Beneath this is a layer of black, organic-rich sediment that includes loose rubble, occasional thin bands of shell, and faunal material. Designated Level A, it is found across all four excavation units that were examined in this dissertation and represents the terminal cultural midden deposit in this area of the Rice Ridge site. Deposits immediately beneath this level are associated with a structure containing a charcoal and red ochre-banded occupation surface and several hearth and pit features. Faunal remains from these deposits are designated as coming from Level B, which is present in units 3, 5 and 6 but absent in unit 2. Level C consists of midden deposits beneath the structure, consisting of mixed rocky and clayey soil with flecks of shell, but is only present in the southern units, 2 and 3. Level D is a second, older red ochre-stained occupation surface present in units 3, 5 and 6. Levels E and F are only present in these units as well. Level E represents shell midden deposits mixed with brown weathered ash between the Level D surface, while Level F is a third deeper red ochre surface with "cooking pit" features. Level G consists of pebbly, brown weathered ash with small pockets of shell midden fill. Level H is also a midden deposit, but it is stratigraphically distinct from Level G in that it is composed mostly of shell midden with dense layers of shell, fishbone, and other faunal remains, and a small amount of grayish-brown ashy and rocky matrix. In unit 6, the shell-poor matrix of Level G apparently dives between sub-layers of Level H but remains stratigraphically more recent than most of Level H in the other units. Level I is another red ochre-stained occupation layer in units 2, 5 and 6, and contains charcoal and several gravelly pit features. Level J is found in all units and represents the earliest midden deposited in these units. It is a fairly compact layer of tan weathered ash and fragmented shell, bone and charcoal. Level K represents the basal occupation surface in these units, and possibly at the site as a whole. This earliest cultural layer is present in units 5 and 6, the eastern units of the analyzed block. On the bags of fauna and the field forms it is referred to as the "black floor" associated with underlying "basal red ochre". Beneath the cultural material in all of the units is an orange tephra that most likely represents weathered volcanic ash deposited shortly after glaciation and before human occupation.

To gain stronger chronological control over the complex stratigraphy of the Rice Ridge site, I obtained National Science Foundation funding (Dissertation Improvement Grant #BCS-0226397) for additional radiocarbon dates to supplement those obtained by previous researchers during excavation of the site. Dates from charcoal samples were deemed to be the best source for this purpose. The original dates were on charcoal, which was collected in large quantities from most of the deposits and stored in level bags at the Alutiiq Museum. AMS dates on bone would have given precise results on the targeted events, when the animals were hunted, and also avoids the problem of dating old wood. However, by far the greatest volume of bone recovered from Rice Ridge is from sea mammals. The local marine reservoir effect has not been investigated for the Kodiak archipelago in any detail (see Ingram 1998; Kennet et al. 1997; Robinson and Thompson 1980 for a regional discussion of variations in the reservoir effect for the north Pacific region in general). Therefore, given the amount of funding, the ability to get a relatively large number of dates across the sequence of deposits by using charcoal was deemed more important than fewer AMS dates from bone samples, which can be dated in the future to cross-check previous dates if necessary (see Cannon 2000; Erlandson and Moss 1999).

After 22 samples were submitted to Beta Analytic, Inc. from charcoal deposited in all levels except E, over half of them required AMS dating and several more required extended counting because of their low levels of final carbon. The dates are listed in Table 4.2. Almost all of the dates are stratigraphically consistent, and generally confirm the beginning and ending dates of occupation at Rice Ridge from about 6000-3900 radiocarbon years before present. One sample from Level J (Beta 171576) underwent extended counting and resulted in an uncorrected date of 6580 ± 220 BP, which barely overlaps with the other dates from the lower levels at

2σ. Although the staff at Beta Analytic, Inc. assured me that they did not detect sea mammal oil contamination in any of the samples (which would make the date somewhat older because of the marine reservoir effect), and the samples themselves appear to have come from smaller diameter branches (avoiding the problem of old wood), I feel that this early date does not reflect the age of deposition of Level J based on the abundance of other dates from the same level that fall within a tight range several hundred years later.

Accumulation rate calculations are shown graphically for the site as a whole in Fig. 4.7 and for the individual units in Figs. 4.8-4.11. As Stein et al. (2002) note, this method allows us to interpret shell midden stratigraphy in a more rigorous, quantitative fashion. Calibrated dates are used in the accumulation rate calculations despite a past general reluctance by many archaeologists in the region to conceptualize regional and site-specific interpretations of Kodiak prehistory using calibrated dates (see Mills 1994). Despite the *appearance* of consistent deposition of cultural materials from about 7000 to 4400 calendar years BP, Fig 4.7 shows three distinct periods of rapid deposition interspersed with two apparent occupational hiatuses. Excluding Beta-171576, the oldest deposits in these units yielded samples between 256 and 204 cm below datum that dated from 7000 to 6710 calendar years BP based on calibrated intercepts.

Using the technique outlined in Stein et al. (2002), 52 cm of deposits accumulated in 219 years at a rate of 0.24 cm/year. That figure is conservative, since there was approximately 4-8 cm of cultural material below the deepest charcoal sample that was dated. There is an 800 year break between these dates and the following cluster. This middle group of dates range from 5910 to 5660 calendar years BP from deposits 189 to 160 cm below datum. The calculated accumulation rate here is about 0.12 cm/year. Another 800 year hiatus exists between these dates and the most recent cultural deposits, whose dates range from 4860 to 4380 calendar years BP between 145 and 80 cm. The third group of dates suggests an accumulation rate of about 0.14 cm/year, although a situation similar to the deepest cluster exists in that the cultural deposits associated with the particular group of radiocarbon dates are more extensive in depth than accounted for by those dates. Therefore, the accumulation rates are not entirely accurate in the case of these samples. However, three discrete cultural depositional periods are apparent, with the oldest deposits accumulating somewhat quicker than the second and third episodes of deposition.

The hiatuses in occupation of this part of Rice Ridge could be explained in several ways. Charcoal samples were collected from level bags at the Alutiiq Museum that correspond most closely with the faunal samples that were collected and analyzed. The possibility exists that organic material was present in cultural deposits that would fill these chronological gaps, but was not recovered and dated. However, samples were sought from as many levels as possible with the goal of obtaining dates spanning the depth of the deposits as completely as possible. Alternatively, the hiatuses in occupation may be real but limited to this part of the site. In other words, during the chronological gaps, the occupants of the site lived and disposed of material away from the deposits I have examined. Excavation units were placed in two other parts of the site that yielded Ocean Bay II material, but were apparently not radiocarbon dated (Hausler-Knecht 1991).

Another possible explanation is that the entire site may have been abandoned for these periods of time. Recently, archaeologists and geologists have asserted that changes in local, relative sea level caused by frequent tectonic activity would have been a phenomenon to which the Alutiit would have been well-adapted from the earliest times. Coastal settlements on the Kodiak archipelago were particularly susceptible to the effects of large subduction earthquakes, both in terms of changes in the position of shorelines and subsidence-generated erosion (Fitzhugh 2003:41; Saltonstall and Carver 2002). Unfortunately, little research in the archipelago has been directed towards determining the relationship between tectonic activity and prehistoric human settlement patterns in the region (but see Fitzhugh 1996:269-277; Gilpin 1995:180-182; Mann 1998; Saltonstall 1997; Saltonstall and Carver 2002). Until such work is done around the Chiniak Bay region, the extent and cause or causes of the occupational hiatuses at the Rice Ridge site can only be loosely speculated upon.

Regarding cultural material, the artifacts found at Rice Ridge contain many types that are characteristic of the Ocean Bay I and II periods. Abundant microblades, chipped stone tools and debitage dominate the lithic assemblages in the lower, earlier layers of the site, while the addition of various ground slate tool types characterizes the upper, more recent layers associated with the Ocean Bay II period (Hausler-Knecht 1991; Steffian et al. 2002). Red ochre occupation floor layers, as well as the grinding stones used to process red ochre, are found throughout the deposits of the site. In addition to these tools, which have been found in other Ocean Bay I and II sites across the Kodiak archipelago and parts of the eastern coast of the Alaska Peninsula, this site provides a very rare glimpse at the organic artifact assemblages of people living at this time. Ideal preservation has allowed the recovery of bone points, harpoons, needles, and other artifacts that have no analogue in other Ocean Bay sites in the region and reflect a fully maritime-adapted economy (Hausler-Knecht 1993).

Rice Ridge most likely represents a semi-permanent campsite in which hunter-gatherers brought and consumed a wide range of prey across several seasons. Until the artifact assemblages and structures are analyzed in greater detail, it is difficult to say with confidence that the function of the site had not changed over its 2500 year occupation. Several lines of evidence, however, do point to consistent use of the site. Casual observations of the assemblages in storage at the Alutiiq Museum suggest that the stone and bone tools used at the site at any one time were geared towards hunting large and small game and catching and processing individual fish throughout the occupation of the site. Initial identification of the remains of juvenile harbor seal and various kinds of marine fish and salmon within discrete deposits suggest that Rice Ridge was not seasonally-restricted in its occupation (Hausler-Knecht 1993).

Crag Point (KOD-044)

Crag Point is a large site containing an extensive shell midden and several semi-subterranean house structures dating primarily to the Kachemak period. It is located at the mouth of Anton Larsen Bay on the north shore of Kodiak Island (Fig. 4.1). The site was excavated both in the 1960s by University of Wisconsin's Aleut-Konyag Project and the Kodiak and Aleutian Islands Historical Society, and in 1986 by Bryn Mawr College (Clark 1970, 1997; Hoffman 1987; Jordan and Knecht 1988; Simon 1992). Unlike the Rice Ridge site, the deposits at Crag Point have been exposed to coastal erosion after occupation. Initial investigations in 1964 were prompted because of this erosion, and it was evident in the 1986 investigation that a large portion of the site had further eroded in the interim between excavations (Hoffman 1987).

Like Rice Ridge, Crag Point is adjacent to numerous marine and littoral resources in a location that would provide easy access to sea mammals, marine fish, mollusks and birds. Although small quantities of salmon can be acquired near the site in small streams and along a passage between the mainland and Anton Larsen Island, the nearest river with a significant present-day salmon run is almost 8 kilometers from the site (Hoffman 1987:59). The location of the site would provide a changing suite of food resources for the occupants of Crag Point throughout most of the year (NOAA 1997).

Of the 13 published radiocarbon dates from the Crag Point site, 12 span the Kachemak period into the early Koniag, from 3340±60 to 910±60 B.P., both uncalibrated (Mills 1994). The other date is from an extremely small sample from a very thin Ocean Bay occupation at the base of the cultural deposits. Standard radiometric dating of the sample required an extended lab count and still resulted in very large error terms, 7790±620 radiocarbon years B.P. (Jordan 1992; Mills 1994). Table 4.2 includes the eight published radiocarbon dates for the Crag Point site that are associated with housefloors and midden layers used in this dissertation. Accumulation rates are not calculated for this site or the following sites because the occupation surfaces that were dated were not superimposed horizontally as they were at the Rice Ridge site.

The 1964 excavations revealed an Early Kachemak component, containing artifacts typical of period such as ground stone plummets, large notched pebbles, and both ground slate fragments and red chert flakes, within a black charcoal-rich matrix (Clark 1970). Overlaying this deeper component were layers of shell midden, gravel, and a semi-subterranean house floor with artifact assemblages and radiocarbon dates consistent with a Late Kachemak occupation.

Bryn Mawr College returned to the site in 1986 and excavated 122 square meters covering the shell midden deposit. Two complete semi-subterranean houses were found in the deposits, along with several partial house floors and pit features. Three major stratigraphic distinctions were made while excavating the shell midden layers, based on matrix color and content. These natural layers were designated 1 (near surface, most recent), 2, and 3 (deepest and earliest midden layer). Layer 3 appears to be contemporaneous with the structures: a well-defined and complete structure designated house floor 1B and an almost complete but vaguely-defined structure designated house floor 1A. Two charcoal samples from hearths in House floor 1B yielded uncalibrated radiocarbon dates of 1890±90 and 2190±90 B.P., and a sample from the base of one of the hearths dated to 2380±70 B.P. (Mills 1994). A partial house floor that stratigraphically post-dates house floors 1A and 1B was also uncovered and designated house floor 3A. A deep orange tephra layer, designated layer 4 (or house floor 4 on some of the artifact and faunal sample bags), lies just above sterile glacial outwash deposits, and appears to be an early Ocean Bay occupation. However, the one radiocarbon date and interpretation of the significance of this component remain inconclusive (Jordan 1992).

Interpretation of the functional and seasonal contexts of Crag Point is difficult because of the lack of analyses of materials recovered from these excavations. The 1964 excavation yielded semi-subterranean house structures and a wide array of hunting and fishing implements, suggesting numerous subsistence pursuits as opposed to any specialized site function (Clark 1970), while information about the artifacts recoverd from the 1986 excavations is very limited (Hoffman 1987; see also Jordan 1992). The faunal remains identified from these excavations described below, however, do not offer much information about the season or seasons of occupation at the site. It is assumed in this dissertation that the Crag Point site was used throughout most of the annual cycle for a variety of subsistence pursuits.

Faunal remains were recovered from both the 1964 and the 1986 excavations, and the small sample from 1964 was analyzed and published by Clark (1970:87). 345

specimens were collected during the 1964 excavation, presumably by hand. Of these, 175 or just over 50% were harbor seal (*P. vitulina*), 96 were identified as "fox" (*V. vulpes*), 23 as dog (*C. familiaris*) and 23 as porpoise (Family Phocoenidae). The remainder was identified as fur seal, sea lion, sea otter, river otter, and bear. Antler and beaver teeth were observed as exotic artifact raw materials, and whale bone was noted but not quantified. The assemblage from the 1986 excavation provides a much greater quantity of faunal remains that were obtained from a variety of depositional contexts (both house floor and midden) and temporal units, and were recovered both by hand and from ¼" screens during excavation. For these reasons, analysis of the faunal remains from the 1986 excavation of house floors 3A, 1B and 4, and from midden layers 1, 2 and 3 was performed for this dissertation in order to obtain data comparable to those from the Rice Ridge assemblage.

Uyak (KOD-145)

The Uyak site, also known as "Our Point" was the location of the first extensive archaeological investigation on Kodiak Island (Hrdlicka 1944). Located near the junction of Larsen Bay and Uyak Bay on the northwest coast of Kodiak Island, this large prehistoric village site covers a point of land in the present town of Larsen Bay (Fig. 4.1). Hrdlicka, who excavated the site during several seasons in the 1930s as part of the Smithsonian Institution's anthropological survey of Alaska, noted shell midden deposits as thick as 6 meters in some places (Heizer 1956:8). Later excavations led by Amy Steffian for her dissertation research at the University of

Michigan and assisted by Bryn Mawr College in 1987 and 1988 uncovered 14 structures and numerous other construction features along with midden deposits (Steffian 1992a).

Hrdlicka's research has drawn considerable attention recently for his quest to obtain Native American human skulls for osteometric analyses (Bray and Killion 1994; Thomas 2000). In the process, he also created the first culture historical scheme for Kodiak Island. From his division of the midden deposits into Upper, Middle, and Lower layers and Heizer's (1956) subsequent attempts to summarize the results of the excavations, Hrdlicka postulated a two-phase prehistoric sequence of earlier Kachemak inhabitants who were replaced at some point by Koniag people, the cultural ancestors of the post-contact Alutiiq. Kachemak and Koniag phases remain part of the culture historical scheme today but the replacement hypothesis has been generally discounted for *in situ* cultural development (Jordan and Knecht 1988; Knecht 1995; Steffian 1992a), although some archaeologists maintain replacement of Kachemak culture on the archipelago by Thule migrations from the Bering Sea (Dumond 1987, 1988a, 1988b, 1994).

The 1987 and 1988 excavations focused on the portion of the site away from the small peninsula jutting into Larsen Bay, representing occupation during the Late Kachemak period that did not have the overlying Koniag component present in the areas of Hrdlicka's excavations. The excavations also recovered large quantities of faunal remains from the shell midden deposit. The five radiocarbon dates obtained from five different structures located across the breadth of the site range from

1320±70 BP to 1130±70 BP, uncalibrated (Steffian 1992a:154). The three dates associated with housefloors examined in this dissertation are listed in Table 4.2. Three of these housefloors were separated stratigraphically and date to the beginning, middle, and endpoint of this range. Having been completely excavated and their contents screened to recover artifacts and faunal remains, faunal assemblages from these three housefloors, designated 7, 10, and 11, and a midden sample were analyzed for this dissertation. Uyak is assumed in this dissertation to have been occupied for most of the year because of the thickness of the midden deposits, the inferred amount of effort involved in construction of the semi-subterranean structures, and the wide variety of tools and ceremonial artifacts found at the site.

Settlement Point (AFG-015)

Settlement Point is a Koniag period village located on Afognak Island, about fifteen kilometers from the north shore of Kodiak Island across Marmot Bay (Fig. 4.1). The site sits on a landform that has changed a great deal since its initial occupation approximately 600 years ago because of tectonic activity. The site was originally recorded in the 1970s (Workman and Clark 1979) and was extensively excavated as part of the Afognak Native Corporation's *Dig Afognak* program (Saltonstall 1997). During this project, seven house depressions and part of an eighth were mapped and most were excavated along with several cubic meters of the substantial midden deposits covering part of the site. Twelve radiocarbon dates were obtained by the principal investigator from various house and midden contexts, indicating that Settlement Point was initially occupied during the Early Koniag phase and semi-subterranean houses continued to be built until approximately 300 years ago. Dates for the contexts from which faunal data used in this dissertation came from are listed in Table 4.2.

The house structures at Settlement Point had from one to seven side rooms attached to a main room with numerous storage pits and boxes. Many of the structures contained an abundance of incised pebbles, which is a further indication of an Early Koniag occupation. Other artifacts indicate activities such as woodworking, fish processing, and hunting. The earliest structure, designated House 1, had an occupation floor with exceptional bone preservation because of an overlying shell midden deposited after the house was abandoned. Faunal remains from this house floor were recovered from 1/4" and 1/8" mesh screens during excavation, and were analyzed by Megan Partlow (2000) for her dissertation. She also analyzed a sample of faunal remains from the exterior shell midden to contrast depositional contexts of housefloors and middens. The careful recovery and analysis of the faunal remains provided Partlow with an ideal data set to test the hypothesis that increasing use of salmon accompanied changes in Koniag house design and storage strategies. An examination of these data in terms of my hypotheses and predictions is included in my dissertation.

Faunal Assemblages: Analysis Methods and Protocol

The four archaeological sites described above are located at different points along the northern coast of Kodiak Island and southern coast of Afognak Island, and were excavated by different principal investigators with different research goals. However, all of these researchers recognized the importance of careful recovery of faunal remains for future analysis, and in the case of Settlement Point this analysis actually occurred shortly after excavation. Deposits from all of these sites were passed through at least ¼" mesh screens, and 1/8" screens as well at Settlement Point. The faunal remains from Rice Ridge, Crag Point, and Uyak were boxed up immediately after excavation and shipped to Hunter College, CUNY for analysis. This analysis never occurred, and I received permission from the landowners of these sites to transfer the animal remains to the University of Washington in 2001 for my dissertation research (Appendix B).

The volume of fauna from each site was quite large, so samples from each assemblage were taken. A 100% sample of fauna from a contiguous block of four 2 meter square excavation units was chosen for the Rice Ridge site. The units in this part of the site offer the greatest diachronic span of the deposits, with well-stratified house floor layers interlaced with shell midden layers. The four units chosen were dug concurrently during the summers of 1988 and 1989 down to sterile glacial deposits. From the Crag Point assemblage, 100% samples were taken from transitional Kachemak-Koniag house floor 3A, which was partially excavated, and from early Late Kachemak house floor 1B, which was completely excavated. Layer

4, the thin Ocean Bay deposit, yielded a small sample of fish bones that were completely analyzed. Additionally, three excavation units were chosen that contained the natural midden strata and lay outside any of the house structures. The faunal assemblages from these three units were completely analyzed as well. At the Uyak site, several house floor deposits were chose that span the occupation, from which 100% of the fauna recovered were analyzed.

A spreadsheet was created for each site, and information on each analyzed specimen was entered into them. These spreadsheets were then transformed into SPSS databases for statistical analysis. Each specimen was identified to the finest taxonomic level possible given the available comparative material (Appendix A), as well as from which skeletal element and element portion the specimen represents. Siding was determined, when possible, if the specimen came from a paired element. For mammal specimens, rough age categories of adult, juvenile, and infant were determined when possible. Butchery marks were also noted when present. The same taxonomic and skeletal data were collected for fish specimens, except for age categories and cutmarks (which were not discernable in any fish specimens except one, a large halibut quadrate). Single landmarks were established for all fish skeletal elements. If present on a specimen, the landmark could then be considered if calculating MNI or MNE. Additionally, the width of Pacific cod angular, dentary, maxilla, and premaxilla specimens with landmarks present were measured in millimeters using a set of Mitutoyo digital calipers. For all specimens, a comments field was used to denote any gnawing, charring, calcining, pathologies, or other unusual conditions that were observed. After analysis, the specimens with the same taxonomic, skeletal, and taphonomic characteristics from the same provenience were bagged together with an acid-free paper tag detailing all provenience and analysis information.

The taxonomic identifications performed for this analysis were dependent upon several sources of comparative skeletal material. Appendix A lists the comparative skeletons that were used, which represent native and introduced taxa found on the Kodiak archipelago and neighboring Alaskan mainland today. Most were borrowed from the Thomas Burke Memorial Museum at the University of Washington, in which most of the non-introduced species of terrestrial mammals, as well as sea mammals, were readily available from both sexes and different ages. Other skeletons were available from the University of Washington Anthropology Department, other graduate students in the department, and from my personal collection, which are primarily fish skeletons used to identify all fish specimens. Several guidebooks were used to supplement the comparative collections, but were not used by themselves for final taxonomic identification. Identification of occasional human specimens found in the assemblages was made with comparative material at the University of Washington Department of Anthropology, along with manuals by Bass (1987) and White (2000). Books used with mammal specimens include Brown and Gustafson (1990) for isolated artiodactyl remains, Kellogg (1925) for otariid remains, and Gilbert (1990) and Hillson (1992) for other mammal bones.

Cannon (1987) was used as a supplement to identify fish specimens and Morrow (1979) aided in identification of fish otoliths.

Table 4.1 Rice Ridge (KOD-363) Radiocarbon Dates
Calibrated using INTCAL98 (Stuiver et al. 1998)

Sample #	Date (radiocarbon years B.P.)	Calib. Date, 1s (years B.P.)	Calib. Date, 2s (years B.P.)	Site Context, Material
Dates obtained from samples submitted during and shortly after excavation (Mills 1994)				
Beta-43135	3850 ± 80	4413-4098	4518-3993	Ocean Bay II Layer
Beta-43134	3860 ± 90	4417-4098	4529-3990	Ocean Bay II Layer
Beta-26230	4310 ± 60	4972-4845	5041-4656	Ocean Bay II Layer
GX-14674	5030 ± 250	6165-5484	6309-5096	Hearth outside structure, Ocean Bay I Layer
GX-14673	6180 ± 305	7420-6729	7589-6319	Ocean Bay I Layer
Dates obtained for this dissertation				
Beta-171559	3900 ± 70	4420-4240	4520-4100	Lev A - Charcoal lens in midden, 80 cmbd
Beta-171560	4310 ± 80	4960-4830	5050-4640	Lev A - Sample from trench, 87 cmbd **(ext. count)**
Beta-171564	4100 ± 70	4810-4450	4830-4420	Lev A - 145 cmbd in pit
Beta-171561	3930 ± 80	4500-4250	4560-4150	Lev B - Hearth on occupation layer, 112 cmbd **(ext .count)**
Beta-171562	5070 ± 40	5900-5740	5920-5720	Lev C - Base of midden/above ochre, 160 cmbd **(AMS)**
Beta-171563	5130 ± 40	5920-5890	5940-5750	Lev D - Between ochre floor layers, 170 cmbd **(AMS)**
Beta-171565	4960 ±110	5880-5600	5920-5470	Lev F - Base of ochre floor, 189 cmbd **(ext. count)**
Beta-171566	6050 ± 40	6940-6800	7000-6770	Lev G - Charcoal-stained ashy midden, 215 cmbd **(AMS)**
Beta-171567	5990 ± 60	6890-6740	6980-6670	Lev G - Charcoal-stained ashy midden, 203 cmbd **(AMS)**
Beta-171568	6090 ± 150	7190-6750	7300-6630	Lev H - Charcoal layer in midden, 205 cmbd **(ext. count)**
Beta-171569	5980 ± 40	6860-6750	6900-6710	Lev H - Loose fill layer in midden, 204 cmbd **(AMS)**
Beta-171570	5970 ± 40	6850-6740	6890-6690	Lev I - Midden fill on floor, 235 cmbd **(AMS)**
Beta-171571	6060 ± 50	6980-6800	7010-6760	Lev I - Mottled ash and charcoal lens, 219 cmbd **(AMS)**
Beta-171572	6040 ± 40	6920-6800	6990-6760	Lev I - Red ochre floor w/pit features, 237 cmbd **(AMS)**
Beta-171573	5970 ± 50	6860-6730	6900-6670	Lev J - Brown/tan ashy midden, 225 cmbd **(AMS)**
Beta-171574	6020 ± 100	6990-6730	7170-6650	Lev J - Tan/clayey midden, 214 cmbd
Beta-171575	5990 ± 40	6870-6750	6900-6730	Lev J - Tan/clayey midden, 234 cmbd **(AMS)**
Beta-171576	6580 ± 220	7650-7270	7840-7000	Lev J - Shell band in tan midden, 216 cmbd **(ext. count)**
Beta-171577	6040 ± 50	6940-6790	7000-6750	Lev J - Tan/clayey midden, 225 cmbd **(AMS)**
Beta-171578	6080 ± 90	7020-6790	7220-6710	Lev K - , 250 cmbd **(ext. count)**
Beta-171579	6140 ± 60	7160-6920	7220-6860	Lev K - Charcoal-stained floor, 252 cmbd
Beta-171580	5900 ± 60	6760-6660	6860-6570	Lev K - Organic stain in tephra layer, 256 cmbd **(AMS)**

Table 4.2 Crag Point, Uyak, and Settlement Point Radiocarbon Dates
[Crag Point and Uyak dates calibrated using CALIB (Stuiver and Reimer 1986), Settlement Point dates calibrated using CALIB 3.0 (Stuiver and Reimer 1993)]

Site	Sample #	Conventional Date (years B.P.)	Calib. Date, 1s (yrs B.P.)	Calib. Date, 2s (yrs B.P.)	Site Context, Material	Reference
Crag Point	Beta-20122	910 ± 60	923-739	940-700	HF3A, slate box, charcoal	Mills 1994
	Beta-45944	910 ± 70	926-733	960-690	HF3A, charcoal	Mills 1994
(KOD-044)	Beta-20533	1890 ± 90	1935-1722	2049-1611	HF1B Hearth, charcoal	Mills 1994
	Beta-48044	2000 ± 70	2050-1878	2139-1820	L2 Midden, Base, charcoal	Mills 1994
	P-1057	2033 ± 52	2057-1935	2139-1880	L2 Midden, charred wood	Mills 1994
	Beta-48043	2190 ± 90	2337-2065	2349-1959	HF1B Hearth	Mills 1994
	Beta-45943	2380 ± 70	2701-2343	2719-2218	HF1B, Base, charcoal	Mills 1994
Uyak	Beta-34281	1130 ± 70	1140-964	1236-930	Str2/HF10, charcoal	Mills 1994, Steffian 1992a
(KOD-145)	Beta-34283	1270 ± 100	1290-1070	1350-970	Str11/HF7, charcoal	Mills 1994, Steffian 1992a
	Beta-34282	1320 ± 70	1299-1177	1350-1070	Str1/HF11, charred wood	Mills 1994, Steffian 1992a
Settlement Point	Beta-101551	620 ± 50	695-600	710-580	House 1, Hearth, charcoal	Partlow 2000
(AFG-015)	Beta-118300	570 ± 60	690-570	710-560	House 1, Floor, charcoal	Partlow 2000
	Beta-101912	440 ± 50	570-520	590-370	Midden L2, Sq 16, charcoal	Partlow 2000
	Beta-114096	370 ± 80	560-360	590-330	Midden L1, Sq 16, charcoal	Partlow 2000
	Beta-101913	390 ± 50	550-370	570-360	Midden L2D, Sq 32, charcoal	Partlow 2000
	Beta-114098	340 ± 60	530-350	560-335	Midden L2G, Sq 34, charcoal	Partlow 2000

Table 4.3 Stratigraphic summary of the Rice Ridge deposits examined in this dissertation

Stratigraphic Layer	Units	Dates (radiocarbon years)	Disposal Context	Description
Katmai Ash	2,3,5,6	AD 1912	-	Ashfall from Novarupta eruption
A	2,3,5,6	3900±70 4100±70 4310±80	Midden	Black, organic rich sediment with loose rubble and thin shell bands
B	3,5,6	3930±80	Floor	Charcoal and red ochre-banded occupation surface with hearth and pit features
C	2,3	5070±40	Midden	Mixed rocky / clay sediment with shell flecks
D	3,5,6	5130±40	Floor	Red ochre-stained occupation surface
E	3,5,6	n.d.	Midden	Shell midden mixed with brown weathered ash
F	3,5,6	4960±110	Floor	Red ochre surface with "cooking pit" features
G	3,5,6	5990±60 6050±40	Midden	Pebbly, brown weathered ash with small pockets of shell midden fill
H	2,5,6	5980±40 6090±150	Midden	Dense shell midden and some grayish-brown ashy and rocky matrix
I	2,5,6	5970±40 6040±40 6060±50	Floor	Red ochre-stained occupation layer with charcoal and several gravel-filled pit features
J	2,3,5,6	5970±50 5990±40 6020±100 6040±50 6580±220	Midden	Fairly compact tan weathered ash and fragmented bone, shell and charcoal
K	5,6	5900±60 6080±90 6140±60	Floor	Basal red ochre and black charcoal-rich occupation floor - basal cultural layer
Sterile	2,3,5,6		-	Culturally-sterile orange tephra

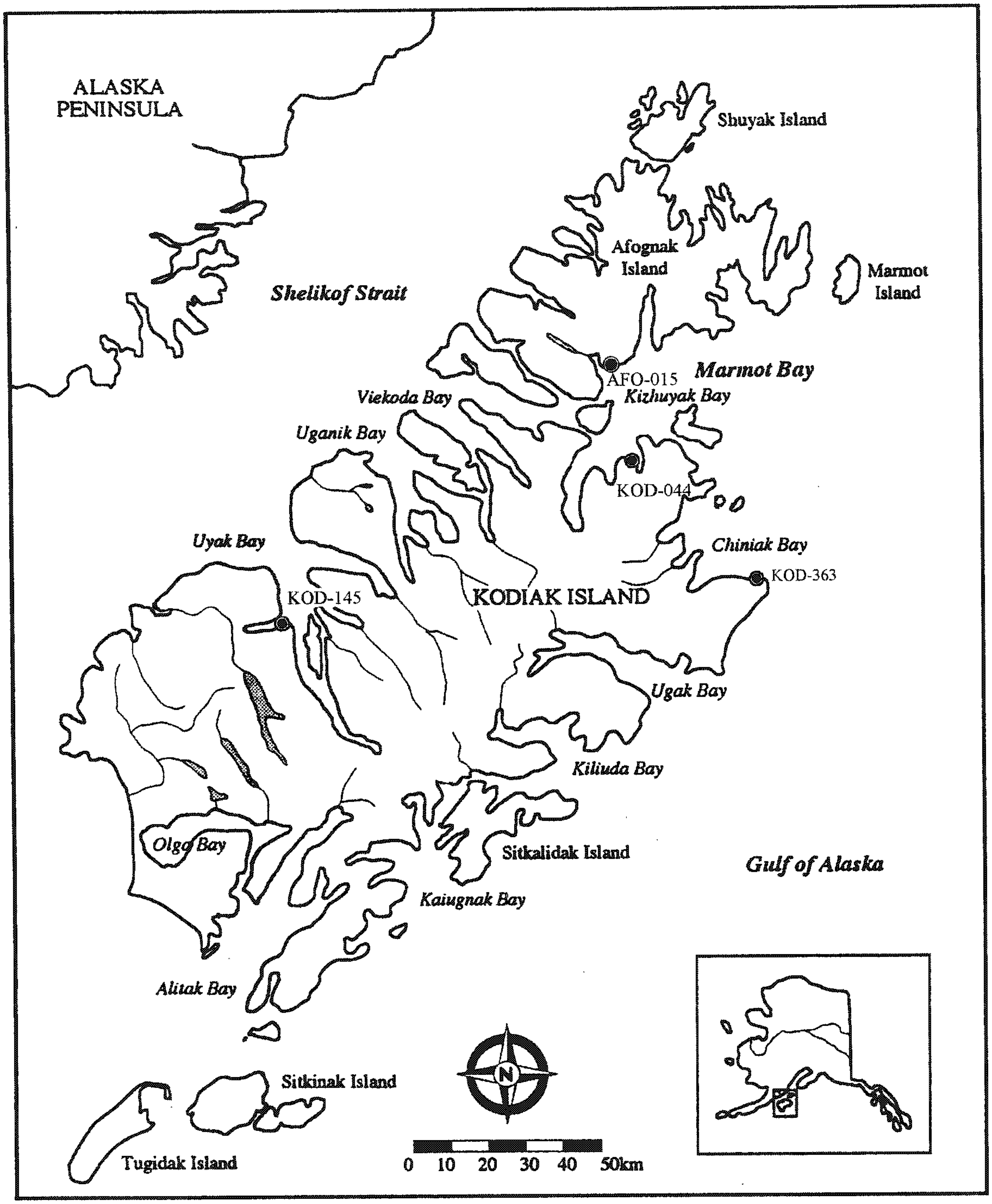


Fig. 4.1 Archaeological Sites with Fauna Analyzed for this Dissertation
(Adapted from Steffian et al. 1998:2)

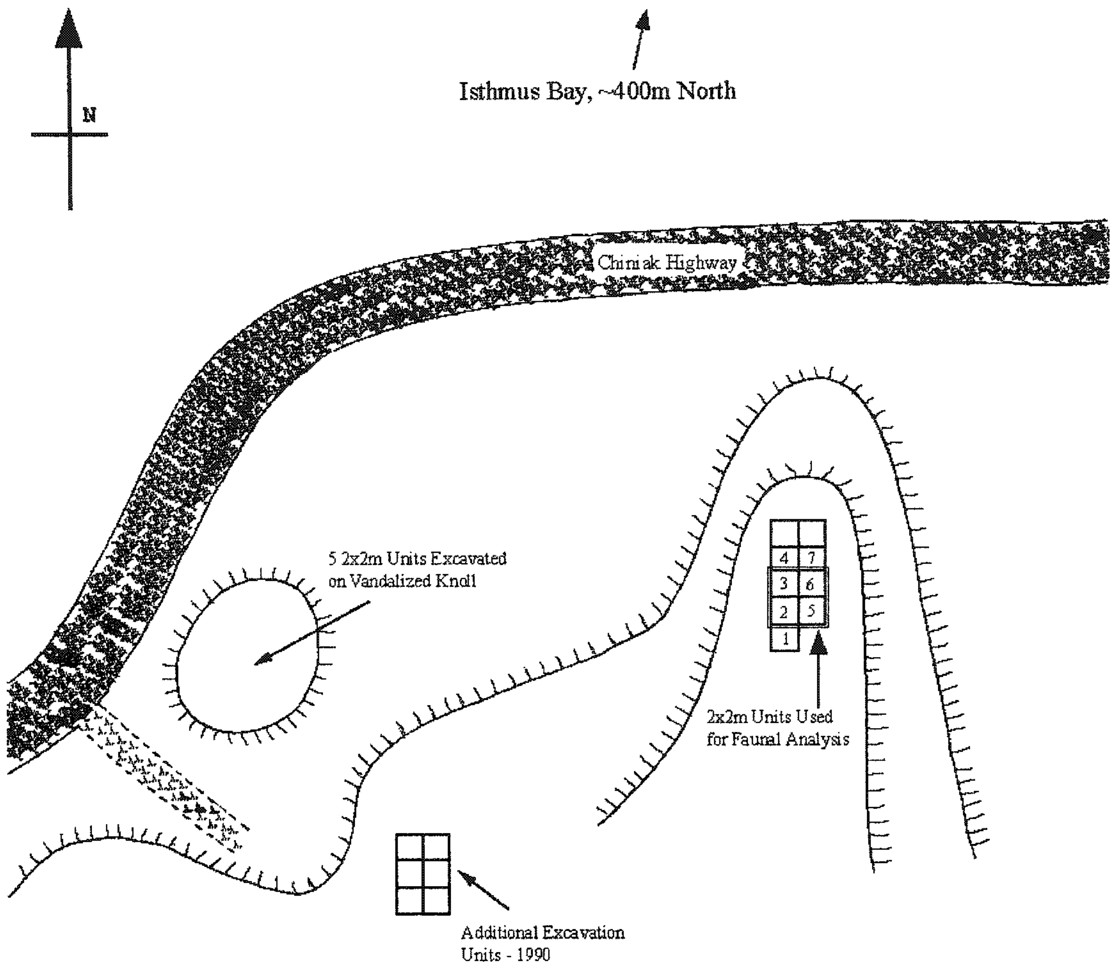


Fig. 4.2 Rice Ridge (KOD-363) Schematic Map and Excavation Units

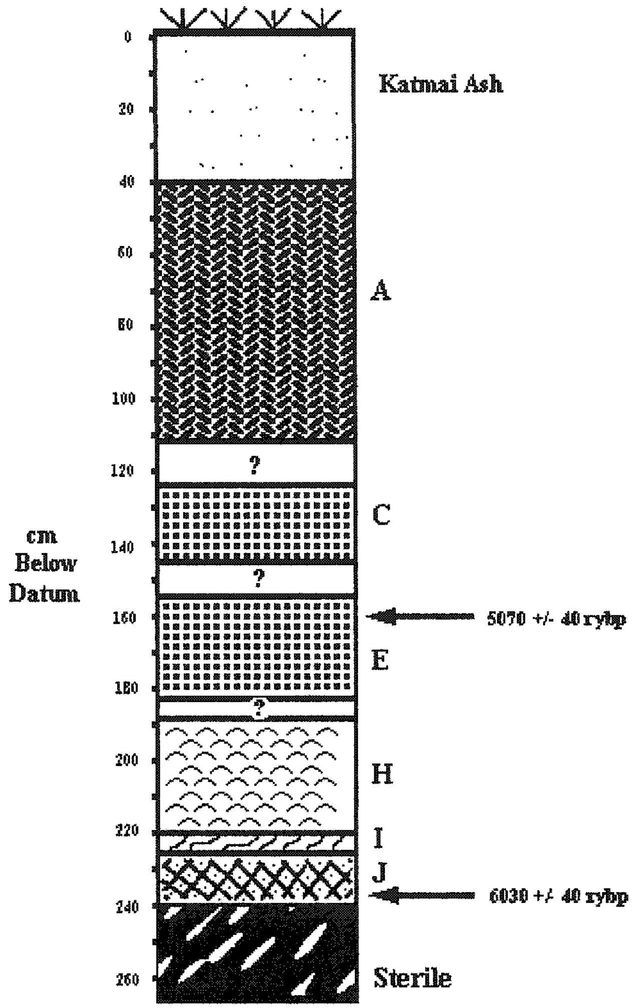


Fig. 4.3 Schematic Profile of Rice Ridge Unit 2

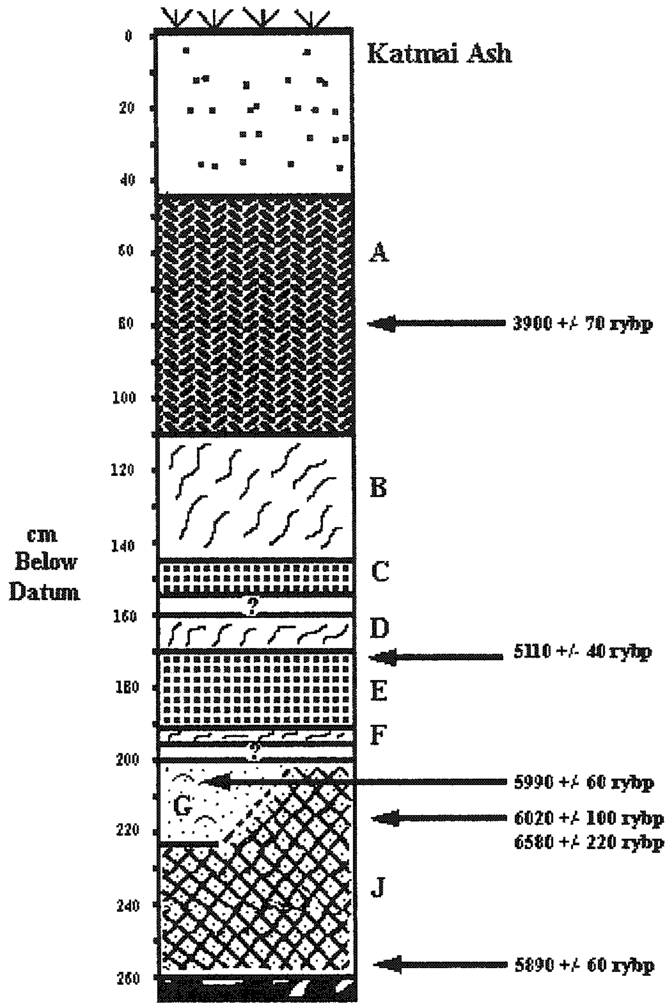


Fig. 4.4 Schematic Profile of Rice Ridge Unit 3

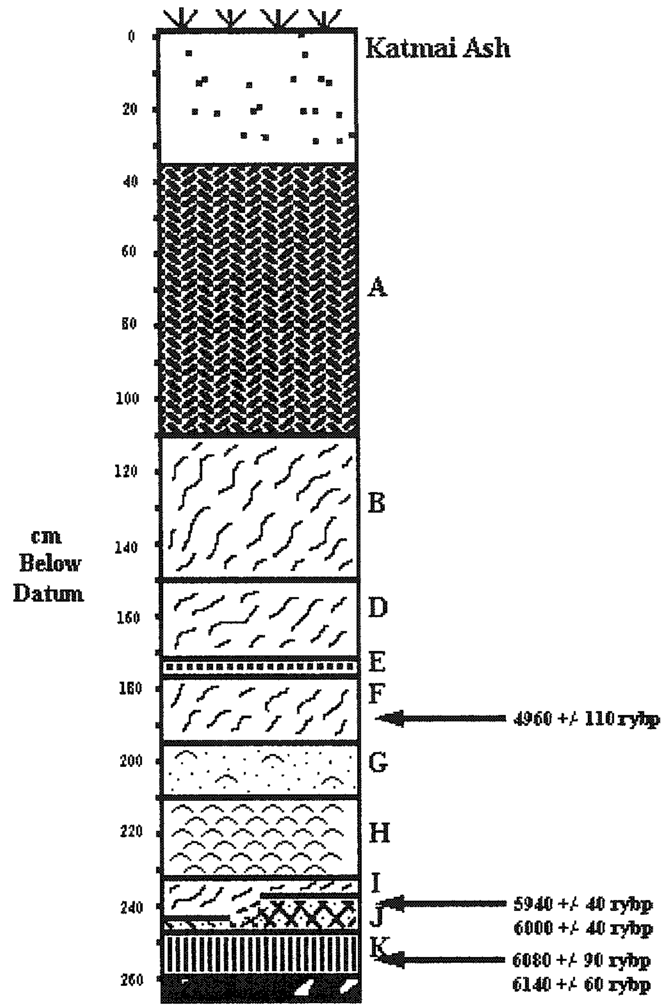


Fig. 4.5 Schematic Profile of Rice Ridge Unit 5

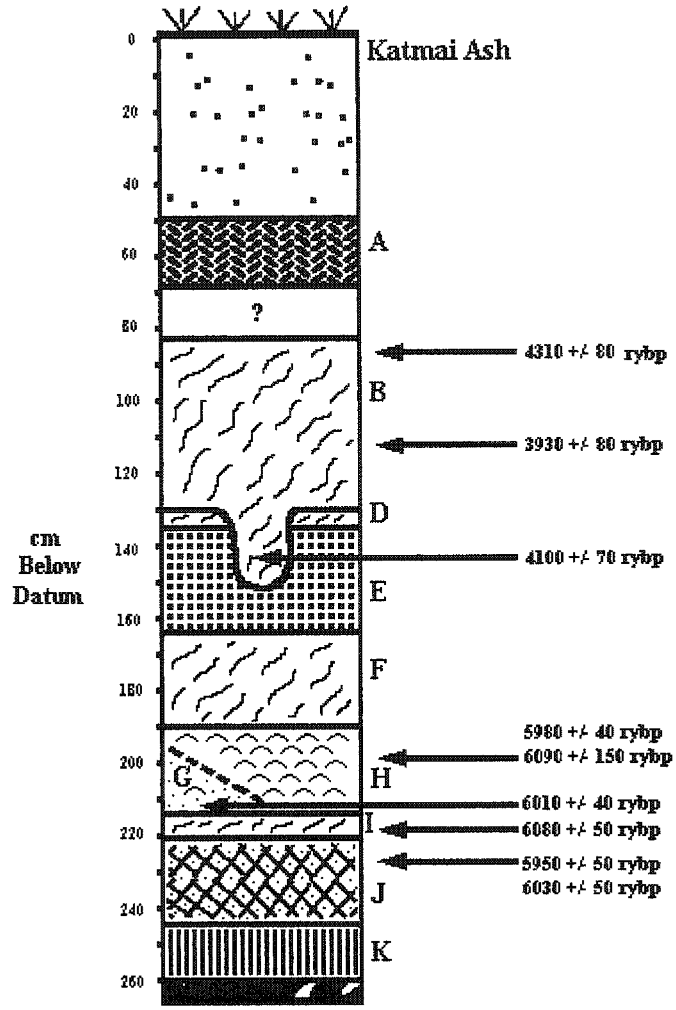


Fig. 4.6 Schematic Profile of Rice Ridge Unit 6

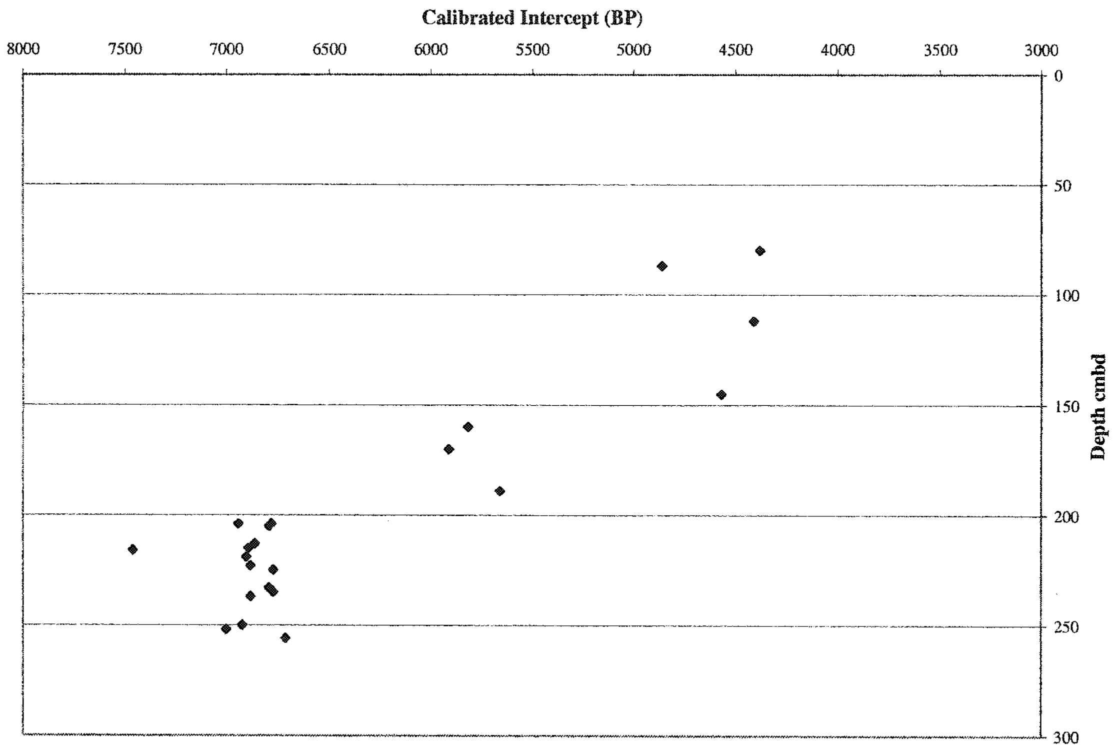


Fig. 4.7 Rice Ridge Age-Depth Profiles: Site-Wide (Units 2, 3, 5 and 6)

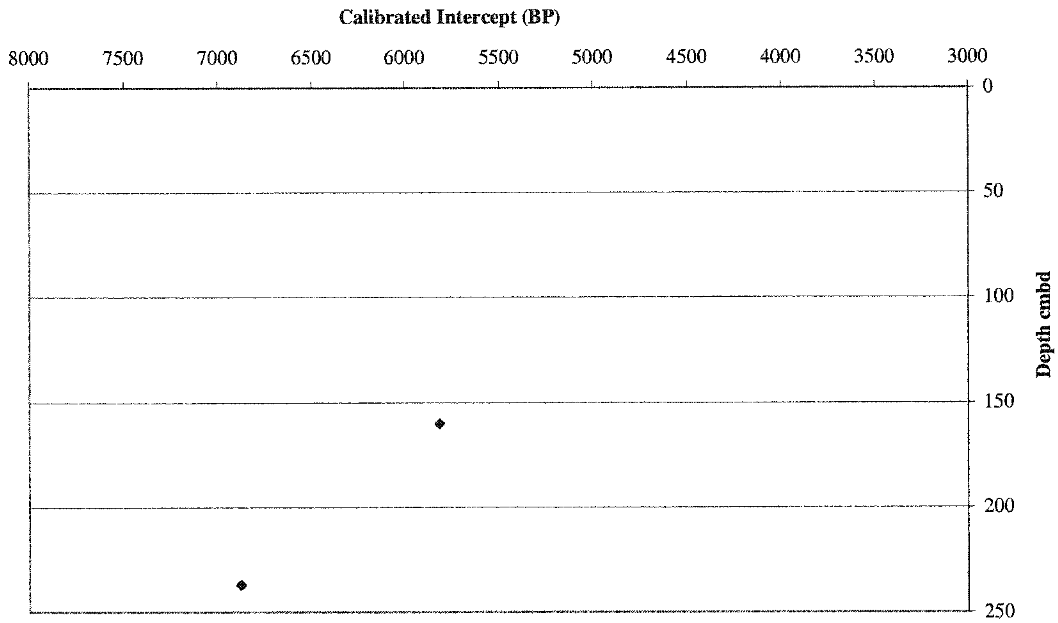


Fig. 4.8 Rice Ridge Age-Depth Profiles: Unit 2

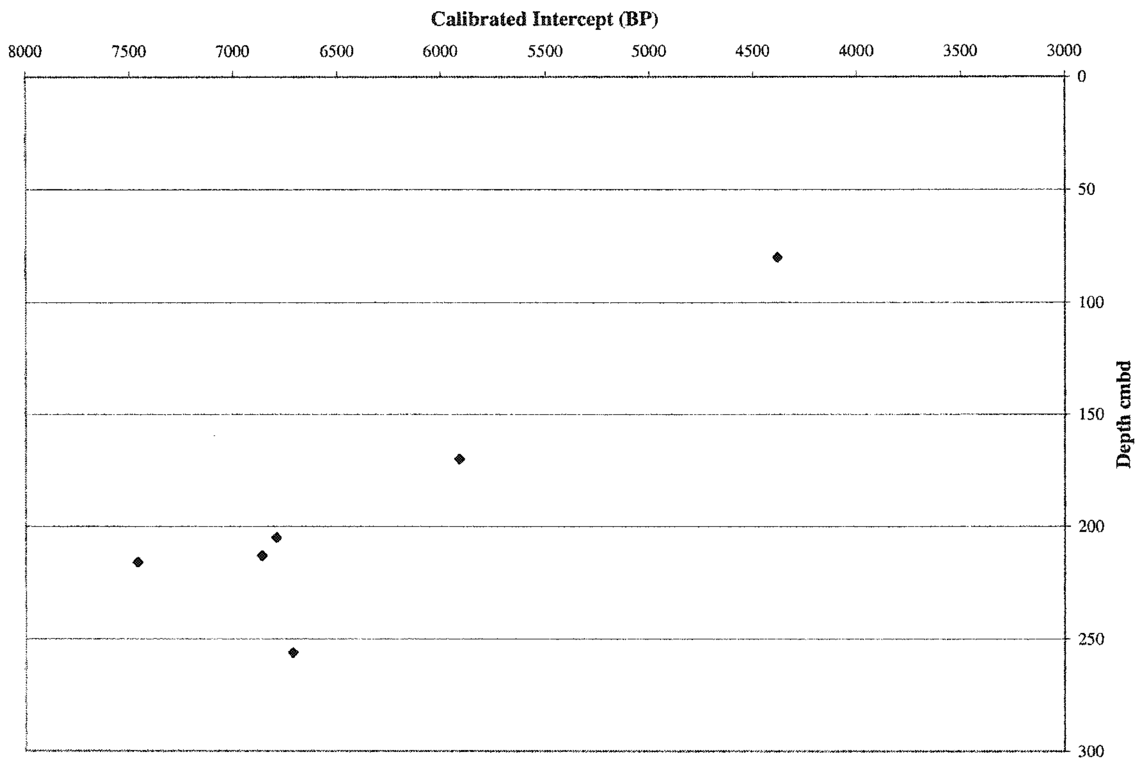


Fig. 4.9 Rice Ridge Age-Depth Profiles: Unit 3

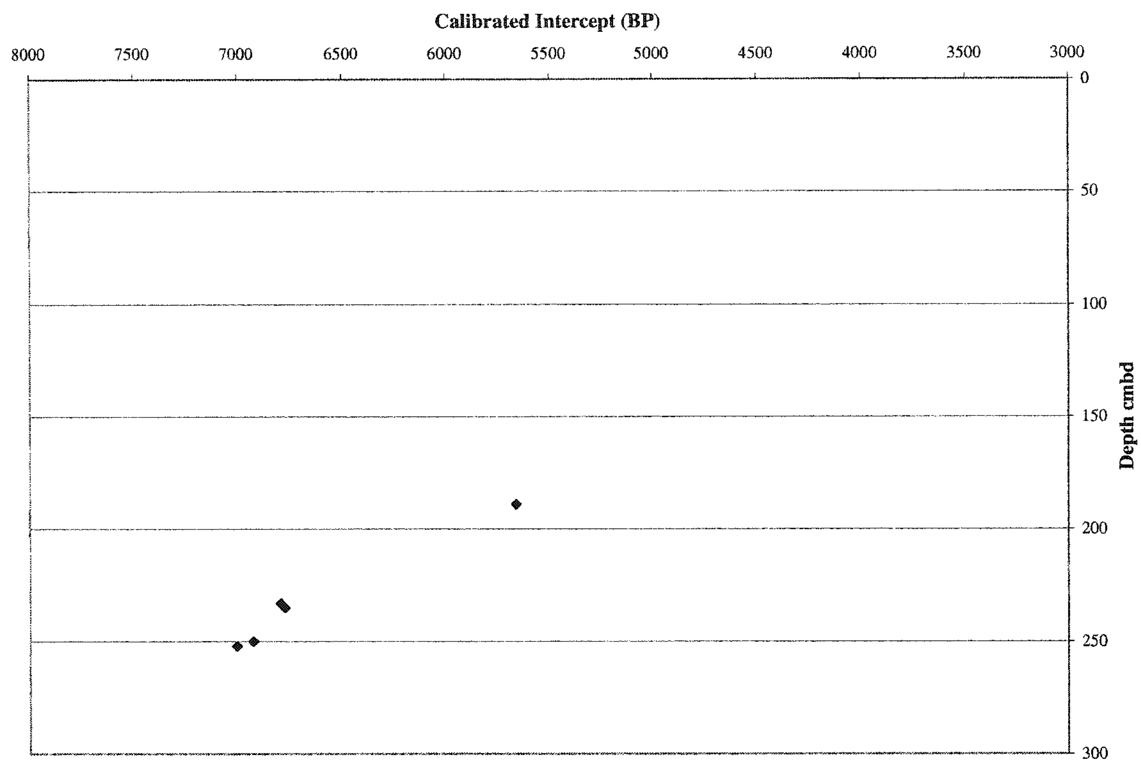


Fig. 4.10 Rice Ridge Age-Depth Profiles: Unit 5

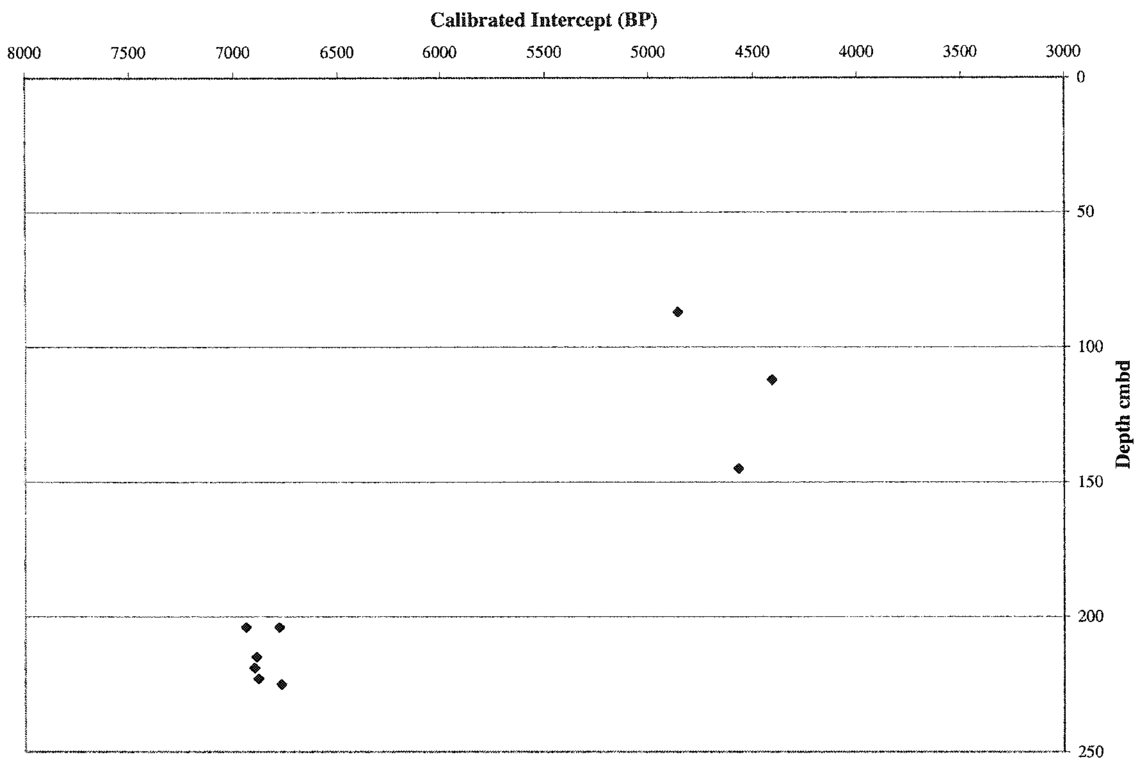


Fig. 4.11 Rice Ridge Age-Depth Profiles: Unit 6

Chapter 5:

Did Resource Intensification Occur on Kodiak? Relative Taxonomic Abundance and Resource Intensification

This chapter describes testing of the intensification hypothesis introduced in Chapter 3. Hunter-gatherer resource intensification implies a decrease in foraging efficiency, characterized by greater reliance on the harvest of lower-return prey. In the case of the Kodiak archipelago, the resource depression model predicts that declining encounter rates with sea mammals led to resource intensification in the form of increased focus on marine fish as well as salmon before the advent of mass-harvesting technology that would make pursuit of those prey more profitable. One measure of resource intensification that can be quantified using the archaeological record is relative taxonomic abundance of the remains of high- and low-ranked prey.

The proportion of high-ranked prey remains to low-ranked prey from a particular resource patch offers a measure of foraging efficiency within that patch. Decreasing proportions of high-ranked prey over time may imply resource intensification. Similarly, decreases in the proportion of prey remains from more profitable patches to prey from less profitable patches over time may indicate intensification between patches. The focus of this chapter is the investigation of these proportions to see if the intensification hypothesis is supported.

Taxonomic Abundance

Analysis of the Rice Ridge, Crag Point, and Uyak faunal assemblages yielded 14,474 taxonomically identified mammal and fish specimens. All of these are from species that currently inhabit the archipelago and its surrounding waters with the exception of a few marmot and cervid specimens. Because all of the tests in this dissertation use data given explicitly in the Tables, I do not put the raw data in a formal attached appendix. Raw tabular data for Rice Ridge, Crag Point, and Uyak, including both identified and unidentified specimens, are available as a CD-ROM from the author.

Tables 5.1-5.4 display the number of identified specimens (NISP) for each taxon from the three sites that were analyzed, along with data from the Settlement Point site presented by Partlow (2000:156, 194; personal communication 2003) that are also used to test this resource depression model. Taxonomic abundances are given for each stratigraphic layer or housefloor deposit from each site in columns arranged chronologically from left to right, grouped by depositional contexts of housefloor and midden. Although Minimum Number of Individuals (MNI) can be calculated from the raw data, the tables in this chapter and subsequent analyses in this chapter are based on NISP. Grayson (1984) establishes the rationale for using NISP to determine relative taxonomic abundance.

Table 5.1 lists the taxonomic abundances for the floor and midden layers of the Rice Ridge site. Except for the most recent midden stratum, Layer A, sea otter comprise the dominant mammalian taxon in the assemblage. Harbor seal and Steller sea lion are also abundant relative to terrestrial mammals. Tundra vole specimens may represent food resources but are assumed here to represent post-depositional intrusions. Two marmot specimens, a mandible and an innominate, and two larger rodent incisors (one approximately porcupine-sized and one beaver-sized) are noteworthy because there is no indication that marmots or other large rodents inhabited the archipelago before Russian colonization (Rausch 1969; USFWS 1987).

Fish remains at Rice Ridge are dominated by Pacific cod and salmon. Including specimens only identified to the cod family taxonomic level, primarily vertebra centrum fragments, codfish are the dominant taxon at the site as a whole and within each stratum except for salmon-dominated midden Layers G and A. Except for the four jaw elements that can be confidently identified as Pacific cod, the identification of other elements to this species are somewhat tentative and based primarily on size. Other taxa of fish found consistently throughout the site are sculpins (including Irish lord), flatfish such as flounder, sole and halibut (although specimens confidently identified to the species level as halibut are few), and herring. Greenling and rockfish are also found sporadically in the site. One calcified vertebra of a cartilaginous fish, more likely a shark than a skate based on its size, was also found.

Table 5.2 lists the abundances of fauna from the Crag Point site, including remains from Houses 4, 1B, and 3A, and samples from midden levels 3, 2, and 1. Unlike Rice Ridge, whose mammalian fauna is dominated by sea otter, the mammal assemblage from Crag Point is dominated by harbor seal. Larger canids represented by dog- or wolf-sized specimens are also abundant and even surpass harbor seal in midden level 2. Specimens identified as red fox dominate the small mammal assemblage of house 3A. The porpoise family, including Dall's and harbor porpoise, is the second most abundant sea mammal taxon in the entire assemblage. Identified terrestrial mammals besides canids are found in smaller numbers and include brown bear and ermine.

One cervid specimen, a scapula with numerous cutmarks recovered from House 1B, is noteworthy because artiodactyls are not considered native to the archipelago (USFWS 1987). There has been some debate regarding the possibility of a caribou population that could have survived from the Pleistocene in a refugium on the southwest part of Kodiak Island (Fitzhugh 1996; Rausch 1969). There is, however, almost no physical evidence of such a population (but see Fitzhugh 1996:177-178). The cervid specimen from House 1B is deer-sized and cutmarked so heavily that it may have been used, or intended to be used, as a tool. The rarity of artiodactyl remains in all analyzed faunal assemblages from the archipelago and the singular nature of this specimen in the Crag Point assemblage lead me to conclude that it was brought over from either the Alaska or Kenai Peninsula for purposes other than subsistence.

The fish remains from Crag Point are somewhat similar in taxonomic composition as Rice Ridge. Cod, as both specimens identified as Pacific cod or walleye pollock, as well as specimens only identified to the cod family, dominate the fish assemblage of every house and midden layer except house 4, which contains only fish remains dominated by salmonids. Compared to Rice Ridge, more specific taxa were identified, including great sculpin and Irish lord in the sculpin family, halibut and starry flounder in the flatfish order, and lingcod in the greenling family. Also, herring are not present in the Crag Point assemblage despite use of the same screen mesh sizes as was used at Rice Ridge. Although species distributions may very well have been somewhat different than they are today, it is interesting to note that there presently are no herring spawning grounds within about 10 km of Crag Point, unlike the locations of the other sites (NOAA 1997).

Table 5.3 lists the taxonomic abundances of mammals and fish from the Uyak site. Similar to the Crag Point site, the mammalian fauna from Uyak are dominated by harbor seal. Red fox are relatively abundant as well. Besides harbor seal, Steller sea lion and sea otter remains were identified in smaller numbers, along with a few remains only identified as eared seal and one femur confidently identified as northern fur seal. Three cervid specimens, two from Structure 11 and one from Structure 10, were identified as well: two cut-marked scapula fragments and part of the proximal end of a metapodial, respectively.

Like the other sites, both cod and salmon dominate the fish bone assemblage at Uyak, with Pacific cod being the most abundant. Specimens identified only to the cod family and walleye pollock specimens are relatively few compared with Rice Ridge and Crag Point. Salmonids are the most abundant fish taxon in midden layer 1A, although there are only 10 identifiable fish bones in this layer.

Table 5.4 lists the identified mammal and fish specimens from Settlement Point, based on Partlow's (2000) research. It is modified from her dissertation by the exclusion of specimens found in the 1/8" screen fraction so the data is comparable to data from the other sites (Partlow, personal communication 2003). She described the results of her analysis of the assemblage in terms of house floor and midden disposal context. The composition of mammal remains from House 1 is similar to that of the other sites I analyzed. Harbor seal is the most abundant, followed by delphinids and canids, a few whale bone fragments, and one sea otter specimen. The midden contains a greater overall abundance of mammal remains. Like the house context, harbor seal is the most abundant mammal, followed by dolphins, whale, canids, river otter, and Steller sea lion.

The fish fauna from both house and midden contexts at Settlement Point show an interesting pattern based upon disposal contexts. Overall, the taxa and their relative abundances are similar to the other sites. Salmonid remains are very abundant along with cod, which she identifies to the family level. In the house deposits, salmonids outnumber all other fish taxa including cod almost 3 to 1. In the midden, however, there are almost twice as many cod remains as salmonids. After testing several possible explanations for this difference, including sampling error and differential preservation, which she dismisses, Partlow (2000:156-160) concludes that disposal behavior by the occupants of the site probably explains this difference in relative abundance between contexts. In relatively smaller abundance in both the house and midden deposits are a variety of sculpin, flatfish, greenling, and rockfish remains, as well as specimens from either a skate or shark.

The various animal taxa identified from these four archaeological sites reflect a consistent reliance upon mammals and fish that were locally available, some seasonally and some year-round. Further examination of the relative taxonomic abundance within and between sites sheds light on changes in foraging efficiency over time. This is the primary means of testing whether or not prehistoric resource intensification occurred on Kodiak. Before I discuss relative taxonomic abundance within the marine and riverine resource patches and between the two patches as well, I introduce the statistical techniques used to quantitatively test the resource intensification hypothesis.

Quantitative Methods

NISP values of certain taxa from the assemblages described above are used to calculate relative taxonomic abundance in two different ways: as taxonomic indices that give a ratio of high-ranked prey NISP to high- and low-ranked prey, and separate NISP values of high- and low-ranked prey arranged in contingency tables. The indices are calculated by the methods described in Chapter 3, giving a single number between zero and one representing the proportion of high-ranked prey in an assemblage composed of both high- and low-ranking prey. A relatively high index value calculated for a particular assemblage is interpreted as an indication of greater foraging efficiency than an assemblage with a lower index value. These indices are useful in graphical displays that show changes in each index over time, inferred as changes in foraging efficiency. A decrease over time in an index may therefore signal resource intensification. Many earlier applications of resource depression models base their inferences in this way (e.g., Broughton 1995, 1997; Butler 2000). However, one disadvantage in reliance on taxonomic indices is that they do not take sample size into account, which is a concern when looking at trends in relative taxonomic abundance (Cannon 2001b; Grayson 1984).

Regression analysis of NISP and a particular index and calculation of Spearman's rho is often used to investigate whether or not differing sample sizes of assemblages can explain differences in relative taxonomic abundance, which would be a confounding factor when trying to detect any change in foraging efficiency (Grayson 1984). Cannon (2001b) has determined that this method is problematic. Concluding that there is no statistical correlation between sample size and relative taxonomic abundance using the sample size correlation method does not necessarily mean that sample sizes are large enough to confidently detect trends in relative taxonomic abundance. On the other hand, finding a statistically significant correlation between the two may be a product of the ordering of the assemblages that are examined. We often expect to see increases in sample size over time when examining faunal assemblages from stratified sites in which preservation of earlier deposits is poor compared with more recent deposits. Therefore, any trend seen in relative taxonomic abundance may very well be significantly correlated with changes in sample size regardless of other underlying reasons related to subsistence behavior.

To mitigate the potential for committing errors in statistical testing, Cannon (2000, 2001a, 2001b) suggests the use of Cochran's test of linear trend along with chi-squared testing of contingency tables. By arranging the abundances of high- and low-ranking prey NISP into a contingency table and performing chi-squared tests that can detect statistically significant differences and trends in relative taxonomic abundances between assemblages, sample size correlations are much less likely to result in statistical errors. In the contingency table, the NISP of high- and low-ranked taxa are arranged into two columns, and each row represents a particular faunal aggregation (usually by layer or site) with the rows ordered in some fashion (chronologically in the case of this dissertation). A chi-square test will determine whether or not the proportions of taxa in each aggregation are statistically different from an expected proportion, and from each other, and examination of the residuals allow detection of departures from the expected proportion in each aggregation (Zar 1996:483-486).

Cochran's test of linear trend, or simply "Chi-square for linear trend" (Zar 1996:564) is an additional test that calculates χ^2_{trend} which is the portion of the chi-square value of a contingency table that is caused by the ordering or linear trend of the aggregations (see Zar 1996:564 for the equation used for this calculation). The remainder of the total chi-squared value (χ^2_{total}) is the portion of the total chi-squared value that is not caused by a linear trend and equals χ^2_{total} - χ^2_{trend}, notated as $\chi^2_{departure}$. A statistically significant value of χ^2_{trend} indicates that there is a trend over time in the proportions of high- and low-ranked taxa in one direction or the other. A significant

$\chi^2_{departure}$ is possible as well, which indicates that some other factor or factors besides sequential ordering of the data can account for the differences in relative taxonomic abundance seen in the χ^2_{total} value. There is the possibility that both χ^2_{trend} and $\chi^2_{departure}$ are statistically significant in a contingency table, which means that there is a trend over time in relative taxonomic abundance, but it cannot account entirely for the differences in the proportions between faunal aggregations. Cochran's test of linear trend has been used with success in recent tests of resource depression models (Cannon 2000, 2001a; Nagaoka 2002) to assess whether there are trends over time in relative taxonomic abundance independent of sample size differences.

Foraging Within the Marine Patch

The marine patch as conceptualized in this dissertation encompasses a wide range of environments, but is considered here to be mutually exclusive with the riverine patch in terms of foraging activities by hunter-gatherers. The bays, rocky reefs, sea stacks and stretches of open water that surround the Kodiak archipelago host abundant sea mammal and marine fish populations. Many marine prey types are only seasonally available but occur in such a regime that there are foraging options year-round. On the other hand, salmon are assumed to be caught at the mouths of streams or along their drainages in the riverine patch, not the marine patch. This dissertation assumes that hunter-gatherers foraging in the marine patch will generally pursue sea mammals upon encounter and catch marine fish when sea mammals are unavailable, whether due to seasonal, locational, or demographic reasons.

Because the marine patch is considered more profitable than the riverine patch upon initial colonization of the archipelago by humans about 8000 years ago, I predict that proportions of high-ranked sea mammals (specifically seals, sea lions, sea otters, and porpoises, but *not* whales) to lower-ranked marine fish (specifically cod, sculpin, flatfish, rockfish, and greenlings) will initially be quite high and then decline over time as encounter rates with sea mammals decrease. As hunter-gatherers shift to a greater reliance on lower-ranked marine fish and the less profitable riverine patch, encounter rates with sea mammals may "rebound", hence their proportions would increase at some point in time. This shift in trend has been shown in several separate cases in which resource depression models were incorporated to explain changes in foraging behavior (e.g., Broughton 1995; Cannon 2001a).

Housefloor Contexts

Fig. 5.1 displays the marine patch index calculated for each housefloor deposit from each site included in this dissertation. The deposits are ordered chronologically from oldest on the far left to most recent to the far right, and the subsequent five bar charts follow the same format but with different deposits for the midden charts. In this figure and the other housefloor figures, Rice Ridge Layers K, I, F, D, and B are followed by Crag Point Housefloor 1B, Uyak Housefloor deposits from Structures 11, 7, 10, Crag Point Housefloor 3A, and Settlement Point House 1. Although the faunal remains from Crag Point Housefloor 4 were described earlier in this chapter with the other deposits from the site, the assemblage is not included in any of these analyses because of its uncertain chronological placement in this sequence and its very small sample size.

A distinct downward trend in the sea mammal index can be seen over time. This trend is most obvious in the earlier Rice Ridge deposits in which there is an increase in the index from the first to second layer and then a step-wise decrease across the next four layers. There is then an increase from the most recent housefloor deposit at Rice Ridge to Crag Point Housefloor 1B and Uyak Structure 11, a decrease to Structure 7, an increase to Structure 10, and then a decrease through Crag Point Housefloor 3A and Settlement Point House 1. Graphically tracking the change in the marine index over time does seem to lend support to my prediction that there was an initial decrease over time in foraging efficiency in the marine patch, with a subsequent rebound. The magnitude of the decrease from the early Ocean Bay I layers of Rice Ridge to the most recent Ocean Bay II layer appears greater than the fluctuations in the Kachemak deposits over time. To further explore the trends in the data I examine them using the chi-squared test of linear trend as a whole and within some individual sites.

Tables 5.5-5.7 display the abundances of sea mammals and marine fish as well as sea mammal index calculations from housefloor deposits. Table 5.5 includes deposits from *all* sites arranged in chronological order from the most recent at the top to the oldest at the bottom of the table. Further partitioning of the data by site shows where the linear trend, if present, can be most strongly accounted for. To accomplish this, within-site quantification is examined by including only those deposits from a single site with at least three strata (because detecting linear trends between two strata is uninformative). Tables 5.6 and 5.7 illustrate this partitioning for the Rice Ridge and Uyak assemblages, respectively. Crag Point has two housefloor aggregations and the Settlement Point data include one aggregation, so they are not examined separately.

Table 5.5 displays sea mammal and marine fish data spanning approximately 6000 years. A χ^2 test of the data gives a very significant result ($\chi^2 = 3536.43$, $p<0.001$), indicating that there are differences in the ratio of sea mammals and marine fish between the housefloor assemblages from Rice Ridge, Crag Point, Uyak, and Settlement Point. The test for linear trend resulted in $\chi^2_{trend} = 1540.95$ ($p<0.001$), therefore somewhat less than half of the total χ^2 value reflects the variability between the ratios associated with some sort of linear trend. Subtracting this from the total χ^2 value gives the amount of variability not related to the linear trend, $\chi^2_{departure} = 1995.48$ ($p<0.001$). Both sources of variability in the total χ^2 value are statistically significant.

Examination of only the housefloor assemblages from Rice Ridge (Table 5.6) also gives a highly significant total χ^2 value ($\chi^2_{total} = 1641.35$, $p<0.001$). By isolating this sequence of five assemblages, however, the linear trend between ratios accounts for a greater portion of the total χ^2 value. Although both the values for the linear trend and the departure are significant ($\chi^2_{trend} = 1229.86$, $p<0.001$; $\chi^2_{departure} = 411.49$, $p<0.001$), the variability associated with a linear trend is about three times the variability associated with a departure from that trend.

The faunal data from the three Uyak housefloor deposits show a very different pattern in the ratios of sea mammals to marine fish. The ratios in the three housefloor assemblages are shown in Table 5.7. The total χ^2 value is significant but smaller than the value for the Rice Ridge assemblages and for all sites combined ($\chi^2_{total} = 58.76$, $p<0.001$). This is not surprising given the smaller sample size and the focus on only three ratios instead of five in the case of Rice Ridge and eleven in the case of all sites combined. Despite the total value for the Uyak housefloors being significant, there is little evidence for these differences in ratios being associated with a linear trend ($\chi^2_{trend} = 0.73$, $p=0.392$; $\chi^2_{departure} = 58.03$, $p<0.001$), which is noticeable from examination of these particular assemblages in the graph in Fig. 5.1.

The linear trend in ratios of sea mammals and marine fish in housefloor assemblages varies between Rice Ridge and the Uyak Site and the combination of all sites. Although a linear trend of the variability in ratios of the two prey types across assemblages is visually noticeable and statistically significant while examining the combined assemblages from all four sites, the linear trend in the Rice Ridge housefloor assemblages when isolated is statistically much stronger. Additionally, the later Uyak assemblages show no such linear trend.

Midden Contexts

Fig. 5.2 is a bar chart displaying the sea mammal index calculated from fauna from midden deposits of the four sites, arranged in chronological order. These deposits are from Rice Ridge Layers J, H, G, E, C, A, Crag Point Midden Layers 3 and 2, Uyak Midden Layer 1A/2, and the Settlement Point Midden deposit. The assemblage from Crag Point midden Layer 1 is not included in any of these analyses despite being described earlier in this chapter because of its uncertain chronological placement in this sequence. Also, Uyak midden Layers 1A and 2 are combined for similar reasons. The general pattern of the midden data is similar to that of the housefloor data in Fig. 5.1. There is a decrease from the earlier Ocean Bay I layers of Rice Ridge to the most recent Ocean Bay II layer, and then fluctuation in the index after that. Unlike the indices calculated from the housefloor assemblages, however, some of the more recent Kachemak midden assemblage indices rebound to levels that equal or exceed some of the indices of the Rice Ridge assemblages.

Table 5.8 displays the ratios of sea mammal and marine fish from all sites. Similar to the case of the housefloor assemblages, there is a very significant difference in the ratios between the assemblages ($\chi^2_{total} = 2616.16$, $p<0.001$). The linear trend between ratios, however, accounts for almost two-thirds of the total value from the midden deposits ($\chi^2_{trend} = 1795.78$, $p<0.001$; $\chi^2_{departure} = 820.38$, $p<0.001$).

Isolating the midden assemblages from Rice Ridge and performing the same test gives an indication of the source of this linear trend. The ratios are statistically different ($\chi^2_{total} = 875.47$, $p<0.001$), with the majority of this variation associated with a linear trend ($\chi^2_{trend} = 781.93$, $p<0.001$; $\chi^2_{departure} = 93.54$, $p<0.001$). Almost 90% of the total value is accounted for by the trend value. As in the case of the housefloor deposits, the Rice Ridge data provide a large portion of the trend value seen in the overall sequence of assemblages from all of the sites and strongly suggest a decline in foraging efficiency during the Ocean Bay period.

Foraging Within the Riverine Patch

Riverine resource patches of the Kodiak archipelago are terrestrial in nature but include both mammals and fish. The most profitable prey in this type of patch are anadromous runs of Pacific salmon, trout, and char, despite the fact that they are only available seasonally for about half of the year along most rivers in the archipelago today and have a large marine component of their life histories (Groot and Margolis 1991). Foxes are another prey taken along the banks and at the mouths of streams that provide lower returns than salmon considering the aggregated nature of salmon encounters.

A decline in the ratio of salmon to foxes in faunal assemblages may imply resource intensification and is predicted theoretically in the resource depression model. Despite observations across the north Pacific of a significant *increase* in salmon consumption evidenced at archaeological sites dating after 5-2000 years BP, depending on the region (e.g., Cannon 1991; Matson 1976), there have been few comparisons of relative abundance of salmon remains to those of other riverine taxa across time (but see Cannon 1991). In this section, I examine the trend in relative abundances of salmon and foxes to see if there is possibly a decline in foraging efficiency within this patch. This is complicated by the very small sample size of fox remains compared with salmonid remains in many of the assemblages that were examined.

Housefloor Contexts

Fig. 5.3 shows the salmon index calculated for each housefloor layer from each site included in this dissertation. Examined in tandem with Table 5.10, which gives the NISP of salmon and fox within each assemblage, this bar chart clearly shows the effect of small sample sizes when investigating changes in prey choice over time. The salmon index is zero for RR-K and RR-I, the earliest two housefloor layers of the Rice Ridge site, indicating no salmon remains present in those assemblages. However, there is only one fox specimen in RR-K and two in RR-F. Salmon remains are present from RR-F onward, as are fox remains except in RR-B.

Table 5.10 lists the relative abundances of salmon and fox for each assemblage of all sites, along with their corresponding salmon index values. Considering the index values range from zero to one, the significance of the total χ^2 value is not surprising ($\chi^2_{total} = 1452.98$, $p<0.001$). Some of this difference between ratios can be attributed to a linear trend from the first two floor layers of Rice Ridge to the subsequent layers ($\chi^2_{trend} = 158.02$, $p<0.001$), but the majority is not attributed to this trend ($\chi^2_{departure} = 1294.96$, $p<0.001$).

Examining ratios of salmon and fox from only the Rice Ridge and Uyak housefloor assemblages by themselves reveals a similar pattern. At Rice Ridge (Table 5.11), the total χ^2 value is significant ($\chi^2_{total} = 264.69$, $p<0.001$) with a small but significant portion due to a linear trend in the proportions ($\chi^2_{trend} = 54.48$, $p<0.001$; $\chi^2_{departure} = 210.22$, $p<0.001$). At the Uyak Site (Table 5.12), the total value is also significant ($\chi^2_{total} = 36.37$, $p<0.001$) and some of the total value explained by a linear trend ($\chi^2_{trend} = 10.43$, $p = 0.001$; $\chi^2_{departure} = 25.94$, $p<0.001$). This value, which just considered significant at the 0.001 level, is somewhat surprising given the pattern of the salmon index between the three Uyak floor deposits in Fig. 5.3. The salmon index in structure 11 is 0.833. It rises to 0.933 in structure 7, and then falls to 0.722 in the most recent structure 10. Graphical and statistical comparisons of proportions and ratios of salmon and fox, by means of the salmon index tracked over time and detection of linear trends in ratios using Cochran's chi-squared test, do not support the prediction that the ratio of salmon to fox decreased over time. Similar results are visible in the examination of salmon and fox proportions from midden contexts, described next.

Midden Contexts

Fig. 5.4 and Table 5.13 show quite clearly that people were harvesting salmon in the earlier layers of Rice Ridge. Unlike the earliest floor layers of this site, in which salmon remains are entirely absent, *all* midden layers show a dominance of salmon over fox. The two midden layers from Crag Point and the midden assemblage from Uyak show a step-wise decline in the salmon index over time, and then a very significant "rebound" in the Settlement Point midden assemblage. Sample size appears to be a problem once again, however, when the numbers of identified salmon and fox specimens are examined in Tables 5.13 and 5.14.

Table 5.13 displays the abundances of salmon and fox for each midden layer from all sites. Total sample size of both salmon and fox specimens is under 100 in half of the layers, including three from Rice Ridge, the second midden layer from Crag Point, and the Uyak midden layer. Although there are salmon remains present in all layers, including several thousand from the Settlement Point midden, fox remains are totally absent from three midden layers at Rice Ridge and are very few in number in the rest of the assemblages. The second midden layer from Crag Point and the Uyak midden assemblage have small total sample sizes of combined salmon and fox specimens, and the Uyak assemblage is the only one examined that had more fox remains than salmon. Statistically the ratios of the two taxa is quite different between assemblages ($\chi^2_{total} = 1223.09$, $p<0.001$), although chronological order seems to have nothing to do with this variation ($\chi^2_{trend} = 0.22$, $p = 0.641$; $\chi^2_{departure} = 1222.87$, $p<0.001$).

The Rice Ridge midden layers examined alone do not show a linear trend either. Table 5.14 displays the abundances of salmon and fox in these layers. The salmon index is consistently quite high, and there is some difference between ratios ($\chi^2_{total} = 45.93$, $p<0.001$). There is no trend, however, associated with this sequence at the 0.05 level of statistical significance ($\chi^2_{trend} = 3.33$, $p = 0.068$; $\chi^2 = 42.60$). As in the case of the housefloor context, the prediction that greater use of fox relative to salmon occurred over time is not supported.

Foraging Between Patches

Testing whether or not salmon intensification occurred in the region is one of the major goals of this dissertation. This test can be accomplished by comparing the remains of animals brought back from the marine and riverine patches. Salmon are considered high-ranked and abundant within the riverine patch, yet the marine patch is assumed to provide greater overall foraging returns. Unlike the previous two sections that test whether or not resource intensification happened *within* patches, considered to be marine fish intensification and fox intensification, salmon intensification implies that salmon are lower-ranked than some other resource and a shift was made from use of that other resource to a greater reliance on salmon in the absence of any technological change that may change prey rankings. This is the assertion made in many models of cultural complexity for the north Pacific coast (e.g., Fitzhugh 2003).

Marine and riverine resource patches provide very different foraging opportunities and costs to hunter-gatherers living in the Kodiak archipelago. Therefore, examining changes in the abundance of high-ranked prey from one patch relative to high-ranked prey of another will allow the detection of decreasing foraging efficiency *between* patches. According to the patch choice model, as foraging returns from one patch decline to a level equal to that of other nearby resource patches, a forager will likely move to another resource patch. In the case of Kodiak, hunters and fishers brought prey back to the central locations of Rice Ridge, Crag Point, Uyak and Settlement Point from both patches year after year, as seen in Tables 5.1-5.4, although in differing amounts throughout the annual round based on availability of particular prey. If salmon intensification occurred, then the proportion of sea mammal remains to sea mammal and salmon remains, or the marine patch index, should decline over time. Assuming comparability in season and duration of site occupation within and between sites, if intensification was caused by declining encounter rates with sea mammals and there was a subsequent period of time in which encounter rates with sea mammals rebounded, then the index may likewise increase in the same fashion as the sea mammal index in the marine patch.

Housefloor Contexts

Fig. 5.5 displays the marine patch index for each housefloor assemblage from each site. In a pattern similar to the sea mammal index calculated for the housefloor assemblages, the marine patch index initially reflects an absence of salmon and then declines over time within the Rice Ridge site as the proportions of sea mammals decrease. The marine patch index calculated for the Crag Point and Uyak assemblages are lower than the Rice Ridge assemblages with the exception of the most recent housefloor stratum, Layer B. The proportion of sea mammal remains fluctuates between about 0.15 and 0.35 in these assemblages, and then drops in the Settlement Point housefloor assemblage to about 0.01, which has a sea mammal NISP of only 75 and a salmon NISP of 6303. As predicted by the salmon intensification hypothesis, salmon remains do increase in proportion to sea mammals over time, with some fluctuation in the Kachemak-period assemblages.

Table 5.15 displays the abundances of sea mammals and salmon in the housefloor assemblages from all sites, along with their corresponding marine patch index values. Chi-squared tests of the data mirror the strong trend in the marine patch index calculations seen in Fig. 5.5. The ratios of the two prey types are significantly different between the assemblages ($\chi^2_{total} = 5248.90$, $p<0.001$). The portion of this value associated with a linear trend is likewise significant and accounts for most of the variation between the proportions ($\chi^2_{trend} = 4408.99$, $p<0.001$; $\chi^2_{departure} = 839.91$, $p<0.001$). Statistically and graphically, the data from the housefloor assemblages from all the sites appears to strongly support the hypothesis that salmon intensification did occur.

Calculation of the same statistics for the Rice Ridge and Uyak housefloor separately shows some interesting differences. The Rice Ridge housefloor assemblages examined in isolation closely mirror this pattern of a decline in the ratio of sea mammal remains to salmon remains (Table 5.16). The difference between ratios is significant ($\chi^2_{total} = 783.35$, $p<0.001$) along with the linear trend ($\chi^2_{trend} = 675.10$, $p<0.001$; $\chi^2_{departure} = 108.25$). On the other hand, the later Uyak assemblages reflect the fluctuation of ratios but without the strong linear trend seen at Rice Ridge (Table 5.17). The difference between the Uyak housefloors is significant ($\chi^2_{total} = 26.14$, $p<0.001$) but the portion associated with a linear trend is not significant at the 0.010 level ($\chi^2_{trend} = 4.27$, $p = 0.039$; $\chi^2_{departure} = 21.87$, $p<0.001$).

Midden Contexts

Fig. 5.6 shows the marine patch index values for each of the midden assemblages from all sites over time. There seems to be a trend over time but not particularly unidirectional. The Rice Ridge midden layers exhibit a decline in the index similar to the housefloor layers from that site, with the exception of midden Layer G that represents a large drop in the proportion of sea mammals, followed by an increase in Layer E and then a decline to C and A. The Kachemak midden layers from Crag Point and Uyak show a step-wise increase in the proportion of sea mammals. The midden assemblage from Settlement Point shows a steep decrease in this proportion compared to the previous layers.

Table 5.18 displays the abundances of sea mammal and salmon remains from all of the midden assemblages. As with all the previous tests, the ratios are significantly different from each other ($\chi^2_{total} = 2492.01$, $p<0.001$), and slightly under half of this value is associated with a linear trend ($\chi^2_{trend} = 1213.15$, $p<0.001$; $\chi^2_{departure} = 1278.86$, $p<0.001$). The ratios from just the Rice Ridge midden layers (Table 5.19) are also significantly different from each other ($\chi^2_{total} = 1453.05$, $p<0.001$) and show a stronger linear trend than from combining all the midden layers ($\chi^2_{trend} = 955.22$, $p<0.001$; $\chi^2_{departure} = 497.83$). The midden assemblages show a similar initial decrease in the relative abundance of sea mammals compared with salmon associated with the Ocean Bay period, but a stronger "rebound" in this proportion during the Kachemak period than what the housefloor data suggest.

Confounding Factors

Fragmentation

Because differential bone fragmentation between assemblages and species can affect observed trends in relative taxonomic abundance, it is explored in greater detail in this section. The remains of the various animals found in archaeological sites are susceptible to varying amounts of fragmentation based on factors intrinsic to the structure of the bone, such as bone density, as well as extrinsic factors such as cultural preferences towards processing particular elements from particular animals for grease or marrow. Regardless of the underlying reasons, increased fragmentation of skeletal elements that are still identifiable to a particular taxon will inflate that taxon's NISP - relative to another taxon if the fragmentation process is limited to just one of the taxa, or relative to the same taxon's abundance in different assemblages if the process changes over time or across space.

Methods of measuring fragmentation in faunal assemblages are greatly varied and chosen depending upon the types of animals and elements present and the kinds of data available for each assemblage. The work of Lyman (e.g., 1984, 1994), Butler and Chatters (1994), and Kreutzer (1992), to name a few, have focused on the effects that structural bone density has on differential fragmentation and survivorship of the remains of particular animal taxa. Detailed bone density measurements using photon densitometry equipment allow a direct test of the hypothesis that density-mediated fragmentation of bone has had an influence of relative taxonomic abundance. This method, however, requires a substantial amount of experimental data on modern specimens from the same taxon that is being examined in prehistoric assemblages. Another method evaluates post-depositional destruction of bone in an assemblage by calculating a "completeness index" of compact bones that would probably not be intentionally fragmented by humans (Marean 1991). Other useful measures have been calculated that compute the ratio of proximal and distal ends of long bones and ribs to their shafts and shaft fragments (e.g., Grayson and Delpech 1998; Grayson et al. 2001; Todd and Rapson 1988). Use of these measures presumes that increased fragmentation will have a greater negative effect on the identifiability of the ends of long bones and ribs compared with shafts. Therefore an increase in the ratio of shafts to ends is interpreted as an increase in the intensity of fragmentation of the remains of a particular taxon between assemblages.

The latter method of investigating fragmentation, by calculating the ratios of long bone and rib ends to shafts and making cross-assemblage and cross-taxa comparisons, is the method used in this dissertation for mammal remains. A similar method is used to measure fragmentation of fish specimens. Although structural density data from photon densitometer experiments are available for phocid seal skeletal elements (Chambers 1992 in Lyman 1994) and Pacific salmon elements (Butler and Chatters 1994), there have been no experiments on elements from other species commonly found around the Kodiak archipelago, including sea otter, porpoise, sea lion, Pacific cod or other fish species. Observations of the portion of the skeletal element represented by each specimen from the Rice Ridge, Crag Point, and Uyak assemblages were made during analysis. Therefore, measures of fragmentation are examined for these three sites for consistency, since this particular data is not available from the Settlement Point assemblage. Fragmentation of salmonid specimens between assemblages is described first, followed by fragmentation of sea otter and harbor seal remains.

A fragmentation index for salmonid fish can be made by comparing the ratio of whole vertebra or ones with a landmark to vertebral fragments without a landmark. The salmonid vertebra is an ideal element for examining fragmentation because it is identifiable in extremely small fragments because of its distinctive morphology (Wigen and Stucki 1988) and is by far more abundant than any other salmonid element in these assemblages. Salmon vertebral specimens are considered to have a landmark if they posses the central portion of the centrum. The presence or absence of this landmark was originally observed so that MNI estimates could be calculated if required. The proportion of whole vertebrae, or at least ones with the landmark present, to whole vertebrae plus fragments of salmon vertebrae gives an index of salmon bone fragmentation. An increase in this proportion is interpreted here to indicate a decline in fragmentation.

Table 5.20 displays the ratios of salmon vertebral specimens with the central landmark to those without it for each housefloor assemblage from Rice Ridge, Crag Point, and Uyak, along with the proportion of vertebrae with the landmark to all salmonid vertebrae in each assemblage. The latter three Rice Ridge housefloor assemblages contain salmonid remains, and show varied intensity of fragmentation. The earlier housefloor assemblage at Crag Point, 1B, shows a very high ratio of whole vertebrae to fragments, and in the Uyak housefloor assemblages whole verterbrae consistently outnumber fragments several times over. This may have something to do with the coarse, ¼" mesh screens that were used in each excavation. If fragmentation of salmonid vertebrae remained constant over time in the housefloor assemblages, then there should still be little or no difference in the fragmentation proportions between those assemblages. A χ^2 test on the ratios from the floor assemblages with salmon remains (i.e. all except Rice Ridge Layers K and I) shows a very significant difference between the assemblages ($\chi^2_{total} = 286.20$, $p<0.001$). An examination of the adjusted residuals of this test indicate that whole vertebrae are underrepresented and a greater degree of fragmentation has occurred in the deeper layers of Rice Ridge, D and F, while the more recent layers show a greater-than-expected proportion of whole vertebrae. There is some linearity in the trend of fragmentation over time as well ($\chi^2_{trend} = 101.43$, $p<0.001$; $\chi^2_{departure} = 184.77$).

The midden assemblages show highly variable amounts of salmon vertebrae fragmentation as well (Table 5.21). A chi-squared analysis of these figures gives significant results ($\chi^2_{total} = 78.00$, $p<0.001$), although there is no linear trend associated with this variation at the 0.10 level ($\chi^2_{trend} = 2.11$, $p = 0.146$; $\chi^2_{departure} = 75.89$, $p<0.001$). A non-linear fluctuation is seen in the residuals from this test. Under-representation and over-representation of whole vertebrae alternate between midden layers over time with the exception of the Crag Point and Uyak assemblages, in which fragmentation appears to decline as whole vertebrae are consistently over-represented.

Construction of a fragmentation index for non-salmonid fish vertebrae is not as straightforward, given their usual lack of identifiability to a specific taxon once fragmented. However, a measurement of fragmentation is just as important in this case given the role that the relative abundance of marine fish plays in the sea mammal index. A similar principle to the one used when examining salmon fragmentation is assumed here: an increase in fragmentation of marine fish vertebrae will result in a decrease in the ratio of whole vertebral specimens or ones with at least the central landmark to vertebrae fragments without the landmark. Proportions were calculated using the NISP of non-salmonid vertebrae with landmarks divided by the NISP of vertebral fragments plus vertebrae with landmarks. Most of the vertebral fragments were unidentified to specific marine fish taxon, although some were confidently identified to species, such as halibut, or order, such as flatfish, even without the presence of the landmark, and were still included in the vertebral fragment count.

The abundances of non-salmonid vertebrae, both with and without landmarks, are given for the Rice Ridge, Crag Point, and Uyak house floor assemblages in Table 5.22. Although the proportion of vertebral specimens with landmarks is consistently high, only dropping to 0.5 in one layer, there is a statistically significant difference between assemblages ($\chi^2_{total} = 120.59$, $p<0.001$). There is no linear trend in these ratios, however ($\chi^2_{trend} = 0.32$, $p = 0.570$; $\chi^2_{departure} = 120.27$, $p<0.001$). A similar significant difference between ratios is exhibited in the midden assemblages, shown in Table 5.23 ($\chi^2_{total} = 205.04$, $p<0.001$). There is a slight indication of a linear trend associated with variation between these assemblages ($\chi^2_{trend} = 6.11$, $p = 0.013$;

$\chi^2_{departure}$ = 198.93, p<0.001). I interpret these results as an indication that differential fragmentation of fish remains between assemblages is not driving observed changes in their abundances.

Fragmentation measures were calculated for harbor seal long bone and rib specimens, because harbor seal was the most abundant mammal across all the house floor and midden assemblages. Calculations from sea otter long bone and rib specimens were made as well for the Rice Ridge layers, since this is the dominant mammal species at the site. The ratio of shafts and shaft fragments of long bone and rib specimens to ends and end fragments were calculated for each assemblage and compared. A relatively higher ratio of shafts or diaphyses to ends or epiphyses indicates a higher rate of fragmentation for that taxon.

Long bone and rib shaft and end specimens from sea otters were only present in quantities greater than one or two in the Rice Ridge assemblages, so comparison of fragmentation of sea otter remains over time is only performed for the assemblages from this site. Table 5.24 displays the ratios of shafts to ends in the Rice Ridge house floor assemblages. The proportions of diaphyses in these sub-assemblages range from 0.432 in Layer D to 0.750 in Layer I. The difference between the ratios is not quite statistically significant at the 0.05 level (χ^2_{total} = 9.11, p = 0.058). There does not appear to be a linear trend in them either (χ^2_{trend} = 3.29, p = 0.070; $\chi^2_{departure}$ = 5.82, p = 0.121). The sea otter remains from the Rice Ridge midden assemblages do not exhibit a significant change in ratio of shafts to ends either (Table 5.25). Here the variation in the proportion of shafts is even more constricted from 0.451 in Layer G to

0.667 in Layer A. Not surprisingly, the chi-squared value is even less significant than from the house floor assemblage (χ^2_{total} = 4.16, p = 0.527; χ^2_{trend} = 0.14, p = 0.710; $\chi^2_{departure}$ = 4.02, p = 0.403). Despite a change in the abundance of sea otter remains over time in the Rice Ridge assemblage, it does not appear that the degree of fragmentation occurring to the remains changes significantly.

The abundances of shafts and ends of harbor seal long bones and ribs from house floor assemblages are given in Table 5.26. Sample sizes are small in all of the assemblages, and both shaft and end fragments are entirely absent from the more recent house floor assemblage at Crag Point, 3A. A comparison of ratios, excluding that layer, indicates an insignificant difference between them (χ^2_{total} = 9.24, p = 0.323). No linear trend is associated with them either (χ^2_{trend} = 0.47, p = 0.492; $\chi^2_{departure}$ = 8.77, p = 0.270). The midden assemblages (Table 5.27), on the other hand, do show a significant difference in ratios of seal long bone ends and shafts (χ^2_{total} = 43.42, p<0.001). Additionally, a significant amount of this variation is associated with a linear trend (χ^2_{trend} = 21.21, p<0.001; $\chi^2_{departure}$ = 22.22, p = 0.002). Examination of the ratios listed in the table and the adjusted residuals of the proportions clearly show a large increase in the ratio of shafts to ends between the Ocean Bay assemblages at Rice Ridge, in which the proportions of shafts do not exceed 0.471, and the more recent Kachemak assemblages in which the lowest proportion is 0.769.

Other Taphonomic Factors

Evidence for specific taphonomic factors that may play a role in fragmentation of certain skeletal elements is visible in the form of gnawing and chewing marks, as well as indications of burning. Several zooarchaeologists have studied the effects that carnivore ravaging has had on faunal assemblages (e.g., Lyman 1994; Marean and Spencer 1991). Despite the presence of canids in most of the assemblages examined in this dissertation, indicating the continued presence of an agent that may increase the fragmentation of some skeletal material, there is very little direct evidence in any assemblage of carnivore ravaging. Only nine specimens from Rice Ridge and two from the Uyak site exhibited any sort of gnaw marks or canine punctures. The effects of burning on bone have also been frequently discussed in the literature (e.g., Lubinski 1996; Lyman 1994; McCutcheon 1992; Shipman et al. 1984). Although the majority of specimens examined in this dissertation are not burned, those that are account for a greater percentage of the assemblages than those with evidence of carnivore ravaging and therefore are dealt with in greater detail here.

During analysis, specimens from the Rice Ridge, Crag Point, and Uyak assemblages were examined for physical alterations that might indicate burning. Although numerous macroscopic and microscopic criteria can be used during analysis to detect the occurrence and extent of burning, a fine-grained determination of the extent of burning was not considered necessary for the research questions posed in this dissertation. Instead, the presence of burning on a specimen was acknowledged if it exhibited a black, brown, or chalky-white color as determined visually (without the aid of a Munsell color chart). Black or brown specimens were further noted as "charred" and chalky-white specimens as "calcined". Following McCutcheon (1992), I assume that the charred specimens have undergone burning at a lower temperature and/or shorter duration than the calcined specimens.

In the Rice Ridge assemblage, 31 specimens were recorded as being charred and 25 specimens recorded as being calcined. Of the charred specimens, four are fragments of the head of a sea otter femur; one is the centrum of a thoracic vertebra of a sea otter; one is a mostly-whole thoracic vertebra from a sea otter. The proximal epiphysis of a tibia from a harbor seal and a distal phalanx of a canid were the remaining identified mammal specimens that were charred. Twenty-one more unidentified mammal bone fragments were charred. Two fish specimens were identified as being charred, the trochlear end of a Pacific cod quadrate and one unidentified fish vertebra fragment. Of the calcined specimens, only one was taxonomically identified beyond class, as a salmonid vertebra fragment. Another unidentified calcined fish vertebra fragment was noted, along with 23 unidentified calcined mammal bone fragments.

All but one of the burned specimens from Rice Ridge is considered fragmented, but any link to burning and fragmentation in this assemblage cannot be made because of the small sample size. Burning probably had an effect on the fragmentation of these specimens, but this was a very small number compared to the unburned specimens. Also, none of the burned specimens exhibit cutmarks, and they come from various axial and appendicular portions of the animals. Adding to the seemingly random nature of the small burned bone assemblage from Rice Ridge is that they are found scattered in all of the midden and housefloor layers.

Similar to Rice Ridge, there are a few charred and calcined specimens found in several house floor and midden assemblages at Crag Point. Seventeen specimens were observed as charred and three were observed as calcined. Five of the charred specimens, all unidentified mammal bone fragments, comprise the burned bones from house floor 1B. One vertebral centrum fragment from a porpoise and three unidentified fish vertebra fragments from house floor 3A were charred. One charred and mostly whole lumbar vertebra of a harbor porpoise, 7 charred and unidentified mammal bone fragments, and 3 mostly whole, calcined cervical vertebrae identified as a larger canid were present in midden layer 2.

Most of the burned specimens from the Uyak site are limited to one excavation unit in the midden deposits. All are charred and not calcined. Two unidentified mammal bone fragments were found in the floor deposits of house 10. Seven burned specimens were identified from the midden in excavation square 120. These include two whole thoracic and one whole lumbar vertebrae identified as fox, one sea otter rib, one 2nd vertebra of a harbor seal, one brown bear scapula, and a distal phalanx from the front flipper of a sea lion or fur seal, all of which are mostly whole.

Despite the presence of charred and calcined specimens in the assemblages from these three sites, burning probably had little effect on relative taxonomic abundance trends. The numbers of specimens that have been burned are uniformly small across assemblages and represent a variety of taxa and body parts. Additional samples may yield larger proportions of burned specimens, in which case the association of burning with fragmentation and butchery can be examined in the future.

In sum, changes are apparent in the amount of fragmentation between some of these assemblages, yet obvious physical processes such as animal gnawing or burning do not seem to be the cause of this fragmentation. Changes in fragmentation occur in the remains of the most abundant taxa represented in the assemblages: salmon, marine fish, sea otter, and harbor seal. The direction of these changes, when they do occur, cannot account for changes relative taxonomic abundance indicative of changing subsistence choices.

Technological Change

Increased use of a lower-ranked prey in the wake of technological innovations that may increase the energetic returns of that prey per unit of time spent during its harvest cannot be considered resource intensification. According to the foraging theory-based definition, intensification implies a *decrease* in foraging efficiency. Intensification of marine fish or salmon in this case means putting more energy into their capture compared with sea mammal hunting during a period of time spent foraging. At some point during the history of human occupation of the archipelago, fishing technology shifted from targeting individual fish, which was probably a more costly endeavor than sea mammal hunting in terms of net-energetic returns, to mass harvesting of anadromous runs of salmon and possibly marine fish using nets which would significantly lower the pursuit costs of these foraging options. If mass harvesting innovations occurred before or concurrent with the shifts in prey choice towards greater use of marine fish and salmon described above then intensification as defined in this dissertation did not happen.

On Kodiak, archaeological evidence suggests that fish in both marine and riverine environments were being caught individually using hooks made of bone, and possibly small spears or harpoons throughout the Ocean Bay period. The limited organic artifact record from this early period, almost exclusively from the well-preserved deposits at Rice Ridge, contains tools ideal for hunting sea mammals as well as a variety of fish hooks and leister prongs (Hausler-Knecht 1993). Personal examination of the entire artifact collection from the Rice Ridge site stored at the Alutiiq Museum revealed fishing gear aimed at harvesting individual fish. Despite the presence of ground stone tools by the Ocean Bay II phase, appearing in the more recent deposits of Rice Ridge, the ground stone plummets and notched pebble net sinkers so common in later Kachemak sites are not found in Rice Ridge or other Ocean Bay sites (Clark 1984a; Hausler-Knecht 1993). Evidence for mass harvesting of fish, in the form of net weights, does not appear until the Kachemak period, after about 3500 radiocarbon years B.P., along with ground slate tools allowing more efficient processing of fish and storage and drying features that gave fish additional advantages over sea mammals (Clark 1982, 1997; Fitzhugh 2002; Saltonstall et al. 2001).

Summary

The timing of the trends in prey and patch choice described earlier in this chapter indicates that resource intensification of both marine fish and salmon did indeed occur relative to sea mammals, although there is no support for intensification of terrestrial resources relative to salmon over time. Decreases in the sea mammal (Figs. 5.1 and 5.2) and marine patch (Figs. 5.5 and 5.6) indices occur shortly after initial occupation of the Rice Ridge site, and continue in a dramatic downward trajectory. This pattern is seen in assemblages dating between about 6000 and 3800 radiocarbon years BP, ending several centuries before the beginning of the Early Kachemak phase and presumably the advent of mass harvesting of fish. Similar decreases in the indices that occur between later assemblages at Crag Point and Uyak, and for that matter some *increases* in the indices, may not be related to intensification *per se* as they occur well after the introduction of grooved line weights, notched net sinkers, ground slate flensing knives and *ulus*, and other cultural phenomena that indicate a well-tuned technological adaptation to the harvest, processing, and storage of large quantities of fish (Fitzhugh 2001, 2002). An apparent decline in foraging efficiency in the absence of mass harvest technology is shown here, however, in the Rice Ridge faunal assemblages.

Table 5.1 Taxonomic Abundances (NISP) from the Rice Ridge Site (KOD-363)

Taxon	Floor Lev:	K	I	F	D	B	Midden Lev:	J	H	G	E	C	A	Total
Mammal														
Sea Otter		90	136	288	165	78		374	482	132	105	152	18	2020
Harbor Seal		15	16	134	53	63		84	119	69	47	73	27	700
Steller Sea Lion		9	7	5	13	5		36	85	4	6	10	9	189
Brown Bear		8	21	6	5	3		19	8	6	3	15		94
Whale								55	2	1		3		61
Canid Family				3	4	5		3	8	2	2	8	2	37
Harbor Porpoise		1		4	2	3		7	16	1		1		35
Red Fox		1	2	3	3			1	3			6		19
Tundra Vole				1				10	1	4				16
Eared Seal Family			1	1					3		2			7
Porpoise Family				3					1					4
Dall's Porpoise								1	2					3
Nor. River Otter				2										2
Marmot sp.					1								1	2
Rodent sp.						1						1		2
Weasel sp.												1		1
Fish														
Pacific Cod		13	5	13	48	1689		58	45	15	28	566	268	2748
Salmon Family				88	90	575		20	66	345	35	110	551	1880
Cod Family		49	9	79	50	123		45	209	46	52	9	123	794
Sculpin Family		2	2	11	10	121			37	2	2	56	19	262
Flatfish		4	1	22	7	22		20	32	6	9	18	5	146
Herring			3	2	14	10		13	16		9	9	2	78
Greenling Family			1	9		5			37	2	1		5	60
Halibut			4	7		3		10	7	3			2	36
Rockfish Family						1		1						2
Irish Lord						2								2
Cartilag. Fish			1											1
Total:		192	209	681	465	2709		757	1179	638	301	1038	1032	9201

Table 5.2 Taxonomic Abundances (NISP) from the Crag Point Site (KOD-044)

Taxon	Floor Levels:	4	1B	3A	Midden Levels:	3	2	1	Total
Mammal									
Harbor Seal			41	3		82	52	62	240
Canid Family			3			17	77	11	108
Red Fox			15	8		37	8	24	92
Harbor Porpoise			14			31	15	29	89
Dall's Porpoise			1	1		16	3	16	37
Porpoise Family			6	1		6	4	7	24
Steller Sea Lion			1	1		6	4	6	18
Brown Bear			1	1		4	3	6	15
Whale			1			4	5	4	14
Eared Seal Family								3	3
Sea Otter			1					2	3
Ermine							1		1
Cervid Family			1						1
Fish									
Pacific Cod		2	578	197		221	44	199	1241
Walleye Pollock			7	6		19	534	1	567
Salmon Family		117	126	23		163	14	72	515
Irish Lord			21	16		5	6	12	60
Halibut		7	3			5	11	22	48
Sculpin Family			5	12					17
Flatfish			6	1			2	2	11
Great Sculpin			1				10		11
Cod Family			10						10
Greenling Family			2					1	3
Rockfish Family								1	1
Lingcod			1						1
Starry Flounder			1						1
Total:		126	846	270		616	793	480	3131

Table 5.3 Taxonomic Abundances (NISP) from the Uyak Site (KOD-145)

Taxon	**Floor Levels:**	**11**	**7**	**10**	**Midden Levels:**	**2**	**1A**	**Total**
Mammal								
Harbor Seal		60	31	83		22	149	345
Red Fox		39	15	66		12	28	160
Steller Sea Lion		6	4	5		1	26	42
Sea Otter		5	1	5			10	21
Brown Bear			1	1		1	13	16
Canid Family		3	1	3		1	2	10
Harbor Porpoise		3	1				2	6
Northern River Otter		2		1		2	1	6
Whale		1		2			3	6
Eared Seal Family			2	1			1	4
Cervid Family		2		1				3
Tundra Vole				2				2
Ermine				1				1
Northern Fur Seal							1	1
Fish								
Pacific Cod		178	393	210		69		850
Salmon Family		195	210	171			5	581
Irish Lord		17	5	11		4		37
Halibut		1	2	13			4	20
Sculpin Family		4	9	1				14
Cod Family		2	2	3				7
Flatfish		1		3				4
Great Sculpin				2			1	3
Walleye Pollock			2					2
Lingcod			1					1
Total:		519	680	585		112	246	2142

Table 5.4 Taxonomic Abundances (NISP) from Settlement Point (AFG-015) (adapted from Partlow 2000:156,194; personal communication 2003)

(All Data from Partlow 2000; Megan Partlow pers. Comm. 2003)

Taxon	House 1	Midden	Total
Mammal			
Harbor Seal	60	448	508
Dolphin Family	14	55	69
Whale	5	42	47
Canid Family	12	19	31
Northern River Otter	0	7	7
Steller Sea Lion	0	5	5
Sea Otter	1	0	1
Fish			
Salmon Family	6303	1783	8086
Cod Family	2366	2840	5206
Irish Lord	87	188	275
Scorpaeniform Order	78	115	193
Sculpin Family	45	61	106
Flatfish	54	48	102
Cartilaginous Fish	78	1	79
Great Sculpin	34	25	59
Greenling Family	1	3	4
Rockfish Family	0	2	2
Total:	9138	5642	14780

Note - specimens recovered from 1/8" screens not included

Table 5.5 Numbers of Identified Sea Mammal and Marine Fish Specimens from Housefloor Contexts in All Sites (χ^2_{total} = 3536.43, p<0.001; χ^2_{trend} = 1540.95, p<0.001; $\chi^2_{departure}$ = 1995.48, p<0.001)

Site	Layer	Sea Mammal NISP	Marine Fish NISP	Total NISP	Sea Mammal Index
Settlement Point	1	75	2743	2818	0.027
Crag Point	3A	6	232	238	0.025
Uyak	10	94	243	337	0.279
Uyak	7	39	414	453	0.086
Uyak	11	74	203	277	0.267
Crag Point	1B	64	635	699	0.092
Rice Ridge	B	149	1966	2115	0.070
Rice Ridge	D	233	115	348	0.669
Rice Ridge	F	435	141	576	0.755
Rice Ridge	I	160	22	182	0.851
Rice Ridge	K	115	68	183	0.628
Total		1444	6782	8226	0.176

Table 5.6 Numbers of Identified Sea Mammal and Marine Fish Specimens from Housefloor Contexts at Rice Ridge (χ^2_{total} = 1641.35, p<0.001; χ^2_{trend} = 1229.86, p<0.001; $\chi^2_{departure}$ = 411.49, p<0.001)

Layer	Sea Mammal NISP	Marine Fish NISP	Total NISP	Sea Mammal Index
B	149	1966	2115	0.070
D	233	115	348	0.669
F	435	141	576	0.755
I	160	22	182	0.851
K	115	68	183	0.628
Total	1092	2312	3404	0.321

Table 5.7 Numbers of Identified Sea Mammal and Marine Fish Specimens from Housefloor Contexts at the Uyak Site (χ^2_{total} = 58.76, p<0.001; χ^2_{trend} = 0.73, p=0.392; $\chi^2_{departure}$ = 58.03, p<0.001)

Layer	Sea Mammal NISP	Marine Fish NISP	Total NISP	Sea Mammal Index
10	94	243	337	0.279
7	39	414	453	0.086
11	74	203	277	0.267
Total	207	860	1067	0.194

Table 5.8 Numbers of Identified Sea Mammal and Marine Fish Specimens from Midden Contexts in All Sites (χ^2_{total} = 2616.16, p<0.001 ; χ^2_{trend} = 1795.78, p<0.001; $\chi^2_{departure}$ = 820.38, p<0.001)

Site	Layer	Sea Mammal NISP	Marine Fish NISP	Total NISP	Sea Mammal Index
Settlement Point	Midden	508	3283	3791	0.134
Uyak	1A/2	212	78	290	0.731
Crag Point	2	78	607	685	0.114
Crag Point	3	141	250	391	0.361
Rice Ridge	A	54	422	476	0.113
Rice Ridge	C	236	649	885	0.267
Rice Ridge	E	160	92	252	0.635
Rice Ridge	G	206	74	280	0.736
Rice Ridge	H	708	367	1075	0.659
Rice Ridge	J	502	134	636	0.789
Total		2805	5956	8761	0.320

Table 5.9 Numbers of Identified Sea Mammal and Marine Fish Specimens from Midden Contexts at Rice Ridge (χ^2_{total} = 875.47, p<0.001; χ^2_{trend} = 781.93, p<0.001; $\chi^2_{departure}$ = 93.54, p<0.001)

Layer	Sea Mammal NISP	Marine Fish NISP	Total NISP	Sea Mammal Index
A	54	422	476	0.113
C	236	649	885	0.267
E	160	92	252	0.635
G	206	74	280	0.736
H	708	367	1075	0.659
J	502	134	636	0.789
Total	1866	1738	3604	0.518

Table 5.10 Numbers of Identified Salmon and Fox Specimens from Housefloor Contexts in All Sites (χ^2_{total} = 1452.98, p<0.001; χ^2_{trend} = 158.02, p<0.001; $\chi^2_{departure}$ = 1294.96, p<0.001)

Site	Layer	Salmon NISP	Fox NISP	Total NISP	Salmon Index
Settlement Point	1	6303	12	6315	0.998
Crag Point	3A	23	8	31	0.742
Uyak	10	171	66	237	0.722
Uyak	7	210	15	225	0.933
Uyak	11	195	39	234	0.833
Crag Point	1B	126	15	141	0.894
Rice Ridge	B	575	0	575	1.000
Rice Ridge	D	90	3	93	0.968
Rice Ridge	F	88	3	91	0.967
Rice Ridge	I	0	2	2	0.000
Rice Ridge	K	0	1	1	0.000
Total		7781	164	7945	0.979

Table 5.11 Numbers of Identified Salmon and Fox Specimens from Housefloor Contexts at Rice Ridge (χ^2_{total} = 264.69, p<0.001; χ^2_{trend} = 54.47, p<0.001; $\chi^2_{departure}$ = 210.22, p<0.001)

Layer	Salmon NISP	Fox NISP	Total NISP	Salmon Index
B	575	0	575	1.000
D	90	3	93	0.968
F	88	3	91	0.967
I	0	2	2	0.000
K	0	1	1	0.000
Total	753	9	762	0.988

Table 5.12 Numbers of Identified Salmon and Fox Specimens from Housefloor Contexts at the Uyak Site (χ^2_{total} = 36.37, p<0.001; χ^2_{trend} = 10.43, p=0.001; $\chi^2_{departure}$ = 25.94, p<0.001)

Layer	Salmon NISP	Fox NISP	Total NISP	Salmon Index
10	171	66	237	0.722
7	210	15	225	0.933
11	195	39	234	0.833
Total	576	120	696	0.828

Table 5.13 Numbers of Identified Salmon and Fox Specimens from Midden Contexts in All Sites (χ^2_{total} = 1223.09, p<0.001; χ^2_{trend} = 0.22, p=0.641; $\chi^2_{departure}$ = 1222.87, p<0.001)

Site	Layer	Salmon NISP	Fox NISP	Total NISP	Salmon Index
Settlement Point	Midden	1783	19	1802	0.989
Uyak	1A/2	5	40	45	0.089
Crag Point	2	14	8	22	0.636
Crag Point	3	163	37	200	0.815
Rice Ridge	A	551	0	551	1.000
Rice Ridge	C	110	6	116	0.948
Rice Ridge	E	35	0	35	1.000
Rice Ridge	G	345	0	345	1.000
Rice Ridge	H	66	3	69	0.957
Rice Ridge	J	20	1	21	0.952
Total		*3092*	*114*	*3206*	*0.964*

Table 5.14 Numbers of Identified Salmon and Fox Specimens from Midden Contexts at Rice Ridge (χ^2_{total} = 45.93, p<0.001 ; χ^2_{trend} = 3.33, p=0.068; $\chi^2_{departure}$ = 42.60, p<0.001)

Layer	Salmon NISP	Fox NISP	Total NISP	Salmon Index
A	551	0	551	1.000
C	110	6	116	0.948
E	35	0	35	1.000
G	345	0	345	1.000
H	66	3	69	0.957
J	20	1	21	0.952
Total	1127	10	1137	0.991

Table 5.15 Numbers of Identified Sea Mammal and Salmon Specimens from Housefloor Contexts in All Sites ($\chi^2_{total} = 5248.90$, $p<0.001$; $\chi^2_{trend} = 4408.99$, $p<0.001$; $\chi^2_{departure} = 839.91$, $p<0.001$)

Site	Layer	Sea Mammal NISP	Salmon NISP	Total NISP	Marine Patch Index
Settlement Point	1	75	6303	6378	0.012
Crag Point	3A	6	23	29	0.207
Uyak	10	94	171	265	0.355
Uyak	7	39	210	249	0.157
Uyak	11	74	195	269	0.275
Crag Point	1B	64	126	190	0.337
Rice Ridge	B	149	575	724	0.206
Rice Ridge	D	233	90	323	0.721
Rice Ridge	F	435	88	523	0.832
Rice Ridge	I	160	0	160	1.000
Rice Ridge	K	115	0	115	1.000
Total		1444	7781	9225	0.157

Table 5.16 Numbers of Identified Sea Mammal and Salmon Specimens from Housefloor Contexts at Rice Ridge ($\chi^2_{total} = 783.35$, $p<0.001$; $\chi^2_{trend} = 675.10$, $p<0.001$; $\chi^2_{departure} = 108.25$, $p<0.001$)

Layer	Sea Mammal NISP	Salmon NISP	Total NISP	Marine Patch Index
B	149	575	724	0.206
D	233	90	323	0.721
F	435	88	523	0.832
I	160	0	160	1.000
K	115	0	115	1.000
Total	1092	753	1845	0.592

Table 5.17 Numbers of Identified Sea Mammal and Salmon Specimens from Housefloor Contexts at the Uyak Site ($\chi^2_{total} = 26.14$, $p<0.001$; $\chi^2_{trend} = 4.27$, $p=0.039$; $\chi^2_{departure} = 21.87$, $p<0.001$)

Layer	Sea Mammal NISP	Salmon NISP	Total NISP	Marine Patch Index
10	94	171	265	0.355
7	39	210	249	0.157
11	74	195	269	0.275
Total	207	576	783	0.264

Table 5.18 Numbers of Identified Sea Mammal and Salmon Specimens from Midden Contexts in All Sites (χ^2_{total} = 2492.01, p<0.001; χ^2_{trend} = 1213.15, p<0.001; $\chi^2_{departure}$ = 1278.86, p<0.001)

Site	Layer	Sea Mammal NISP	Salmon NISP	Total NISP	Marine Patch Index
Settlement Point	Midden	508	1783	2291	0.222
Uyak	1A/2	212	5	217	0.977
Crag Point	2	78	14	92	0.848
Crag Point	3	141	163	304	0.464
Rice Ridge	A	54	551	605	0.089
Rice Ridge	C	236	110	346	0.682
Rice Ridge	E	160	35	195	0.821
Rice Ridge	G	206	345	551	0.374
Rice Ridge	H	708	66	774	0.915
Rice Ridge	J	502	20	522	0.962
Total		2805	3092	5897	0.476

Table 5.19 Numbers of Identified Sea Mammal and Salmon Specimens from Midden Contexts at Rice Ridge (χ^2_{total} = 1453.05, p<0.001; χ^2_{trend} = 955.22, p<0.001; $\chi^2_{departure}$ = 497.83, p<0.001)

Layer	Sea Mammal NISP	Salmon NISP	Total NISP	Marine Patch Index
A	54	551	605	0.089
C	236	110	346	0.682
E	160	35	195	0.821
G	206	345	551	0.374
H	708	66	774	0.915
J	502	20	522	0.962
Total	1866	1127	2993	0.623

Table 5.20 Proportion of whole salmon vertebrae from house floor assemblages.

Site	Layer	Salmon Vertebrae NISP (w/landmark)	Salmon Vertebrae Frag. NISP (no landmark)	Total Vert. NISP	Proportion of Verts w/Landmark to Total Verts
Crag Point	3A	22	0	22	1.000
Uyak	10	43	7	50	0.860
Uyak	7	87	3	90	0.967
Uyak	11	57	3	60	0.950
Crag Point	1B	109	1	110	0.991
Rice Ridge	B	504	69	573	0.880
Rice Ridge	D	27	63	90	0.300
Rice Ridge	F	46	42	88	0.523
Rice Ridge	I	0	0	0	-
Rice Ridge	K	0	0	0	-
Total		895	188	1083	0.826

Table 5.21 Proportion of whole salmon vertebrae from midden assemblages.

Site	Layer	Salmon Vertebrae NISP (w/landmark)	Salmon Vertebrae Frag. NISP (no landmark)	Total Vert. NISP	Proportion of Verts w/Landmark to Total Verts
Uyak	1A/2	3	0	3	1.000
Crag Point	2	8	0	8	1.000
Crag Point	3	126	19	145	0.869
Rice Ridge	A	396	155	551	0.719
Rice Ridge	C	87	23	110	0.791
Rice Ridge	E	25	10	35	0.714
Rice Ridge	G	311	33	344	0.904
Rice Ridge	H	34	30	64	0.531
Rice Ridge	J	15	4	19	0.789
Total		1005	274	1279	0.786

Table 5.22 Proportion of whole non-salmonid (marine) fish vertebrae from house floor assemblages

Site	Layer	Non-Salmonid Vertebrae NISP (w/landmark)	Non-Salmonid Vertebrae Frag. NISP (no landmark)	Total Vert. NISP	Proportion of Verts with Landmark
Crag Point	3A	101	41	142	0.711
Uyak	10	71	20	91	0.780
Uyak	7	169	1	170	0.994
Uyak	11	81	3	84	0.964
Crag Point	1B	263	64	327	0.804
Rice Ridge	B	1297	230	1527	0.849
Rice Ridge	D	78	1	79	0.987
Rice Ridge	F	107	4	111	0.964
Rice Ridge	I	11	11	22	0.500
Rice Ridge	K	53	21	74	0.716
Total		2231	396	2627	0.849

Table 5.23 Proportion of whole non-salmonid (marine) fish vertebrae from midden assemblages

Site	Layer	Non-Salmonid Vertebrae NISP (w/landmark)	Non-Salmonid Vertebrae Frag. NISP (no landmark)	Total Vert. NISP	Proportion of Verts with Landmark
Uyak	1A/2	36	28	64	0.563
Crag Point	2	23	1	24	0.958
Crag Point	3	135	14	149	0.906
Rice Ridge	A	358	14	372	0.962
Rice Ridge	C	446	215	661	0.675
Rice Ridge	E	64	2	66	0.970
Rice Ridge	G	73	10	83	0.880
Rice Ridge	H	333	54	387	0.860
Rice Ridge	J	86	8	94	0.915
Total		1554	346	1900	0.818

Table 5.24 Abundances of sea otter long bone and rib shaft and end fragments from house floor assemblages.

Site	Layer	Sea Otter Diaphysis NISP	Sea Otter Epiphysis NISP	Total NISP	Proportion of Diaphyses
Rice Ridge	B	15	11	26	0.577
Rice Ridge	D	19	25	44	0.432
Rice Ridge	F	46	40	86	0.535
Rice Ridge	I	27	9	36	0.750
Rice Ridge	K	25	15	40	0.625
Total		132	100	232	0.569

Table 5.25 Abundances of sea otter long bone and rib shaft and end fragments from midden assemblages.

Site	Layer	Sea Otter Diaphysis NISP	Sea Otter Epiphysis NISP	Total NISP	Proportion of Diaphyses
Rice Ridge	A	4	2	6	0.667
Rice Ridge	C	35	25	60	0.583
Rice Ridge	E	15	18	33	0.455
Rice Ridge	G	23	28	51	0.451
Rice Ridge	H	66	71	137	0.482
Rice Ridge	J	59	48	107	0.551
Total		202	192	394	0.513

Table 5.26 Abundances of harbor seal long bone and rib shaft and end fragments from house floor assemblages.

Site	Layer	Harbor Seal Diaphysis NISP	Harbor Seal Epiphysis NISP	Total NISP	Proportion of Diaphyses
Crag Point	3A	0	0	0	-
Uyak	10	6	10	16	0.375
Uyak	7	5	4	9	0.556
Uyak	11	3	5	8	0.375
Crag Point	1B	9	7	16	0.563
Rice Ridge	B	8	9	17	0.471
Rice Ridge	D	3	5	8	0.375
Rice Ridge	F	10	20	30	0.333
Rice Ridge	I	10	3	13	0.769
Rice Ridge	K	3	2	5	0.600
Total		57	65	122	0.467

Table 5.27 Abundances of harbor seal long bone and rib shaft and end fragments from midden floor assemblages.

Site	Layer	Harbor Seal Diaphysis NISP	Harbor Seal Epiphysis NISP	Total NISP	Proportion of Diaphyses
Uyak	1A/2	28	6	34	0.824
Crag Point	2	10	3	13	0.769
Crag Point	3	19	3	22	0.864
Rice Ridge	A	2	13	15	0.133
Rice Ridge	C	8	9	17	0.471
Rice Ridge	E	0	3	3	0.000
Rice Ridge	G	6	11	17	0.353
Rice Ridge	H	13	18	31	0.419
Rice Ridge	J	12	18	30	0.400
Total		98	84	182	0.538

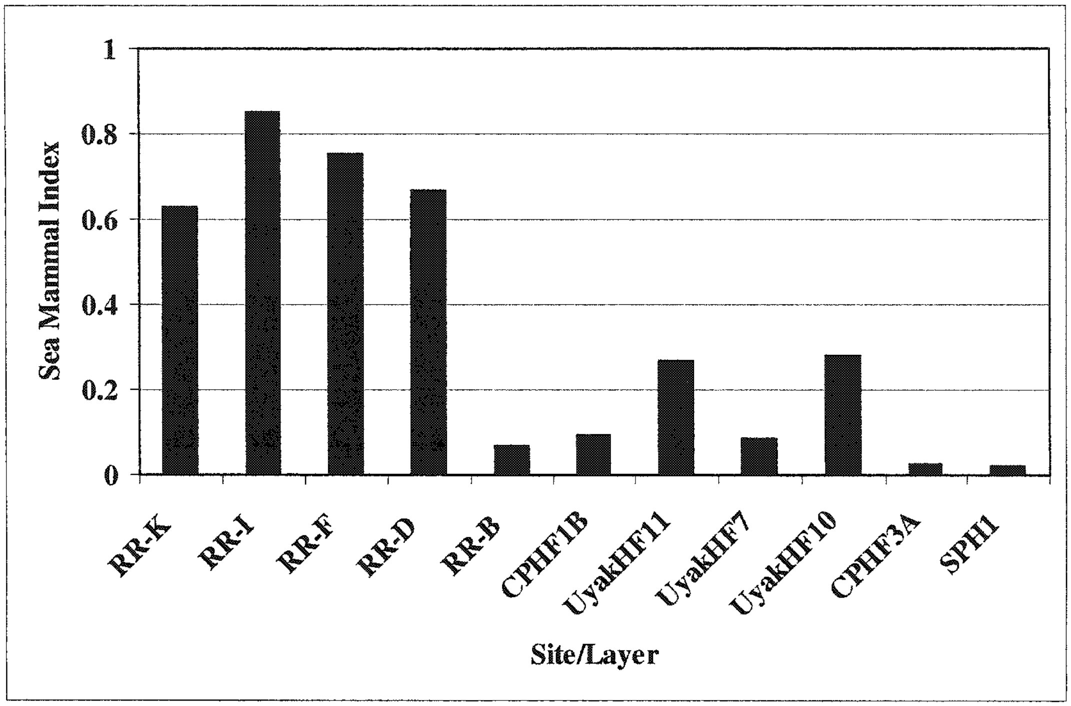


Fig. 5.1 Change Over Time in Sea Mammal Index from Housefloor Contexts

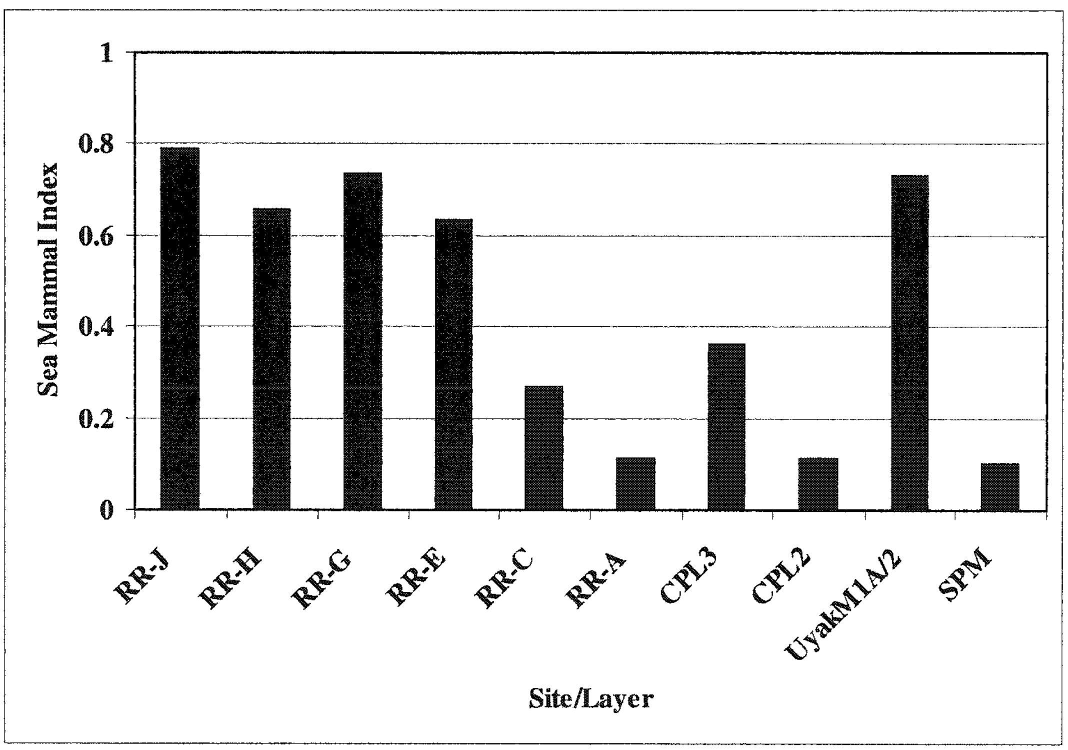


Fig. 5.2 Change Over Time in Sea Mammal Index from Midden Contexts

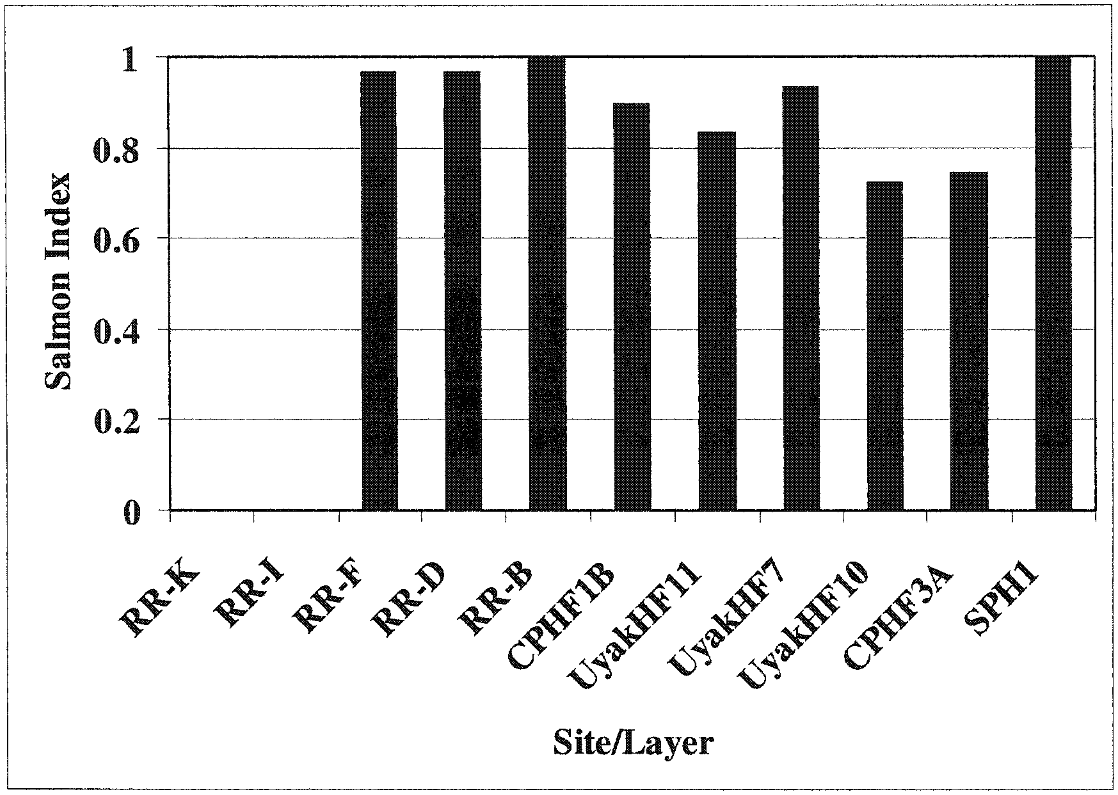


Fig. 5.3 Change Over Time in Salmon Index from Housefloor Contexts

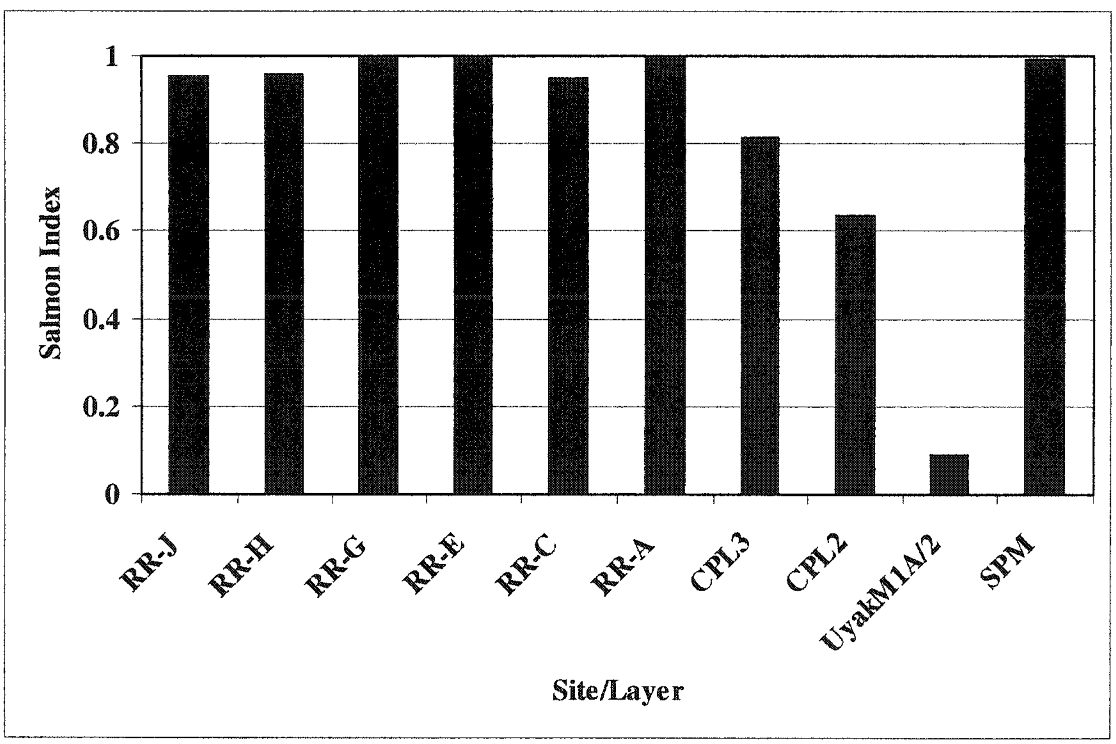


Fig. 5.4 Change Over Time in Salmon Index from Midden Contexts

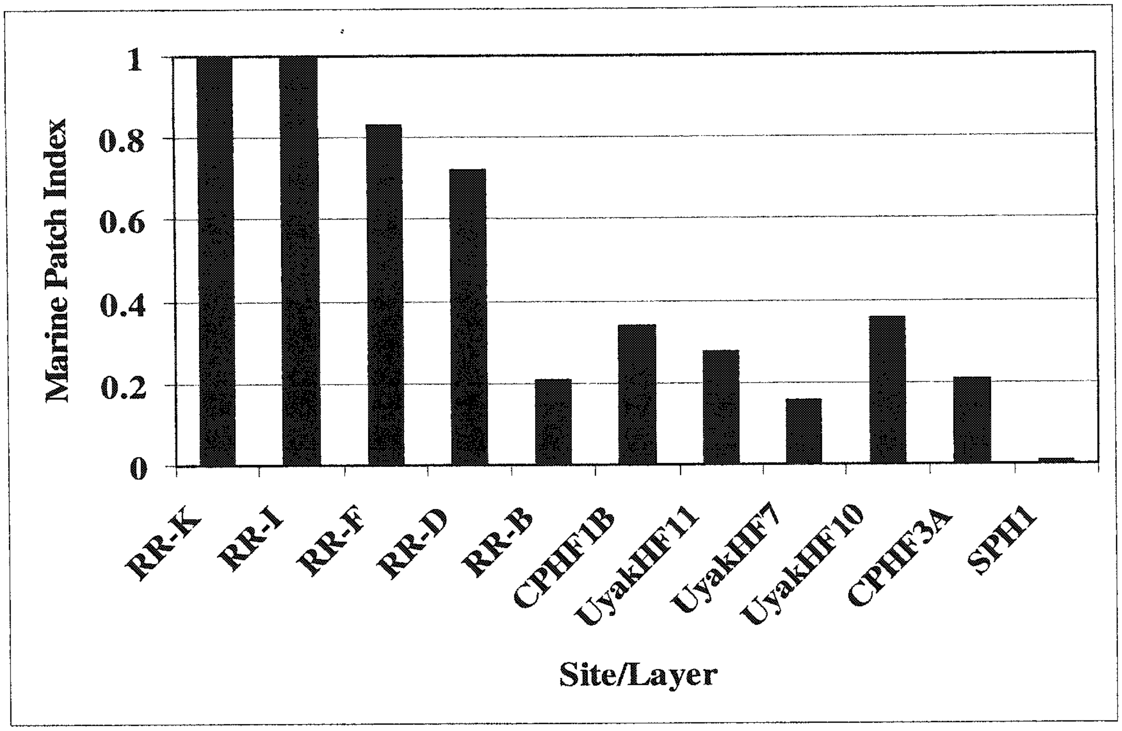


Fig. 5.5 Change Over Time in Marine Patch Index from Housefloor Contexts

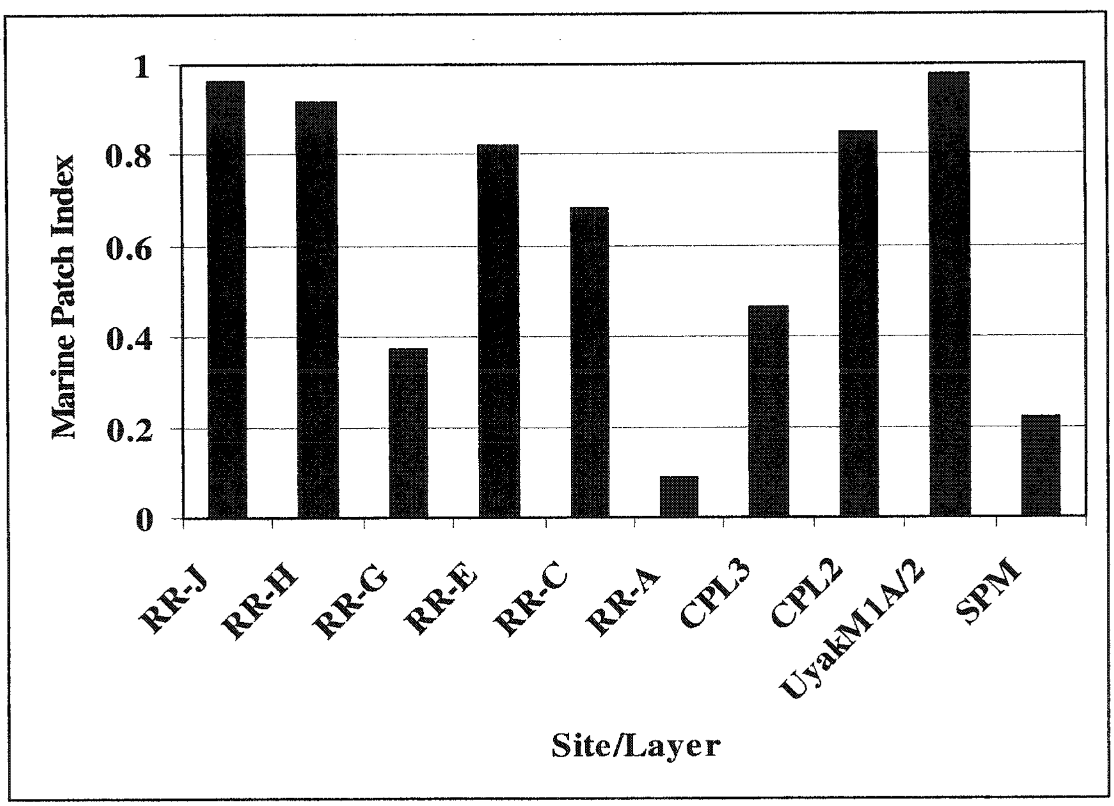


Fig. 5.6 Change Over Time in Marine Patch Index from Midden Contexts

Chapter 6:

Is Resource Depression a Possible Cause of Intensification? Transportation, Butchering, and Age Structures of Prey

The second main hypothesis this dissertation addresses is whether or not resource depression of high-ranked prey occurred in the Kodiak region, and if it played some part in the intensification of lower-ranked resources. A reduction in encounter rates with sea mammals that would lead to a greater focus on the harvest of salmon and marine fish, consequently lowering foraging efficiency, may be the result of one or several factors, including human harvest pressure. Other factors include changing climate and habitat conditions. Charnov et al. (1976) have conceptualized three kinds of resource depression: exploitation, behavioral and microhabitat. Behavioral and microhabitat resource depression occur when encounter rates with prey are reduced because of adaptations on the parts of the prey to avoid encounters with predators. Exploitation depression, on the other hand, is a reduction in the actual abundances of prey caused by predation.

Exploitation depression is archaeologically detectable and I test for it in this chapter, along with the possible influence of climate change on the patterns of prey abundance that I have already shown. The proportions of different sea mammal carcass parts, indications of butchery on bones, and the age structures of prey are used to test the hypothesis that human activity had an impact on prey populations.

Paleoclimatic data are then examined to see if climatic change played a role in structuring prey abundance as well.

Differential Body Part Transport of Sea Mammals

The resource depression model makes specific predictions about the ways in which hunter-gatherers butcher and transport prey as encounters with them become less frequent. If foragers are experiencing declining encounter rates with high-ranked prey in patches near a base camp, they will likely travel farther from the central place to operate in patches in which foraging return rates have not been reduced (Charnov et al. 1976; Hamilton and Watt 1970; Orians and Pearson 1979). As travel costs increase, the body parts of prey brought back to camp will likely become more and more limited to those providing the most utility. In other words, to offset increased distances traveled, foragers will be more selective by culling the parts of carcasses that would provide less meat.

Four types of sea mammals were pursued by hunters in the Kodiak archipelago and appear in the archaeofaunal record, not including large cetaceans: harbor seals, otariids such as sea lions and fur seals, porpoises, and sea otters. Even the smallest of these, the sea otter, would be a considerable burden to carry at any length if it were an adult individual. The others would be too heavy, even as juvenile specimens, given their average weights (e.g., Wynne 1997). Boats obviously help reduce transport costs but would not negate them. Ethnohistoric accounts of boat-based hunting of sea mammals by the Alutiit are extensive, although descriptions tend to focus on hunting methods and use of various non-meat portions of the animals than actual meat butchery choices (e.g., Holmberg 1985; Veniaminov 1984). Davydov (1977:222), however, notes that the Chugach of Prince William Sound, Alaska, were limited to 10-12 seals per vessel and had to carefully compensate for any added weight. Recent oral history clearly indicates that the advent of larger motorized boats *did* essentially negate carcass numbers and weights as a factor in travel costs, although selective butchery still occurs (Mishler 2001).

Not surprisingly, body part representation of each type of sea mammal mentioned above differs between the Rice Ridge, Crag Point, and Uyak faunal assemblages. Detailed, comparable body part data, however, is not available for the Settlement Point site (Partlow 2000). Tables 6.1-6.8 display the abundances of skeletal elements and element portions for harbor seals, otariids (including both Steller sea lions and limited northern fur seal remains), porpoises, and sea otters from both house and midden assemblages. The abundances are given in minimum number of elements or element portions (MNE). Average bone density is given for each element portion, which is explained in detail in the following section. The abundances of the different elements for all archaeological floor or midden assemblage are followed by a final column representing a "null" assemblage, which gives abundances based on the number of times the element or element portion occurs in an entire individual. This represents unselective transport of a whole carcass. Further evaluation of changing carcass transport behavior requires a measure of the utility of the various body parts of these animals as well as consideration of non-human agents that may have played a role in structuring the body part representation of these assemblages.

Meat utility indices offer a framework for evaluating faunal assemblages in terms of their skeletal element representation. Pioneered by Binford (1978) to infer butchering and consumption behavior at archaeological sites in terms of the types of bones left behind, this frame of reference has withstood critical examination (e.g., Grayson 1989; Lyman 1985, 1992; Metcalfe and Jones 1988). If other explanations of skeletal part representation can be controlled for, especially density-mediated destruction, then reasonable behavioral inferences can be made using utility indices. Indeed, they have been used with some success to evaluate other resource depression models (e.g., Broughton 1995; Cannon 2001a). Ideally, a food utility index in the vein of the artiodactyl food utility index created by Metcalfe and Jones (1988), which assigns utility values for very specific parts of the artiodactyls skeleton based on experimental butchery data, would be available for each sea mammal taxon.

Utility indices have been published for phocid seals (Diab 1998; Lyman et al. 1992), otariid seals and sea lions (Savelle et al. 1996) and small toothed whales such as porpoises (Savelle and Friesen 1996). They were created using the same methods as earlier non-sea mammal indices by calculating the meat weight of different body parts from several individual animals, averaging these weights, modifying the weights by associated skeletal elements and "rider" elements that tend to be included in meat portions, and optionally scaling the index to 100 based on the body part with the greatest modified meat weight. The derivation of these indices also demonstrates the importance of sea mammal parts not associated with particular skeletal elements, particularly the blubber and viscera which are unfortunately invisible in the archaeological record. Also, there has been no index created for the sea otter, which is dealt with later in this section.

Changes in mean utility between assemblages, based on these indices, can be quantified using analysis of variance (ANOVA) following Cannon (2001a, 2003). This method requires the mean utility and standard deviation from all skeletal portions to be calculated for each assemblage. A significant F value indicates that there is a statistical difference in the mean utility of the skeletal elements between assemblages. The resource depression model predicts that over time, as hunters travel farther to access undepleted sea mammal habitats, the mean utility of the carcass portions they transport back to a site will increase, reflected by a significant increase in the mean utility per animal part seen in the faunal assemblages. This trend may change to a decrease in mean utility if nearby sea mammal populations rebound and travel costs for hunters are lowered by exploiting these patches once more.

Tables 6.9-6.14 display the skeletal parts from house floor and midden assemblages of seals, otariids, and porpoises, excluding infant specimens and transformed from the minimum number of elements given in the previous set of tables to numbers corresponding to the animal parts used in the different meat utility indices. Also listed for each part is the unstandardized modified meat utility index (MMUI) values. The non-cranial axial skeleton values have been modified somewhat from the published indices by dividing their values by the number of times the individual bones occur in the particular body part. For example, the value for phocid seal lumbar vertebrae used in this dissertation is the MMUI value determined by Lyman et al. (1992), 2150, divided by 5 vertebrae. Rib values were divided by the number of ribs *per side* found in a complete carcass, since the MMUI values for ribs are based on sided ribcages. The numbers of each skeletal part in an individual carcass are also listed in each table under the "null" assemblage column, and are based on the numbers found in complete skeletons from the Burke Museum at the University of Washington during my analysis. By formulating the MMUI this way, I allow for portions of the rib cage and vertebral and sternal series to be quantified consistently with other single-bone body parts. The MMUI value of seal and otariid pelves in the published indices are divided into fourths, split equally between the two sided innominates, the sacral vertebrae, and the caudal vertebrae. The values for the latter two parts are subdivided by the number of vertebral elements occurring in a complete skeleton.

The "null" assemblage values are similar to the ones in the previous set of tables, giving the abundances of the various animal parts and elements that can be expected if an entire carcass was brought to the site without being selectively butchered. Following Cannon (2001a, 2003), the mean utility per part can be calculated for this null assemblage as a quantitative standard to see if a particular archaeological assemblage represents selective transport of carcass parts. A one-sample t-test is used to compare the mean MMUI of each faunal assemblage with the hypothetical mean generated from the "null" assemblage. A significant positive t value suggests that an assemblage may be the product of selective transport favoring high-utility body parts. The resource depression model predicts that the mean MMUI value of an assemblage will be significantly greater than the mean null MMUI value if transport costs are increased.

Tables 6.15 -6.20 display the mean MMUI and standard deviation of each assemblage for harbor seal, otariid and porpoise in both house floor and midden contexts. Also displayed are the value and probability of the t statistic for each sample against the hypothesized null assemblage, which are discussed later in this section. To obtain these calculations I multiplied the utility value of each body part by the number of times it occurs in the assemblage. These numbers are summed and divided by the total number of parts included, giving a distribution with a mean MMUI and a standard deviation. The mean, standard deviation, and subsequent analysis of variance were calculated by computer using SPSS.

Table 6.15 displays the MMUI data for harbor seal body parts from housefloor assemblages. The mean MMUI fluctuates from about 985 to 625 in the earlier assemblages, and then generally decreases to a low of 243 in the most recent assemblage, house floor 3A at Crag Point (Fig. 6.1). ANOVA results indicate no statistical change across assemblages, however ($F = 1.170$, $p = 0.317$).

Mean utility of harbor seal skeletal parts in the midden assemblages does show a statistical change that follows my prediction (Table 6.16). The mean MMUI rises from about 700 in the earliest layers of Rice Ridge to a peak of over 1100 in the most recent midden layers of Rice Ridge. The later midden assemblages at Crag

Point and Uyak show declining mean utility values reaching below original levels (Fig. 6.2). The F value for this sequence, 2.137, is significant at the 0.05 level ($p = 0.041$).

Sample sizes of otariid body parts is much less than that of harbor seals in both disposal contexts, making visual inspection of the different mean MMUI values hard to interpret (Figs. 6.3-6.4). Note that because the MMUI values are not standardized to a scale of 100 but instead represent actual modified meat weights, the larger values for otariids correspond with their much larger body size. I exercise caution in the interpretation of statistical analyses of these data as well since several of the assemblages in both the floor and midden sequences have sample sizes of zero or one. In the case of the floor assemblage (Table 6.17), the largest sample is from Layer I of Rice Ridge with 5 skeletal parts. Therefore the test statistic ($F = 1.674$, $p = 0.200$) has little meaning. The midden samples are only slightly larger (Table 6.18), ranging from 3 to 22, and give a similar unsignificant result ($F = 1.220$, $p = 0.261$).

Porpoise representation suffers from small sample sizes similar to the case of otariids. The mean MMUI fluctuates a great deal (Figs. 6.5-6.6) but not in a way that is statistically significant. In floor assemblages with samples greater than one (Table 6.19), the porpoise data give an F value of 0.558 ($p = 0.781$). In the four midden assemblages with a sample size greater than one (Table 6.20), the results are also not significant ($F = 1.057$, $p = 0.407$).

Several factors hamper the statistical analysis of changing mean utility values represented by these samples. As indicated above, sample size for both otariid and porpoise is very small, eliminating several of the assemblages from the analyses. Those that are incorporated appear highly variable graphically but are not different statistically. Also, smaller sample sizes create heterogeneous variances between assemblages, which violate the assumption of similar variances while performing ANOVA (Zar 1996:187). The Levine statistic, which tests for homogeneity of variance between samples, was calculated by SPSS along with each F statistic and indicated that only the porpoise assemblages, both from the floor and midden samples, had statistically similar variances. SPSS offers an additional statistical test, Welch's test, for the equality of means that remains robust when variances between samples differ. In the case of harbor seals, Welch's test is significant at the 0.10 level for both housefloor ($F_{welch} = 2.244$, $p = 0.058$) and midden assemblages ($F_{welch} = 1.949$, $p = 0.082$). Otariid mean MMUI values remain unsignificant using Welch's test, although the sample size was only large enough in the midden assemblages to conduct this test ($F_{welch} = 1.989$, $p = 0.155$).

Comparison of mean MMUI values in these assemblages with the hypothesized null assemblage is done with one one-sample t-tests. Along with the data required to conduct analysis of variance between the assemblages, Tables 6.15-6.20 display the mean MMUI of the null assemblage and the corresponding value and probability of each t statistic, testing the null hypothesis that the mean MMUI of an assemblage is the same as the null assemblage.

Table 6.15 shows t values of seal assemblages from house floors. Five of the first 7 assemblages have t values significant at the 0.10 level, and include assemblages from all three sites. Values for the latter three assemblages from Uyak and Crag Point, however, are not only insignificant but negative, implying that people were possibly selecting for parts with *less* utility or transporting higher-utility parts elsewhere. A similar pattern emerges in the seal midden assemblages (Table 6.16). Here the mean MMUI values of the Rice Ridge assemblages are significantly greater than the null assemblage, while values for the Crag Point and Uyak midden assemblages do not statistically differ from the null assemblage.

Similar to the situation with the ANOVA test, sample size is an obvious problem in the application of the t-test to both otariid and porpoise assemblages. T-tests show all of the otariid house floor assemblages (Table 6.17) and all but one of the midden assemblages (Table 6.18) are either statistically the same as a null assemblage or contain skeletal parts with *lower* mean utility. The mean MMUI of the Uyak midden assemblage is statistically greater than the null assemblage, and also has the only sample size greater than 10. All of the assemblages with porpoise remains exhibit negative t values for mean MMUI of this taxon (Tables 6.19-6.20).

The most abundant sea mammal taxon, at least in the Rice Ridge assemblages, is the sea otter, which currently does not have a published meat utility index. The same prediction can be made for this species that has been made for the other sea mammal taxa, but an alternative means of testing is required in the absence of experimentally-derived part-by-part rankings of a sea otter carcass. Without these rankings or ethnohistoric observations of sea otter butchery for any reason other than hide procurement, I follow the general pattern of other utility indices I have incorporated and consider the axial skeleton high-ranked and the limbs low-ranked. Specifically, I employ an index similar to the proportional measures of the taxonomic abundance of high-ranked prey used in the previous chapter. The index measures the proportion of high-ranked sea otter body parts relative to low-ranked parts for each assemblage and is examined across time. A chi-square test of linear trend is used to measure the ratios from the midden and floor assemblages.

In this test, I use the ratio of the minimum number of elements (MNE) of cervical, thoracic, and lumbar vertebra specimens compared to the MNE of major limb elements (humerus, radius, ulna, femur, tibia and fibula). Specimens from infant sea otters are not included in this particular analysis for the same reason they aren't included in the tests for other sea mammal taxa. A chi-square test determines whether this ratio is different between assemblages, and the Cochran's chi-square test indicates how much of this value is associated with a linear trend. By conceptualizing this ratio as a proportion of vertebrae in an assemblage of vertebrae and limb bones, a "vertebrae index" can be constructed and examined visually:

$$\frac{\Sigma\ (\text{MNE Cervical, Thoracic and Lumbar Verts})}{\Sigma\ (\text{MNE Verts} + \text{MNE Major Limb Elements})}$$

Similar to the tests above, these values can be compared to the index value of a "null" assemblage that contained both types of elements in proportion to that of an entire carcass. Assemblages with a higher vertebrae index than the null assemblage indicate selective butchering towards higher-utility skeletal parts. Index values are expected to increase over time as transport costs and travel times increase.

Tables 6.21 and 6.22 list the specific MNE values of vertebrae and limb elements of sea otters in each assemblage. These elements are only present in the housefloor layers from Rice Ridge, and they are present in all the Rice Ridge midden layers except Layer A, and are also present in the Uyak midden as well in small numbers. Tables 6.23 and 6.24 display the ratios of sea otter vertebrae and limb bones in the floor and midden assemblages, respectively, along with the ratio for a "null" assemblage consisting of an entire carcass. Also, the vertebrae index values are given in the last column. Graphical display of the index values over time gives a different impression between disposal contexts (Figs. 6.7-6.8). In the floor assemblages, the proportion of vertebrae to limb bones generally rises from Layer K to Layer D, and then decreases in Layer B, which is the last floor layer containing these sea otter skeletal elements. The midden assemblages demonstrate a much more subtle change, generally increasing from Rice Ridge Layer J to Layer C, while the Uyak midden layer contains only limb bones, resulting in an index value of 0.000.

Chi-Square analysis of the floor and midden assemblages that contain some ratio of these sea otter elements gives similar mixed results. The Rice Ridge floor layers contain significantly different ratios of vertebrae and limb elements (χ^2_{total} = 15.80, p = 0.003). Despite the appearance of an increase over time in the vertebrae index, the linear trend in the ratios is not quite significant at the 0.10 level (χ^2_{trend} = 2.51, p = 0.113; $\chi^2_{departure}$ = 13.29, p = 0.004). On the other hand, the ratios amongst the midden assemblages are not significantly different (χ^2_{total} = 4.65, p = 0.460) and without linear trend (χ^2_{trend} = 0.00, p = 0.960; $\chi^2_{departure}$ = 4.65; p = 0.325). Similar to other sea mammal taxa, comparison to a "null" assemblage indicated hunters were not particularly selective in carcass transport in most of these assemblages. The only assemblage with a higher vertebrae index than a "null" assemblage is Rice Ridge house floor Layer D.

To summarize the skeletal utility and abundance data, of the three taxa that have detailed meat utility indices available, only harbor seal skeletal part representation from midden assemblages shows a statistical indication that hunters may have become more selective in carcass part transport over time. Presumably, this was because of increasing transport costs associated with greater distances traveled to seal habitats. On the other hand, the skeletal part data of otariid and porpoise assemblages from Rice Ridge, Crag Point, and Uyak are insufficient to make inferences about how their carcasses were transported to the sites, or how transport behavior may have changed over time compared with the predictions of the resource depression model. Similar to the case of harbor seals, there is statistical support that over a period of time, sea otter remains that were deposited at Rice Ridge were increasing in the proportion of higher-utility vertebrae compared with lower-utility limb elements. Before the pattern seen in these data can be more confidently attributed to human hunting behavior, non-human agents that may have structured skeletal part representation in these assemblages must be examined.

Relative Skeletal Abundance and Density-Mediated Destruction of Bones

Quick on the heels of the development and refinement of meat utility indices was the elucidation of other reasons besides human hunting, butchering, and transport behavior that can structure faunal assemblages. In the case of artiodactyls, which have enjoyed the greatest attention in seminal zooarchaeological research, a negative correlation has been demonstrated between skeletal part meat utility and measured structural density (Lyman 1985). In other words, it has been shown that those artiodactyl skeletal elements associated with high-utility body parts also tend to have the lowest structural density as measured by a photon densitometer. Assemblages dominated by low-utility body parts which could be explained as a kill site in which the higher-utility body parts were removed for transport back to camp, or as a camp site reflecting hunting activities nearby that incur negligible transport costs, may in fact be explained by differential destruction mediated by structural density. Exploring this issue of equifinality has now become a standard part of zooarchaeological research involving skeletal part representation.

Mirroring the delay that sea mammals have experienced in food utility index development compared with other prey classes, little has been done to investigate the relationship between sea mammal skeletal element utility and structural bone density. Even after the publication of the first sea mammal meat utility index, for phocid seals (Lyman et al. 1992), the possibility of bone density structuring relative skeletal part abundances tends to be downplayed. Lyman et al. (1992) surmise that relatively low amounts of marrow in sea mammal bones would make them unattractive to humans or carnivores for further processing. Additionally, they cite the work of Wall (1983) and Stein (1989), who demonstrate that sea mammal bone density in general is greater than that of terrestrial mammals due to their adaptation to an aquatic environment.

In this dissertation I examine the role of bone density in patterning the sea mammal assemblages analyzed. Wall's (1983) research indicates that not all aquatic mammals have bone density greater than that of terrestrial mammals, and, importantly, there is still variability in average density amongst the different elements of the same marine taxon. Stein (1989) notes that pinnipeds and mustelids have denser limb bones on average than terrestrial and semiaquatic mammals. This pattern, however, is not necessarily the case with their non-limb bones. Therefore, density may be a more important structuring factor in explaining relative skeletal abundance for marine mammals than in the case of terrestrial mammals.

Although I have already shown in Chapter 5 that there is very little evidence of carnivore gnawing on any taxon in any of the assemblages examined, many of the sea mammal specimens have been fragmented. Reasons for fragmentation may be related to natural post-depostional destruction of bone or to selection of certain elements by the human occupants of the sites for modification into tools. Density-mediated structuring of element representation may therefore have occurred. In this section, I examine the possible role of structural bone density to this issue.

The most frequent method of determining whether or not skeletal part abundance is correlated with density is by comparing the relative skeletal abundance of a specific taxon with the measured bone density values of the skeletal elements and parts of elements for that taxon (e.g., Kreutzer 1992; Lyman 1985). A significant positive correlation coefficient resulting from a plot of bone mineral density values against % survivorship indicates a strong relationship between skeletal part representation and density. In this case, explanations involving human hunting behavior may still be relevant but the equifinality of potential factors remains.

In order to determine whether or not the mean structural density of skeletal specimens changes over time between assemblages, I use analysis of variance the same way in which I tested whether or not mean utility of specimens in the assemblages has changed. Significant changes in the mean structural density of bones in these assemblages that parallel changes in the mean utility of those bones may in part explain such a change in prey body part representation. Detailed structural bone density data, however, are available only for phocid seals (Lyman 1994, from Chambers 1992). Therefore, I use this taxon alone to test whether changes in mean skeletal part utility parallels changes in mean density.

Tables 6.1 and 6.2 display the MNE values of all seal element and element portions in both disposal contexts, along with the average bone density values available for most of these parts in g/cm^3. The number of times these parts occur in a complete skeleton is also given in the "null" assemblage column. The density values were obtained by averaging the measurements of all scan sites taken from a particular element or element portion. Two assemblages were not included in this analysis:

Crag Point house floor 3A, which contains only one non-infant seal element with a density value, and Crag Point midden Layer 3, which contains no seal remains.

Figs. 6.9-6.10 show the mean bone density of harbor seal skeletal elements from house floor and midden assemblages, respectively. The floor assemblages appear to gradually decline in mean density over time, although statistically there is no difference between means as shown in Table 6.25 ($F = 1.143$, $p = 0.337$). Because mean seal utility does not increase over time as mean density appears to decrease, density cannot be considered a structuring agent in skeletal representation in the house floor assemblages. The mean density of the midden assemblages, on the other hand, appears to oscillate instead of showing a unidirectional trend (Fig. 6.10, Table 6.26). Indeed, the mean density does change at a statistically significant level ($F = 6.952$, $p<0.001$).

The null assemblage of an entire seal carcass has a mean density of 0.52 per skeletal part, less than or equal to many of the assemblages. The t-values and their probabilities are given in both Table 6.25 and 6.26 for each archaeological assemblage compared with the hypothetical null assemblage. In the floor assemblages, the only one whose mean differs significantly from the null assemblage is the most recent floor deposit at the Uyak site, from Structure 10 ($t = -2.134$, $p = 0.046$). Not only does the analysis of variance indicate that in general the means of the assemblages do not change over time, but the t-tests of all but this layer indicate that they do not differ from the null assemblage either. The early midden assemblages show significantly greater mean density than the null assemblage, while the middle assemblages have a mean density either greater than or equal to the null assemblage, and the most recent assemblage is significantly less dense than the null assemblage.

Summary

Support for the hypothesis that resource depression of particular sea mammal species occurred on Kodiak based on the inferred distance hunters traveled to access them is suggested in the results of my research, but not conclusive. Of the two species with significant sample sizes, only harbor seal has a published meat utility index. The inferred utility of harbor seal parts increases over time between the large samples from midden assemblages at Rice Ridge, and a similar interpretation can be made for sea otter remains based upon an expedient skeletal part index. Seal remains from the smaller samples from floor assemblages do not follow this pattern, however, and the other sea mammal taxa suffer from small sample sizes once the counts were converted to MNE and infant specimens excluded.

The use of the published meat utility indices as a template for ranking sea mammal body parts may be problematic independent of the nature of the samples used. Seals and sea lions are notorious for the fat content of their flippers (Reeves et al. 2002), which is not quantified in these meat utility indices (e.g., Lyman et al. 1992). Mishler (2001) notes an historical preference by Alutiiq hunters for the rib cage of sea lions, which corresponds with a very high index value, but they consider the flippers as a delicacy as well but for their fat content, not the meat value found in them. This is one indication that butchery and transport decisions made by Alutiiq hunters are not based solely upon meat yield from carcass parts.

Cutmarks on Faunal Remains and Intensified Butchery

Another line of evidence used to detect resource depression is a change in the frequency of butchery marks on bones in archaeological faunal assemblages. Tool manufacture aside, the marks that humans make on animal bones are usually the result of the skinning and dismemberment process that occurs before, during, or after transport to a central place, and also from the meat-selection process that occurs any time before consumption. I follow the assumptions noted by Lyman (1994:301-302) that butchery marks present in an archaeological sample represent a certain level of butchering activity, and that this level will covary with butchery behavior and intensity. The resource depression model predicts that if encounter rates with high-ranked prey decrease, cut marks on their remains will increase as butchering intensifies to maximize meat yield from bones. If encounter rates increase, then the need to maximize the yield will lessen and consequently the frequency of butchery marks may decrease.

I make no interpretation about the nature and location of specific cut-marks, but instead compare the proportions of bones with cut-marks to bones without cut-marks following the assumptions above. Detailed criteria and classifications of cut-marks based on macro- and microscopic characteristics are well-established (Lyman 1994; Shipman and Rose 1983). I only considered obvious straight-line striae when determining whether or not a specimen had been cut-marked, but acknowledge that some of these markings may not be from butchery practices. Zooarchaeologists often precisely note the anatomical location and orientation of particular observed cut-marks, counting individual striae on specific portions of skeletal elements while controlling for taphonomic factors that may obscure marks on some specimens (e.g., Lyman 1987, 1991). Because I am concerned with the proportion of bones exhibiting these marks instead of making inferences about specific marks or the number of marks on a particular specimen (see Egeland 2003), I noted for each specimen whether or not it had been cut-marked at least once.

To test whether or not butchering intensity increased over time, I examine marks from the two most abundant high-ranked prey, sea otter and harbor seal. I do control generally for anatomical region by examining the axial skeleton and appendicular skeletal elements separately, as well separating the analysis by disposal context in case butchering frequencies differ between bones deposited in house floors and those in middens. I include all age classes of both species in this analysis. The ratios of the number of identified specimens that have cut-marks to those that do not are given for each portion of sea otter (Table 6.27-6.28) and harbor seal (Tables 6.29-6.30), along with the proportional "cut-mark index" calculated as follows:

$$\frac{\Sigma \text{ (NISP with cutmarks)}}{\Sigma \text{ (Total NISP)}}$$

The indices can be examined graphically (Figs. 6.11-6.14) and Cochran's test of linear trend can be performed on the tabular data.

From Fig. 6.11, the house floor assemblages, a generally increasing proportion of cut-marked sea otter bones is seen in both the limb and axial elements. The sea otter bones from midden assemblages (Fig. 6.12), on the other hand, exhibit less amplitude and more fluctuation, especially amongst axial elements. This difference between disposal contexts is seen in the statistical comparison of the ratios of cut-marked and non-cut-marked sea otter specimens. The chi-square tests are limited to the Rice Ridge assemblages, because of the small sample sizes of sea otter remains in the other site assemblages. Table 6.27 lists the cut and non-cut ratios of both limb and axial elements from floor contexts. The differences between ratios are significant and linear for both limb elements ($\chi^2_{total} = 42.32$, $p<0.001$; $\chi^2_{trend} = 24.68$, $p<0.001$; $\chi^2_{departure} = 17.64$, $p = 0.001$) and axial elements ($\chi^2_{total} = 19.68$, $p = 0.001$; $\chi^2_{trend} = 13.63$, $p<0.001$; $\chi^2_{departure} = 6.05$, $p = 0.109$). In the midden deposits (Table 6.28), however, the change in cut mark ratios is significant and linear for limb elements ($\chi^2_{total} = 30.46$, $p<0.001$; $\chi^2_{trend} = 6.22$, 0.013; $\chi^2_{departure} = 24.24$, $p<0.001$), but neither significant nor linear for the axial elements ($\chi^2_{total} = 2.77$, $p = 0.735$; $\chi^2_{trend} = 0.03$, $p = 0.874$; $\chi^2_{departure} = 2.74$, $p = 0.601$).

An examination of the ratios of harbor seal bones that were cut marked to those that were not exhibits more mixed results. Graphically, the limb bones from the floor deposits (Fig. 6.13) and the axial bones from the midden deposits (Fig. 6.14) *appear* to follow the prediction laid out above. In both of these cases there is an initial rise and then fall in the proportion of cut-marked seal bones, with a good deal of fluctuation afterwards. Similar to the case of sea otter bones, the midden deposits exhibit much lower proportions overall in cut-marked specimens, making changes in the ratio of cut and non-cut bones harder to detect statistically. The floor deposits (Table 6.29) do show statistically significant changes in cut-mark ratios of limb bones over time across all three sites, although there is not a significant linear trend associated with this value ($\chi^2_{total} = 17.53$, $p = 0.025$; $\chi^2_{trend} = 0.00$, $p = 0.987$; $\chi^2_{departure} = 17.53$, $p = 0.014$). Axial elements show a significant, somewhat linear change in ratio ($\chi^2_{total} = 32.13$, $p<0.001$; $\chi^2_{trend} = 3.29$, $p = 0.074$; $\chi^2_{departure} = 28.94$, $p<0.001$). Some of the significance of the linear trend may be due to the sample from Crag Point house floor 3A which had two seal bones, both cut-marked. Of the seal bones from midden deposits (Table 6.30), the limb bone ratios did not change significantly ($\chi^2_{total} = 6.57$, $p = 0.583$; $\chi^2_{total} = 0.38$, $p = 0.539$; $\chi^2_{departure} = 6.19$, $p = 0.517$) and the axial bone ratios did change significantly but not in a linear manner ($\chi^2_{total} = 22.88$, $p = 0.004$; $\chi^2_{trend} = 0.11$, $p = 0.742$; $\chi^2_{departure} = 22.77$, $p = 0.002$).

Summary

In sum, the cut-mark data suggest that in general butchering of sea otter and harbor seal increased in intensity at these sites over time, supporting the hypothesis that resource depression of certain sea mammals occurred. There are statistically significant increases in the ratio of cut to uncut sea otter limb bone specimens from both floor and midden assemblages, and axial bones from the floor assemblages as well. Harbor seal remains show less significant changes in cut-mark proportions, although limb bones from floor contexts show increases in proportion of cut-marked specimens within the Rice Ridge and Uyak sites.

Age Structures of High-Ranked Prey Remains

Age structure data are a third line of evidence used in this dissertation to examine whether or not resource depression of sea mammals occurred. Studies from population ecology suggest that harvest pressure placed on relatively large-bodied, slow-reproducing species by selective targeting of larger, presumably older individuals will result in declines in the mean and maximum ages of the target population (e.g., Caughley 1977:187-191). Tests of resource depression models have shown this reflected to some degree in archaeofaunal assemblages, notably in the case of artiodactyls (e.g., Broughton 1995; Cannon 2001a). Given the known sensitivity of north Pacific sea mammal populations to both human activity and climate change today, and the isolating nature of the Kodiak archipelago in terms of island biogeography (Fitzhugh 2001, 2003), the model in this dissertation predicts that resource depression will be reflected in demographic inferences made from the archaeological sea mammal bone assemblages.

Specific predictions that follow from the hypothesis that resource depression occurred on Kodiak depend on the behavioral and life history characteristics of each species examined. For those sea mammals with age profiles similar to that of herds of large terrestrial mammals, such as some artiodactyls, there will be proportionately more adults encountered than juveniles, and more juveniles than infants. Also similar to the case of artiodactyls, hunters can be expected to pursue larger adults upon encounter, maximizing returns. Harbor seals, sea otters and porpoises are found throughout the archipelago as solitary individuals, in small haul-outs, rafts or pods, or in large aggregations, but their age profiles generally follow this pattern (Wynne 1997). Therefore, I predict that resource depression will result in a reduction in mean and maximum ages of these taxa in both their living populations and reflected in their archaeological remains at the sites used in this dissertation.

Otariids such as the Steller sea lion and northern fur seal exhibit behaviors resulting aggregations with different age profiles than those described above, leading to different predictions in the resource depression model. Encounters with this prey would be the easiest and most predictable at known rookery locations. Scattered across the Kodiak archipelago at rocky headlands and more isolated islets and sea stacks, these aggregations often consist of females and young who are dominated (literally) by a few large males. Because those few males often flee and adult females defend themselves ferociously, leaving their young rather vulnerable, the subadult individuals would likely be targeted by hunters upon encounter. Resource depression would therefore lead to an *increase* in the proportion of adults rather than a decrease.

Because the species with the largest samples from Rice Ridge, Crag Point and Uyak are sea otter and harbor seal, the age profiles of their remains are examined here in more detail than those of otariids and porpoises. During analysis, specimens with evidence of the level of epiphyseal fusion were grouped into three classes. Adult specimens are approximately the same size as the elements from the adult comparative skeletons, and exhibit fusion of the epiphyses. Juvenile specimens may be smaller than adult specimens or the same size, but they differ in this classification in that their epiphyseal portions are unfused. I acknowledge that different elements of the skeleton fuse at different stages in the life history of all mammals, however this should not affect detection and interpretation of general changes in the ratios of all fused to unfused specimens of a particular species between assemblages. Infant specimens are classified as such based on their reduced size, lack of epiphyseal fusion, porosity of cortical bone, and underdevelopment of muscle attachments and other landmarks. Although I identified specimens as infant during analysis according to those criteria, the statistical tests performed here combine juvenile and infant specimens since my predictions focus on changing proportions of *adult* specimens, whether decreasing in the case of sea otters, harbor seals and porpoises or increasing for otariids.

Specimens that are included in this quantification are limited to diaphyses and non-epiphyseal portions of non-long bone elements. Epiphyseal ends of long bones, unfused vertebral centrum discs, and other epiphyseal portions of elements are excluded. This prevents over-representation of these portions and consequent inflation of the counts of juvenile specimens. Individual teeth were not counted either.

To determine whether or not ratios of adult and sub-adult specimens follow the predictions outlined above, I incorporate a graphical examination of the proportional index, in this case the adult specimen index, for all four sea mammal taxa:

$$\frac{\Sigma\,(\text{Adult NISP})}{\Sigma\,(\text{Adult + Subadult NISP})}$$

Cochran's chi-squared test determines whether or not the ratios of adult and subadult specimens differ significantly over time, and with any sort of linear trend. This test is much more powerful when performed on the sea otter and harbor seal assemblages, which have larger sample sizes than the otariid and porpoise assemblages. Inferences about resource depression from these data are site-specific and so examinations of these results only involve intra-site comparisons.

The remains of sea otters in both the house floor and midden assemblages follow the predictions of the model more closely than the remains of other sea mammal taxa. Figures 6.15 and 6.16 show decreases in the proportion of adult specimens to sub-adult specimens in the Ocean Bay assemblages. Amongst the house floor assemblages (Fig. 6.15), the adult specimen index decreases through time at the Rice Ridge site with the exception of a slight increase towards the end of occupation in Layer B. At the Crag Point site, there are only two floor assemblages available but no aged sea otter specimens were found in house floor 3A, so comparison is not possible. At the Uyak site the index increases from the earliest house floor, 11, to the middle floor, 7, before decreasing to floor 10. This does not follow the predictions of the model, but very small sample sizes in all of these assemblages hampers further interpretation. In Fig. 6.16 the midden assemblages show a decline in the adult specimen index during the Rice Ridge occupation, and a small sample from the Uyak midden with an index value higher than those from the upper Rice Ridge midden assemblages.

Sea otters are the first sea mammal listed in Table 6.31, which gives the ratio of adult specimens to sub-adult specimens in floor assemblages. There are statistically significant differences between the ratios of the Rice Ridge floor assemblages ($\chi^2_{total} = 9.59$, $p = 0.048$) and much of this is associated with a decreasing linear trend ($\chi^2_{trend} = 5.15$, $p = 0.023$; $\chi^2_{departure} = 4.444$, $p = 0.218$). Amongst the very small samples from the Uyak site, there is no statistically significant difference in ratios ($\chi^2_{total} = 0.92$, $p = 0.632$) but the mean expected cell value is 1.8, much lower than the suggested minimum threshold of 6 for confidence in the sample sizes for chi-squared tests (Zar 1999). Table 6.32 also lists the ratios of adult and sub-adult sea otter specimens first, but for the midden assemblages. Once again, the Rice Ridge assemblages show a very significant, linear decline in the ratio of adult to sub-adult specimens ($\chi^2_{total} = 23.51$, $p < 0.001$; $\chi^2_{trend} = 13.94$, $p < 0.001$; $\chi^2_{departure} = 9.57$, $p = 0.048$).

Figs. 6.17 and 6.18 display the adult specimen index values of harbor seal remains from floor and midden assemblages, respectively. The proportion of adult specimens fluctuates more in the floor assemblages (Fig. 6.17) than the midden assemblages (Fig. 6.18), which appear to generally decline at both Rice Ridge and Crag Point. This follows the predictions of the resource depression model. Amongst house floor assemblages, however, the proportion of adult specimens decreases, increases and then decreases again at Rice Ridge, decreases between the two floor assemblages at Crag Point, and increases over time at Uyak.

Although not large, the harbor seal sample sizes from the floor assemblages at all three sites are large enough to put some confidence in the chi-squared tests of the ratios of adult to sub-adult seal specimens (no expected mean cell value is less than 6). Amongst the Rice Ridge floor layers, the ratio changes significantly over time ($\chi^2_{total} = 12.25$, $p = 0.016$), but without a significant linear trend associated with it ($\chi^2_{trend} = 2.18$, $p = 0.140$; $\chi^2_{departure} = 10.07$, $p = 0.018$). The Crag Point assemblages will obviously show some sort of directional change because there are only two assemblages that are examined, but the sample size of the more recent of the two, from house 3A, is only two specimens. Despite an insignificant total chi-squared value ($\chi^2_{total} = 0.89$, $p = 0.344$), all of this value is associated with the linear trend between the two ($\chi^2_{trend} = 0.89$, $p = 0.344$; $\chi^2_{departure} = 0.000$). Amongst the Uyak floor assemblages, the difference between ratios is significant ($\chi^2_{total} = 8.65$, $p = 0.013$), and the linear trend is highly significant as well ($\chi^2_{trend} = 8.40$, $p = 0.004$; $\chi^2_{departure} = 0.25$, $p = 0.614$). This trend, however, is in the opposite direction predicted by the model.

The seal remains from the midden assemblages follow the predictions of the model much more closely than those from the floor layers. At Rice Ridge, the change in the ratios is highly significant ($\chi^2_{total} = 23.29$, $p<0.001$) and so is the linear trend ($\chi^2_{trend} = 14.41$, $p<0.001$; $\chi^2_{departure} = 8.88$, $p = 0.064$). At Crag Point, there is also a significant change in the ratio of adult to sub-adult seal specimens ($\chi^2_{total} = 7.12$, $p = 0.008$) and, as in the case of sea otters, because there are just two assemblages being compared all of this value is associated with a linear trend ($\chi^2_{trend} = 7.12$, $p = 0.008$; $\chi^2_{departure} = 0.000$).

Sample sizes of otariids are quite small in both floor and midden assemblages from all of these sites, although the statistical tests are still described here because the model makes different predictions about the age structures of this taxon compared with the others. Changes in the adult specimen index of otariid specimens from house floor assemblages (Fig. 6.19) appear to follow the prediction made for the other taxa, *not* for otariids. At Rice Ridge, the proportion of adult specimens decreases over time, instead of increasing, while at Uyak it declines significantly between the three floor assemblages. The otariid specimens from the midden assemblages (Fig. 6.20) do not show a clear pattern either way amongst the Rice Ridge layers, but a significant decrease between the Crag Point midden layers, which have very small sample sizes.

The ratios of adult to sub-adult otariid specimens from the floor assemblages, given in Table 6.31, readily indicate the problem with sample size. Between the Rice Ridge midden layers, the ratios do not change significantly ($\chi^2_{total} = 3.58$, $p = 0.465$), although the expected mean cell value is 3.0. The linear trend associated with this value insignificant at the 0.10 level ($\chi^2_{trend} = 2.56$, $p = 0.109$; $\chi^2_{departure} = 1.02$, $p = 0.797$). At Crag Point, there is only one aged otariid specimen in floor 1B, a juvenile, and in 3A, an adult. This is an increase in the adult specimen index from zero to 1.000, but obviously has little meaning. The specimens from the Uyak floor assemblages show a significant change in ratio ($\chi^2_{total} = 7.53$, $p = 0.023$), although once again the expected mean cell value is small, in this case 2.3. The trend associated with the chi-squared value is significant (χ^2_{trend} = 7.21, p = 0.007; $\chi^2_{departure}$ = 0.32, p = 0.571) and negative, also going against the prediction of the model.

The ratios of adult to sub-adult otariid specimens from the midden layers (Table 6.32) suffer from sample size problems and do not follow the predictions in the model either. The ratios of specimens from the Rice Ridge midden layers are not significantly different from each other (χ^2_{total} = 3.75, p = 0.587), and have an expected mean cell value of 4.8. The linear trend associated with the chi-squared value is insignificant as well (χ^2_{trend} = 0.05, p = 0.820; $\chi^2_{departure}$ = 3.70, p = 0.449). The seemingly dramatic decline in the adult specimen index value between the two Crag Point midden assemblages is caused by a change from the earlier assemblage, containing 5 adult specimens and 1 sub-adult specimen, to the later assemblage, containing no adult specimens and only 3 sub-adult specimens.

The age structure changes of porpoise specimens are hard to interpret not only because of their small sample sizes but also their inconsistent representation within each site, which can be seen in Figs. 6.21 and 6.22. Chi-squared tests for each site and disposal context resulted in expected mean cell values of less than six with the exception of the two midden layers at Crag Point. These were also the only assemblages besides Crag Point house floor 1B that had double-digit sample sizes. House floor 1B was the only floor assemblage with a total aged porpoise sample size greater than 4, making any sort of comparison between those assemblage unreliable at best. Despite having relatively large sample sizes (the expected mean cell value is

15.8), a test of the difference between the ratios of the two Crag Point midden layers gives statistically insignificant results (χ^2_{total} = 0.29, p = 0.593; χ^2_{trend} = 0.29, p = 0.593; $\chi^2_{departure}$ = 0.000).

Summary

For the species in which sample sizes are large enough, changes in age structure generally follow the predictions of the resource depression model. Proportions of adult sea otter specimens significantly decrease at Rice Ridge. Harbor seals are larger in the midden than the floor contexts, and show a significant decrease in proportion of adult specimens over time as well. The small samples of otariids and porpoises, however, prevent any inferences about their population dynamics near these sites from being made.

Population Dynamics of Low-Ranked Prey Remains

Resource depression of lower-ranked prey, along with continued depression of high-ranked prey, can be expected once resource intensification occurs. As encounter rates with sea mammals decrease, the intensified use of fish in marine patches and salmon in riverine patches has the potential to negatively impact these populations. The complex life histories of Pacific salmon and the high fecundity of fish in general compared to sea mammals (Moyle and Cech 1996) require different methods for testing a similar hypothesis.

Salmon

Salmonids, which are considered high-ranked within the riverine patch but ranked lower than sea mammals even with mass capture technology, are surmised to have been over-harvested commercially in recent times (National Research Council 1996). However, there is significant debate regarding the likelihood that Native American harvest of particular salmon runs could deplete them to an extent noticeable in either historic observations or the archaeological record. Some researchers attribute the "boom" in early historic commercial harvests of Pacific salmon to a rejuvenation period for salmon runs after contact-era decimation of Native American populations (Hewes 1973). Many, however, discount the possibility that the major fluctuations in salmon abundance seen over time can be attributed to non-commercial harvesting practices (e.g., McEvoy 1991).

Unfortunately, testing the hypothesis that exploitation resource depression of salmon stocks occurred prehistorically is made difficult by a combination of several factors, including the uniformity of ages of individual fish upon capture, the difficulty of species-level identification of salmonid remains, and poor preservation of many salmonid elements in the archaeological record. Pacific salmonids are usually semelparous, which means that they die after one spawning opportunity. Related to this is a life history involving fixed life spans of two to five years, depending upon the species and local population (Groot and Margolis 1991). Because the age-at-capture of particular salmon populations are fixed and uniform, depression will affect the abundance but not the age-structure of these populations. Ageing archaeological salmon remains from annuli on bones or otoliths, a common method of determining the ages of fish (e.g., Casteel 1976; Van Neer et al. 1999; Williams and Bedford 1974), will not offer any clues about harvest pressure in this case.

There is evidence that body size of salmonids decreases with increased harvest pressure (Blair et al. 1993; Gross 1985; Hamon 1995; Quinn and Foote 1994). These empirical studies examined living populations of salmonids, and the species of examined individuals were easily determined. If all species of salmonids had the same or similar body size distribution, then a decline in body size inferred from archaeological remains could be considered a possible indicator of resource depression. Because the distribution of salmon body sizes at maturity depends upon the particular species, a change in body size inferred from archaeological remains may be a function of changing species exploitation instead of pressure placed on one species. Determining the species of archaeological salmonid remains is quite difficult and can only be confidently made on very few skeletal elements that are often not present in assemblages due to density-mediated destruction (Butler and Chatters 1994). Advances in DNA extraction from archaeological salmonid remains will hopefully allow easier identification of these remains to the species level (Butler and Bowers 1998; but see Arndt et al. 2003), in which case changes in the size of certain skeletal elements will become more meaningful towards answering questions of depression.

Changing abundances of salmon are therefore the only means to examine whether or not salmonids in general may have undergone depression. As I mentioned above, confident identification of archaeological salmonid remains to a particular species cannot be made. One proxy measure of salmon abundance that may be species-specific is the amount of certain nitrogen isotopes that are present in lake sediment cores (Finney et al. 2000). Sockeye salmon (*O. nerka*) are the only Pacific salmon species that require lake habitats for spawning and rearing. ^{15}N levels in sediment cores from the beds of lakes associated with sockeye populations are used as a proxy for the abundance of carcasses of spawning salmon. Fluctuations in the nitrogen levels, or $\delta^{15}N$, at Karluk and Akalura Lake on Kodiak Island are interpreted by Finney et al. (2000, 2002) as fluctuations in the abundance of mature, returning sockeye salmon to a particular lake system. This line of research, independent of and potentially complimentary to the analysis of salmonid remains in the vicinity of these lakes, may indeed suggest changes in salmon populations, but the underlying cause or causes of such fluctuations remain unanswered.

The equifinality of patterns in salmon abundance further complicate this thread of the resource depression hypothesis. Despite an innovative method of detecting change over time in salmon abundance, Finney et al. can only cautiously and loosely attribute this pattern to climatic change on both short-term time frames of a few hundred years (Finney et al. 2000), and on a longer scale of over 2000 years in which they connect increasing amounts of ^{15}N and other carcass-derived nutrients in lake cores on Kodiak with the Kachemak-Koniag transition and increased Alutiiq salmon fishing (Finney et al. 2002). A survey of recent literature (e.g., National Research Council 1996 and references therein) clearly indicates that we have a long way to go towards understanding even short-term, directly observable changes in the populations of specific salmon runs. Human harvesting, habitat alterations in and around spawning areas, and changes in the conditions of the Pacific ocean have all been posited both individually and in combination as potential causes of depression in salmon populations. Until methods of identification of salmon remains to species-level are refined and the impacts of particular variables on salmon populations are better understood, detecting salmon depression in the archaeological record and attributing it to a particular cause or causes is greatly inhibited.

Pacific Cod

Resource depression of certain marine fish can be examined in a more straightforward manner than salmon, and are an appropriate focus because of their ubiquity in most all of the faunal assemblages used in this dissertation. Unlike salmonids, most marine fish such as cod and their close relatives (Family Gadidae) are not semelparous. They have a life history that involves incremental growth throughout a lifespan that is dependent primarily upon predation by other organisms (e.g., Bjørnstad et al. 1999; Kurlansky 1997). Age is therefore strongly correlated with body size of the living fish (e.g., Love et al. 2002; Moyle and Cech 1996), and dimensions of certain skeletal elements of those fish have been shown repeatedly to be correlated with body size (e.g., Leach and Davidson 1999; Leach at al. 1997; Zohar et al. 1997) If a set of Gadid remains can be confidently identified to species and a proxy of age and/or body size used to detect such changes reflected in the archaeological assemblages, then hypotheses about depression of this relatively low-ranked but heavily-utilized prey can be tested, assuming we know the relationship between harvest pressure and Gadid age and body size. Although a similar regression analysis that demonstrates the relationship between measurements of Pacific cod (*G. macrocephalus*) body size and age at capture, and between body size and particular skeletal element measurements, has not been performed, I assume that a similar relationship holds. Further research in this vein, however, is warranted.

So what happens when increasing harvest pressure is placed upon a non-semelparous fish population? Broughton (1997) has demonstrated a decline in the body size of harvested sturgeon (*Acipenser* sp.) over time at the Emeryville shellmound near San Fransisco Bay, California, which he attributes to harvest pressure. There is some debate, however, regarding the impact of taking more and more fish from a population on the consequent body size and age distribution of that population.

Whether mean body size of a particular fish population *increases* or *decreases* with greater harvest pressure is contentious. Leach and Davidson (2001) maintain that in the case of many subtropical fish species, the removal of larger specimens from a population will lead to an increase in the mean body size of the remaining population as intra-specific competition for food decreases. On the other hand, many studies of historic cod populations in the north Atlantic have explicitly tied human harvesting to declining abundances *and* mean body size of Atlantic cod (*G. morhua*) when environmental factors such as oceanographic conditions and non-human predator influences are held constant (e.g., Beacham 1983; Bjørnstad et al. 1999; Haedrich and Fischer 1996; Jørgensen 1990; Macer and Shepherd 1987; Rätz and Stein 1999). This abundance of recently analyzed data specific to gadids and prehistoric empirical support from Broughton's (1997) research leads me to predict that increased harvest pressure on marine fish caused by resource intensification (see Chapter 5) will result in a decline in the mean body size of both the available gadid populations and their remains in archaeological assemblages. Future research on the population ecology of fish populations undergoing harvest pressure of varying levels will allow a useful reexamination of the patterns and conclusions presented here.

To prevent confusion between gadid species of different average body size such as Pacific cod, walleye pollock, and Pacific tomcod, I only include in this particular analysis those specimens that can be most confidently identified to species. Because Pacific cod are by far the most abundant species identified in the assemblages, I take measurements on specimens that are from elements that are morphologically distinct for this species. The four major paired jaw elements (angular, dentary, maxilla and premaxilla) fit this criterion and are found in large enough samples to infer change over time in Pacific cod body size. Width measurements are taken on landmarks of these elements (Fig. 3.4) in such a way as to allow use of fragmentary specimens. Specimens that cannot be confidently identified to species or lacked any part of these landmarks are not included in the analysis.

Tables 3.33-3.36 display the mean and maximum measurements of angulars, dentaries, maxillae and premaxillae, respectively for each assemblage grouped by site, along with the sample size and standard deviation for each sample and the mean calibrated age associated with each assemblage. Because disposal context shouldn't matter with regards to the sizes of Pacific cod being caught, consumed, and discarded, I do not examine trends in cod element size separately for house floor and midden assemblages. Also, I only use assemblages that have at least one associated radiocarbon date. Some of the assemblages, such as Rice Ridge Layer E, were included in previous analyses because their relative chronological relationship with other assemblages was known and sufficient for those tests, but are excluded in this case because the linear regressions used here require mean calibrated intercepts from radiocarbon dates for their x-axes.

Changes in the distribution of width measurements are displayed as scatterplots in Figs. 6.23-6.25 within the Rice Ridge, Crag Point, and Uyak sites, respectively. The x-axes represent calibrated years after 7000 years before present (for the purpose of creating the scatterplots in SPSS), and the y-axes represent width in millimeters. At Rice Ridge (Fig. 6.23), width measurements decrease very significantly for all four skeletal elements based on the t-values of the regression slope coefficients (t_{slope}). In the Crag Point assemblages (Fig. 6.24), dentaries, maxillae and premaxillae decrease in size significantly at the 0.10 level of probability while there is no statistical or graphical decrease in angulars from the site. In the Uyak assemblages (Fig. 6.25), the slope coefficients of the regressions for all four elements are negative suggesting a decrease in size over time, although only the t-value of the slope for maxillae is significant at the 0.10 level.

With the exception of the cod remains from the Uyak site, there is statistical support for a reduction in cod size over time as they were apparently being harvested with increasing intensity. The strongest evidence comes from the cod remains from Rice Ridge, in which the assemblages span the greatest time depth and also show the most obvious shift towards intensification of marine fish from the earliest deposits to most recent. A significant decrease in the size of all four jaw elements corresponds to a decrease in the sea mammal index over time, described in Chapter 5 (see Figs. 5.1 and 5.2), which indicates more intensive harvesting of marine fish in relation to sea mammals. At Crag Point, there is also evidence that Pacific cod were decreasing in size over time, albeit not as strong as the evidence at Rice Ridge. Similar to Rice Ridge, a decrease in the sea mammal index between Crag Point house floors 1B and 3A, and between midden layers 3 and 2 is concurrent with the reduction in cod size. At the Uyak site there is marginal evidence that Pacific cod decreased in size over time between assemblages. The regression slope values are negative but not strongly significant. Also, the sea mammal index decreases between the earliest and middle assemblages but then increases from the middle assemblage to the most recent.

So what is the relationship between the intensity of Pacific cod fishing and average body size of the cod being caught? To examine this relationship statistically I correlate the sea mammal index from Chapter 5, a measure of cod harvesting intensity relative to sea mammal hunting, with the mean values of measurements taken on cod elements. If intensive harvest pressure is related to reductions in mean body size of cod, I expect a strong positive relationship between the sea mammal index and body size. In other words, I expect assemblages with the remains of larger Pacific cod to covary with higher sea mammal index values, which reflect a greater subsistence focus on sea mammals relative to fish. As the index decreases, so should the mean body size of cod.

Table 6.37 displays both parametric and nonparametric correlation coefficients for the relationships between sea mammal index values and each of the four skeletal measurements, with data from all sites combined. Assuming normality of the distributions of width measurements, the correlation coefficients between the sea mammal index and width measurements of each of the skeletal elements indicate a strong positive relationship as predicted above. The strongest relationship is between the index and mean dentary width (r=0.778, p=0.001), while the weakest is between the index and mean maxilla width (r=0.649, p=0.031).

Some of the assemblages have very small (sometimes singular) samples of a particular cod jaw element that were measured. Therefore, Spearman's rho may be a more appropriate test statistic to use because it is a measurement based upon a nonparametric statistical test. In this case, two of the four element measurements still show strong positive relationships with the sea mammal index: the dentary (r=0.695, p=0.006) and the premaxilla (r=0.792, p=0.001). The angular shows a positive relationship that is not quite significant at the 0.10 level (r=0.449, p=0.107), and the maxilla also exhibits a positive relationship with the index that is not statistically significant (r=0.405, p=0.216). It is unclear why there is a difference in this correlation between the sea mammal index and width of dentaries, premaxillae, and to some extent angulars, as opposed to the lack of correlation between the sea mammal index and maxillae. This element is present in fewer assemblages and in fewer numbers within assemblages that did contain them than the other other elements, however.

Summary

These tests generally indicate positive relationships between intensity of sea mammal hunting relative to marine fishing and Pacific cod body size. Conversely, greater proportions of marine fish in the Kodiak faunal assemblages, in this case Pacific cod, are associated with inferred smaller body sizes. It might be tempting to interpret this pattern as a human-induced reduction in cod size from harvest pressure, but changes in climate may account for the pattern as well. The trends shown here that suggest a decrease in cod body size begin at a very early time in which the human population of the Kodiak archipelago may not have been large enough to have an impact on a prey type with such high reproductive rates. The next section examines climate change in south-central coastal Alaska as another possible explanation for this trend.

Climate Change

The patterns shown in the Kodiak archaeofaunal assemblages described above suggest that sea mammals, most notably sea otters and harbor seals, were becoming more scarce on the landscape between about 7000 and 1000 years before present.

Less-profitable resources, in this case Pacific cod, were undergoing size reductions over the same period. Human-induced resource depression of sea otter and seal populations concurrent with intensified use of marine fish is one possible explanation for these patterns, but long-term climate change and habitat alterations are other explanations. Physical changes in the environment may drive patterns seen in age structure and size data, therefore indications of resource depression may not be appropriately explained by human harvest pressure. Therefore, I examine the paleoclimatic record for the north Pacific and compare it to the patterns described earlier in this chapter.

Reconstructions

The paleoclimate record for the North Pacific has been reconstructed at various resolutions and for different time periods based upon several sources of data. Reconstructions from tree ring measurements are perhaps the most fine-grained but are limited to the past 300 years along the north coast of the Gulf of Alaska (Wiles et al. 1996). Glacial geology offers another means of reconstructing climate, and a detailed record has been reconstructed for the past 2000 years from the icefields of the Kenai Peninsula to the north and east of the Kodiak archipelago (Wiles and Calkin 1994). However, it appears as though different parameters are responsible for glacial fluctuations depending upon whether the specific glacier is maritime, in which case winter snowfall amounts are paramount, or continental, in which case glacier movement responds most noticeably to summer temperatures (Wiles et al. 1995).

Oxygen isotope data from deep-water cores offer a long record of change in reconstructed sea surface temperatures, but specific interpretations of warm and cold intervals remain in disagreement (e.g., Kennett and Kennett 2000; Pisias 1978; Sabin and Pisias 1996). Transfer functions from pollen frequency data that reconstruct summer temperatures give coarse-grained results that have the advantage of covering larger periods of time than other methods and can be compared between core samples taken from large areas to discern broad geographic patterns and/or dissimilarities (Anderson et al. 1991; Bradley 1999:375-383).

Summer temperature fluctuations over the past 10,000 years along the north Pacific coast have been interpreted from pollen data at several locations. Reconstructions by Heusser et al. (1985) are based upon fossil pollen obtained from muskeg near Icy Cape and the Malaspina Glacier at the juncture of the Alaskan panhandle and mainland Alaska and indicate a warm interval between 10,000 and 8,000 radiocarbon years before present followed by a warmer and drier hypsithermal from 8,000 to 6,000 BP. A cooler and wetter transitional period lasted from about 6,000 to 4-3,500 BP. The neoglacial period corresponds to cool, wet conditions and lasts through the twentieth century with several warm "spikes", including the so-called Medieval warm period around 1,100 radiocarbon years BP.

The timing and intensity of the Heusser et al. (1985) model is generally supported from pollen records in other locations along the Pacific coast, including the Queen Charlotte Islands (Pellat and Mathewes 1997) and Glacier Bay (Hansen and Engstrom 1996), as well as from interior records from the central Yukon valley

(Cwynar and Spear 1991). Pollen records in the vicinity of the Kodiak archipelago reflect the paucity of large woody plant species growing in the area before the recent incursion of Sitka spruce (*Picea stichensis*), and are therefore more informative of the vegetation patterns in the immediate area of the core sample than long-term climatic changes (e.g., Heusser 1983; Nelson and Jordan 1988). Therefore, I compare the trends in faunal data presented in my research with the reconstructed summer temperature curves given in Heusser et al. (1985) and adapted by Mann et al. (1998).

Figures 6.26 and 6.27 display the summer temperature curves adapted from Heusser et al. (1985) and Mann et al. (1998) with the mean radiocarbon ages of Kodiak floor and midden assemblages, respectively, placed on the curves. With the exception of the Crag Point floor deposits, there are apparent decreases in temperature over time between assemblages within each site. At Rice Ridge, both the floor and midden deposits chronologically correspond with the end of the hypsithermal period of warmer, drier climatic conditions. The two Crag Point house floor deposits examined in this dissertation date before and after the medieval warm period and suggest a possible increase in temperature from house floor 1B to 3A. The only midden deposit with an associated radiocarbon date, level 2, corresponds with an interval of the neoglacial at perhaps its coldest. The three house floor deposits examined from the Uyak site correspond with a sharp cooling trend following the peak of the medieval warm period. Finally, both the house floor and midden deposit from Settlement Point correspond with the cooler climatic conditions of the little ice age.

There is some danger in the examination of one chronology (the sequence of Kodiak faunal assemblages) in light of another (mean July temperatures throughout the Holocene), as noted by Grayson et al. (2001) while examining trends in faunal evenness and their correspondence with temperature reconstructions from Eastern France (e.g., Guiot et al. 1989). For Kodiak, the chronology of the faunal assemblages is based upon associated radiocarbon dates (i.e. probability statements) from charcoal, while the chronology of mean July temperatures for the north Pacific is based upon transfer functions of pollen data and radiocarbon dates as well. The standard deviations of most of the radiocarbon dates associated with the faunal assemblages are between 40 and 80 years, but dramatic shifts in temperature are shown by Heusser et al. (1985) to occur over brief intervals.

Hopefully further paleoclimatic research in the area will refine and corroborate the reconstructions created so far, and more rigorous dating of analyzed faunal assemblages will give greater confidence in comparisons between the two kinds of chronology. For the purpose of my research, however, I interpret the comparisons shown in Figs. 6.26 and 6.27 as an indication of cooling trends within and between the Rice Ridge assemblages and Uyak assemblages and a slight warming trend between the Crag Point assemblages, along with a broad cooling trend in general from the early assemblage at Rice Ridge to the most recent Crag Point and Settlement Point assemblages.

Climate and Sea Mammal Populations

So can changing temperatures possibly explain the apparent resource depression of sea otters and harbor seals that occurred at these sites? To answer this, I must first examine the effects that climatic change may have on these sea mammal populations in the north Pacific. These changes affect not only survivorship and abundance of the sea mammal populations themselves but the prey upon which they feed as well.

Sea surface temperature (SST) elevations that occur on a very short time interval, namely El Niño/Southern Oscillation (ENSO) events, have been shown to impact both pup and juvenile survival rates of some sea mammal species. Whether this creates a positive or negative effect seems to depend on latitude, however. For northern fur seal (*C. ursinus*) populations, warming SST coinciding with recent ENSO events has apparently been detrimental to pup survival at the rookery on San Miguel Island on the southern California coast (DeLong and Antonelis 1991; Trillmich et al. 1991), while the same climatic events had no noticeable effect on pups at the Pribilof Island rookery in the Bering Sea (Gentry 1991) and a *positive* effect on juvenile male survivorship at the Pribilof rookery (York 1991). Unfortunately much less research has been done on the direct effects of changing sea surface temperatures on harbor seal and sea otter populations specifically (Kenyon 1969; Reeves et al. 2002). For sea otters, geographic distribution throughout the Pacific probably varies with periodic intrusion of warm, nutrient-poor water related to ENSO events or extensions of cold nutrient-rich water when the California current strengthens, while local distribution is affected by weather and sea conditions that can disrupt kelp canopies and rafting locations (Reidman and Estes 1991:73, 79-81). In the case of fur seals, however, it is clear that survivorship rates can change dramatically over a very short span of time, the direction of this change depending upon geographic location, and is probably true of other species as well.

Adding to this complicated pattern of response is the effect changing temperatures and nutrient upwelling intensity have had on fish populations, the primary prey of seals, sea lions, and porpoises. Also, sea otter population dynamics and availability to human hunters have been tied closely to their prey (primarily invertebrates such as sea urchin and mollusks) and the habitat of their prey, such as eel grass and kelp beds (Simenstad et al. 1978). As discussed in greater detail below, the relationship between changes in fish population dynamics and climatic variables remains poorly understood. In general, however, cooler sea surface temperatures allow greater upwelling of nutrients from the ocean floor, increasing the primary production of phytoplankton and zooplankton, and consequently creating more food for fish populations.

Cooling temperatures from the hypsithermal to the neoglacial and the establishment of the Aleutian low-pressure cell near the Kodiak archipelago may have created a more abundant food base for sea mammals over time, but may have also had a negative effect on pup and juvenile survival for some sea mammal species. Until the effects of climatic fluctuations on sea mammal populations themselves and on their prey are clarified, I cannot rule out the possible role that climate change may have had on the patterns shown here on sea mammal remains from the archaeological assemblages I have examined.

Climate and Marine Fish Populations

Changes in marine fish abundance and size might also be explained by changes in the temperature of the north Pacific ocean, but the relationships between various marine fish species and climatic perturbations are anything but clear. Despite the connections drawn between cooler temperatures and greater upwelling of nutrients that may allow greater carrying capacity for fish such as cod and walleye pollock (Jakobsson et al. 1995; Mecklenburg et al. 2002), some fish populations do not respond to this increase in primary production, and some even decrease in abundance during these intervals. Pacific herring and Pacific hake, one of the primary predators of herring, are such examples. Studies of herring population dynamics off the coast of British Columbia suggest that growth and recruitment of herring are not temperature dependent, but are instead density-dependent processes (Zebdi and Collie 1995). Their availability along the coast tends to increase during spring and summer months that are warmer than normal, attracting a greater number of Pacific hake, a gadid fish closely related to Pacific cod (Ware 1991; Ware and McFarlane 1995). Studies of rockfish on the California coast indicate an actual decrease in their availability at times when upwelling is unusually high. In this case, current strength is a greater determinant of abundance than sea surface temperature (Ainley et al. 1991).

The difficulty in generalizing the effects of climate change on fish populations at the same temporal scale that is represented archaeologically should be apparent from these studies. An increase in the production of a particular species of fish, or invertebrate or phytoplankton for that matter, is hard to connect with others amidst changing climatic conditions at varying scales.

Climate and Salmon Populations

Pacific salmon, as perhaps the most economically and politically important genus of fish inhabiting the north Pacific, have received the greatest attention by fisheries biologists in an effort to understand their population dynamics and relationship to their marine and riverine habitats, and yet these dynamics remain elusive (e.g., National Research Council 1996). In part, this relates to their complicated life history involving a dependence upon both freshwater streams and lakes as well as estuaries and open ocean (Groot and Margolis 1991). Climatic perturbations at sea may or may not coincide with changes in temperature or precipitation around riverine or lacustrine spawning, hatching, and rearing grounds. Anthropogenic alteration of freshwater salmon habitats compounds the influences on salmon populations (Quinn 1994).

The patterns of salmon dynamics that emerge exist for the most part at the scale of inquiry used by fisheries biologists and not archaeologists. Francis and Hare (1994) observe a cyclical pattern between climate change and salmon abundance on an interdecadal scale, and a clear pattern between climate change and zooplankton on an interannual scale. The level of winter storminess in the northeast Pacific seems to affect interannual variability of zooplankton production, but not salmon catches or escapement counts. The lack of pattern between climate change and salmon abundance at an interannual level suggests to them no direct connection between salmon production and climate change (Francis and Hare 1994:289).

Chatters et al. (1995) approach the relationship between climate change and salmon productivity from a very different temporal scale. They compare paleoclimate reconstructions for the Columbia River basin with fluvial sediment data that indicate changes in stream flow and streambed conditions affecting salmon populations, along with several archaeofaunal assemblages containing salmonid remains. Preliminary modeling seems to indicate that warmer conditions before about 4000 radiocarbon years BP coincided with poor stream conditions for salmon spawning and rearing around the Columbia River basin. Increasing abundances of salmon remains in several archaeological sites in the area after about 4000 BP follow a general pattern of cooler, wetter conditions in the region.

As with other species of fish and sea mammals in the north Pacific, elucidating the effects of climate change on salmon populations and then using this knowledge to test hypotheses regarding prehistoric salmon population dynamics remains a difficult task. Modern fluctuations in salmon abundance from California to Alaska appear to be tied to interdecadal climate changes that can create vast differences in salmon abundances (and consequently the catches by fishing fleets as well) between the Alaskan coast and the coasts of British Columbia, Oregon, and

Washington during the same year (Mantua et al. 1997). Finney et al. (2000, 2002) have shown that this complicated pattern probably extended some distance into the past for the lake systems of Kodiak Island. This type of research, using proxy indicators of salmon abundance that have a relatively large time depth, fine-scale temporal resolution, and can be compared to both paleoclimate reconstructions and archaeofaunal data, has the potential to allow testing hypotheses about the role of climate change in structuring prehistoric salmon populations.

Summary

Given the long time depth of the faunal remains examined for this dissertation and the coarse-grained temporal resolution represented by those assemblages, I cannot rule out the general trend of cooler and wetter conditions from about 6000 radiocarbon years BP to Russian colonization as playing some role in shaping the patterns seen archaeologically. Specifically, this broad trend in mean summer temperatures across the north Pacific may have created conditions that reduced human encounters with sea mammal populations, and may have changed abundances and body sizes of various fish species independently of human hunting and fishing activities. A more thorough knowledge of the variables affecting these animal populations over broad time spans, along with more analysis of faunal remains from archaeological sites representing different time periods, ecological settings, and functions will of course aid in the evaluation of paleoclimate as an agent of resource depression.

Table 6.1 Harbor Seal Skeletal Elements and Element Portions: Bone Density (g/cm^3), Abundance (MNE) in House Floor Layers, Abundance in a Whole Skeleton

Skeletal Part	Avg. Bone Density	RR-K	RR-I	RR-F	RR-D	RR-B	CP HF1B	Uy HF11	Uy HF7	Uy HF10	CP HF3A	"Null" Assemb.
Cranium	-	1		3	2	2	2					1
Mandible, Ramus	0.87			2	1							2
Mandible, Body	0.78			1								2
Cervical Vert.	0.47	1		1	1	1	1					7
Thoracic Vert	0.36		2	3	1	6	2	1	2	1		15
Lumbar Vert	0.38		1	1	1	2	1		2	2	1	5
Sacrum	0.39			1								1
Caudal Vert	-			4							1	11
Innom., Ilium	0.57		1	2	1							2
Innom., Ischium	0.67				1	1						2
Innom., Pubis	0.63		1	1	1	1		1				2
Rib, Head	0.45	1	1	7	4	3	3	7	1	7		26
Rib, Shaft	0.51	1	3	1	3	3	2	8	1	5		26
Sternebra	-			1	5	6	2		1	3		9
Scapula, Head/Neck	0.53			2			2	1				2
Scapula, Body	0.52			1	2	1						2
Humerus, prox	0.41		1				1			1		2
Humerus, shaft	0.57		1							1		2
Humerus, dist	0.64					2		1		2		2
Radius, prox	0.66			3	1	2	1					2
Radius, shaft	0.71					1						2
Radius, dist	0.42			1								2
Ulna, prox	0.55			3					1			2
Ulna, shaft	0.79	1	1	1					1			2
Ulna, dist	0.35			1					1			2
Metacarpal, prox	-			4	1	2		1		2		10
Metacarpal, shaft	-			3	1	3		1		2		10
Metacarpal, dist	-			2	2	1		1		2		10
Carpal	-											10
Femur, prox	0.52	1					1	1				2
Femur, shaft	0.69	2		2		1	1	1				2
Femur, dist	0.51	1				1	1	1				2
Patella	-			4	1	1						2
Tibia, prox	0.43	1	2		1		2		1			2
Tibia, shaft	0.86		1		1		2					2
Tibia, dist	0.52			1			1	2				2
Fibula, prox	0.59											2
Fibula, shaft	0.90					1						2
Fibula, dist	0.82	1		2								2
Astragalus	0.52		1	2				2				2
Calcaneus	0.45	1		2				1				2
Metatarsal, prox	-			4	2	1	2	2		2		10
Metatarsal, shaft	-			6	3	2	2	2		2		10
Metatarsal, dist	-			5	3	2	2	2		2		10
Tarsal	0.57			4	1			1	1	1		10
Phalanx	-	4		27	14	9	4	6	4	11		52

Note: Longbone Specimens Identified as "Whole" or "Mostly Whole" during analysis are entered as 1 for each portion
Calculations are for minimum number of elements or element portions (MNE); No infant specimens included

Table 6.2 Harbor Seal Skeletal Elements and Element Portions: Bone Density (g/cm^3), Abundance (MNE) in Midden Layers, and Abundance in a Whole Skeleton

Skeletal Part	Avg. Bone Density	RR-J	RR-H	RR-G	RR-E	RR-C	RR-A	CP3	CP2	Uy M1/2A	"Null" Assemb.
Cranium	-	1	2	2	1	1	2		2		1
Mandible, Ramus	0.87	2	4			3	1				2
Mandible, Body	0.78	3	3			1					2
Cervical Vert.	0.47	4	4	2	2	2	1		3	3	7
Thoracic Vert	0.36	3	7	3					1	19	15
Lumbar Vert	0.38	1		1	2					10	5
Sacrum	0.39								1		1
Caudal Vert	-		2		1	1	1				11
Innom., Ilium	0.57	1	1	1	1	1				2	2
Innom., Ischium	0.67	1	1		1	2	1			2	2
Innom., Pubis	0.63	2	1			1				3	2
Rib, Head	0.45	9	2	2	2	1				22	26
Rib, Shaft	0.51	4	4	1	1		1		1	22	26
Sternebra	-		3	1		1				3	9
Scapula, Head/Neck	0.53	1	5	2	3	3				2	2
Scapula, Body	0.52		2		1					2	2
Humerus, prox	0.41	3	2	2		1					2
Humerus, shaft	0.57	3	3	1		1					2
Humerus, dist	0.64	4	3	2							2
Radius, prox	0.66	5	1			2				1	2
Radius, shaft	0.71	2	1							1	2
Radius, dist	0.42									1	2
Ulna, prox	0.55	2	2	1		1					2
Ulna, shaft	0.79	2	1	2		1					2
Ulna, dist	0.35	2	1	2							2
Metacarpal, prox	-	1	5	6	2	4	2			1	10
Metacarpal, shaft	-	1	6	6		4	2			1	10
Metacarpal, dist	-	1	6	6	2	4	3				10
Carpal	-	1				1					10
Femur, prox	0.52					1				3	2
Femur, shaft	0.69	1	3	1					1	3	2
Femur, dist	0.51	3	2			1			1	3	2
Patella	-		1	1	1	1				2	2
Tibia, prox	0.43	1	2	2		1				1	2
Tibia, shaft	0.86	3	1	1		3				1	2
Tibia, dist	0.52		2	2							2
Fibula, prox	0.59				1		1				2
Fibula, shaft	0.90										2
Fibula, dist	0.82		1	2							2
Astragalus	0.52		1			1					2
Calcaneus	0.45	1									2
Metatarsal, prox	-	1	8	5	2	5				4	10
Metatarsal, shaft	-	1	3	3	2	3				5	10
Metatarsal, dist	-		2	3	2	3				4	10
Tarsal	0.57	1	1	5	1	4				1	10
Phalanx	-	7	16	8	16	14	3			3	52

Note: Longbone Specimens Identified as "Whole" or "Mostly Whole" during analysis are entered as 1 for each portion
Calculations are for minimum number of elements or element portions (MNE); No infant specimens included

Table 6.3 Otariid Skeletal Elements and Element Portions: Abundances (MNE) in House Floor Layers

Skeletal Part	RR-K	RR-I	RR-F	RR-D	RR-B	CHF1B	UyHF11	UyHF7	UyHF10	CHF3A
Cranium										
Mandible, Ramus	1									
Mandible, Body	1									
Cervical Vert.	1	1								
Thoracic Vert										
Lumbar Vert		1								
Sacrum										
Caudal Vert										1
Innom., Ilium		1								
Innom., Ischium										
Innom., Pubis										
Rib, Head					1		1	1		
Rib, Shaft		1					1			
Sternebra								1		
Scapula, Head/Neck										
Scapula, Body										
Humerus, prox										
Humerus, shaft				1						
Humerus, dist										
Radius, prox				2						
Radius, shaft										
Radius, dist									1	
Ulna, prox										
Ulna, shaft										
Ulna, dist										
Metacarpal, prox				1	1			1		
Metacarpal, shaft				1				1		
Metacarpal, dist				1				1		
Carpal								1	1	
Femur, prox										
Femur, shaft										
Femur, dist										
Patella										
Tibia, prox										
Tibia, shaft										
Tibia, dist			1							
Fibula, prox										
Fibula, shaft										
Fibula, dist										
Astragalus										
Calcaneus										
Metatarsal, prox						1				
Metatarsal, shaft			1			1				
Metatarsal, dist		1		1		1				
Tarsal	1		1							
Phalanx	4	2	2	4	1		4	1	4	

Note: Longbone Specimens Identified as "Whole" or "Mostly Whole" during analysis are entered as 1 for each portion
Calculations are for minimum number of elements or element portions (MNE); No infant specimens included

Table 6.4 Otariid Skeletal Elements and Element Portions: Abundances (MNE) in Midden Layers

Skeletal Part	RR-J	RR-H	RR-G	RR-E	RR-C	RR-A	CP3	CP2	UyM1/2A
Cranium			1						1
Mandible, Ramus									
Mandible, Body									
Cervical Vert.									
Thoracic Vert	2	1	1						1
Lumbar Vert					1				1
Sacrum									
Caudal Vert									
Innom., Ilium		1				1			
Innom., Ischium		1				1			
Innom., Pubis						1			
Rib, Head	4			1	2	1			6
Rib, Shaft	4				1				5
Sternebra	2	2		1					1
Scapula, Head/Neck		1							2
Scapula, Body		1							2
Humerus, prox									4
Humerus, shaft									3
Humerus, dist		1				1			6
Radius, prox									1
Radius, shaft				1		1			1
Radius, dist						1			
Ulna, prox									
Ulna, shaft									
Ulna, dist									
Metacarpal, prox		2	2						
Metacarpal, shaft		1							
Metacarpal, dist		1							
Carpal						1			
Femur, prox									2
Femur, shaft									2
Femur, dist									2
Patella					1				
Tibia, prox					1				
Tibia, shaft		1							
Tibia, dist	1								1
Fibula, prox									
Fibula, shaft									
Fibula, dist				1					
Astragalus									
Calcaneus									
Metatarsal, prox	1								
Metatarsal, shaft	1								
Metatarsal, dist				1					
Tarsal	1								
Phalanx	16	2		2	2				7

Note: Longbone Specimens Identified as "Whole" or "Mostly Whole" during analysis are entered as 1 for each portion
Calculations are for minimum number of elements or element portions (MNE); No infant specimens included

Table 6.5 Porpoise Skeletal Elements and Element Portions: Abundances (MNE) in House Floor Layers

Skeletal Part	**RR-K**	**RR-I**	**RR-F**	**RR-D**	**RR-B**	**CP HF1B**	**Uy HF11**	**Uy HF7**	**Uy HF10**	**CP HF3A**
Cranium	1		1			3				
Mandble								1		
Cervical Vert.										
Thoracic Vert			3	1		7				2
Lumbar Vert					1	1				
Sacrum										
Caudal Vert			1			3				
Innom., Remnant										
Rib, Head										
Rib, Shaft										
Sternebra										
Scapula					1					
Humerus, prox							1			
Humerus, shaft							1			
Humerus, dist						1	1			
Radius, prox						1	1			
Radius, shaft						1	1			
Radius, dist						1	1			
Ulna, prox						1	1			
Ulna, shaft						1	1			
Ulna, dist						1	1			
Metacarpal, prox										
Metacarpal, shaft										
Metacarpal, dist										
Carpal										
Phalanx										

Note: Longbone Specimens Identified as "Whole" or "Mostly Whole" during analysis are entered as 1 as each portion
Calculations are for minimum number of elements or element portions (MNE); No infant specimens included

Table 6.6 Porpoise Skeletal Elements and Element Portions: Abundances (MNE) in Midden Layers

Skeletal Part	RR-J	RR-H	RR-G	RR-E	RR-C	RR-A	CP3	CP2	UyM1/2A
Cranium	1	1						1	
Mandble									1
Cervical Vert.		7							
Thoracic Vert	3	5	1					3	1
Lumbar Vert	1	3			1				
Sacrum									
Caudal Vert	2	1							
Innom., Remnant									
Rib, Head									
Rib, Shaft									
Sternebra									
Scapula									
Humerus, prox									
Humerus, shaft									
Humerus, dist									
Radius, prox									
Radius, shaft									
Radius, dist									
Ulna, prox									
Ulna, shaft									
Ulna, dist									
Metacarpal, prox									
Metacarpal, shaft									
Metacarpal, dist									
Carpal									
Phalanx		1							

Note: Longbone Specimens Identified as "Whole" or "Mostly Whole" during analysis are entered as 1 as each portion
Calculations are for minimum number of elements or element portions (MNE); No infant specimens included

Table 6.7 Sea Otter Skeletal Elements and Element Portions: Abundances (MNE) in House Floor Layers

Skeletal Part	RR-K	RR-I	RR-F	RR-D	RR-B	CP HF1B	Uy HF11	Uy HF7	Uy HF10	CPHF3A
Cranium	1	3	4	1	1					
Mandble	2		4	2	1					
Cervical Vert.	1		13	9	1					
Thoracic Vert	5	5	6	8	4					
Lumbar Vert	4	5	7	5	2					
Sacrum			1							
Caudal Vert	1	3	6		4		1			
Baculum			1						1	
Innominate	1	1	3	3	1					
Rib, Head	1	6	13	8	4		2	1	2	
Rib, Shaft	5	5	8	8	4				2	
Sternebra	1	1	5	3	2					
Scapula	3	2	3	3	2					
Humerus, prox	1		4							
Humerus, shaft	4	1	6		1					
Humerus, dist	4	1	2		1					
Radius, prox			1		2					
Radius, shaft			5		1					
Radius, dist			5							
Ulna, prox			10		4					
Ulna, shaft	4	2	8		2					
Ulna, dist			5		1					
Metacarpal, prox	1	1	8	8						
Metacarpal, shaft	1	2	9	8						
Metacarpal, dist	1	2	8	8						
Carpal										
Femur, prox	2	1	2	1						
Femur, shaft	4	3	2	1						
Femur, dist	1	1	4	1						
Patella	1		1							
Tibia, prox	1	1	3	2	3					
Tibia, shaft	3		6		3					
Tibia, dist	2		5		1					
Fibula, prox	2									
Fibula, shaft			1							
Fibula, dist	1		1	1						
Astragalus	2	4	1	5						
Calcaneus	2	4	5	7	2					
Metatarsal, prox	7	8	16	17	5					
Metatarsal, shaft	6	9	11	14	6					
Metatarsal, dist	4	7	14	13	6					
Tarsal	1	2	11	9	2					
Phalanx	12	15	37	15	3		1			

Note: Longbone Specimens Identified as "Whole" or "Mostly Whole" during analysis are entered as 1 for each portion
Calculations are for minimum number of elements or element portions (MNE); No infant specimens included

Table 6.8 Sea Otter Skeletal Elements and Element Portions: Abundances (MNE) in Midden Layers

Skeletal Part	RR-J	RR-H	RR-G	RR-E	RR-C	RR-A	CP3	CP2	UyM1/2A
Cranium	7	7	2	1					
Mandble	4	4	1	2					
Cervical Vert.	5	10	1	2					
Thoracic Vert	8	8	5	4					
Lumbar Vert	5	13	3	3					
Sacrum	1	2		2					
Caudal Vert	12	12	8	2					
Baculum		1							
Innominate	2	6		3					1
Rib, Head	17	23	7	7					1
Rib, Shaft	21	13	3	4					1
Sternebra	3	5		1					
Scapula	7	6	4						2
Humerus, prox	6	6		1					3
Humerus, shaft	3	5		4					
Humerus, dist	5	10	3	3					
Radius, prox	5	6	3	2					
Radius, shaft	8	5		1					
Radius, dist	7	4		1					
Ulna, prox	2	8	2	2					1
Ulna, shaft	5	10	4	1					1
Ulna, dist	3	4	2						
Metacarpal, prox	8	8	5	3	1				
Metacarpal, shaft	8	8	5	3	1				
Metacarpal, dist	8	8	5	3	1				
Carpal	2								
Femur, prox	10	1	4	1					1
Femur, shaft	6	5	4	2					1
Femur, dist	8	6	1	5					1
Patella	1	4		4					
Tibia, prox	7	3	2	2					
Tibia, shaft	3	7	2	1					
Tibia, dist	2	2		1					
Fibula, prox		2							
Fibula, shaft	2	4							
Fibula, dist	1	1	1						
Astragalus	9	9	2	4					
Calcaneus	7	6	4						
Metatarsal, prox	30	20	15	3	14				
Metatarsal, shaft	23	16	8	1	11				
Metatarsal, dist	14	21	7	2	4				
Tarsal	13	11	2	2					
Phalanx	39	40	11	7					1

Note: Longbone Specimens Identified as "Whole" or "Mostly Whole" during analysis are entered as 1 for each portion
Calculations are for minimum number of elements or element portions (MNE); No infant specimens included

Table 6.9 Harbor Seal Skeletal Part Abundances: Modified Meat Utility Index Values (MMUI), Minimum Animal Units (MAU) in House Floor Layers, and the Abundances in a Whole Skeleton.

Harbor Seal Skeletal Part	**MMUI**	**RRK**	**RRI**	**RRF**	**RRD**	**RRB**	**CP HF1B**	**Uy HF11**	**Uy HF7**	**Uy HF10**	**CP HF3A**	**"Null" Assemb.**
Cranium	1754.5	1		3	2	2	2					1
Cervical Vert.	284.1	1		1	1	1	1					7
Thoracic Vert	231.1		2	3	1	6	2	1	2	1		15
Lumbar Vert	430.0		1	1	1	2	1		2	2	1	5
Sacrum	154.6			1								4
Caudal Vert	56.2			4							1	11
Innominate	618.3		1	2	1	1		1				2
Rib	427.2	1	3	7	4	3	3	8	1	7		13
Sternebra	316.9			1	5	6	2		1	3		9
Scapula	3325.5			2	2	1	2	1				2
Humerus	846.5		1			2	1	1		2		2
Radius/Ulna	430.0	1	1	3	1	2	1		1			2
Front Flipper	197.5			4	2	2		1		2		2
Femur	1695.5	2		4	1	1	1	1				2
Tibia/Fibula	918.0	1	2	2	1	1	2	2	1			2
Rear Flipper	673.5	1	1	2	1	1	1	2		1		2

Note:

No infant specimens included

MMUI modified from Lyman et al. (1992)

Table 6.10 Harbor Seal Skeletal Part Abundances: Modified Meat Utility Index Values (MMUI), Minimum Animal Units (MAU) in Midden Layers, and the Abundances in a Whole Skeleton.

Harbor Seal Skeletal Part	MMUI	RRJ	RRH	RRG	RRE	RRC	RRA	CP3	CP2	Uy M1/2A	"Null" Assemblage
Cranium	1754.5	1	2	2	1	2	2		2		1
Cervical Vert.	284.1	4	4	2	2	2	1		3	3	7
Thoracic Vert	231.1	3	7	3					1	19	15
Lumbar Vert	430.0	1		1	2					10	5
Sacrum	154.6								1		4
Caudal Vert	56.2		2		1	1	1				11
Innominate	618.3	2	1	1	1	2	1			3	2
Rib	427.2	9	4	2	2	1	1		1	22	13
Sternebra	316.9		3	1		1				3	9
Scapula	3325.5	1	5	2	3	3				2	2
Humerus	846.5	4	3	2		1					2
Radius/Ulna	430.0	5	2	2		2				1	2
Front Flipper	197.5	1	2	2	1	1	1			1	2
Femur	1695.5	3	3	1	1	1			1	3	2
Tibia/Fibula	918.0	3	2	2	1	3	1			1	2
Rear Flipper	673.5	1	2	1	1	1				1	2

Note:

No infant specimens included

MMUI modified from Lyman et al. (1992)

Table 6.11 Otariid Skeletal Part Abundances: Modified Meat Utility Index Values (MMUI), Minimum Animal Units (MAU) in House Floor Layers, and the Abundances in a Whole Skeleton.

Otariid Skeletal Part	MMUI	RRK	RRI	RRF	RRD	RRB	CP HF1B	Uy HF11	Uy HF7	Uy HF10	CP HF3A	"Null" Assemb.
Cranium	15942.0	1										1
Cervical Vert.	3440.4	1	1									7
Thoracic Vert	1649.5											15
Lumbar Vert	1102.4		1									5
Sacrum	452.0											3
Caudal Vert	193.7										1	7
Innominate	1356.0		1									2
Rib	1814.4		1			1		1	1			14
Sternebra	1733.0								1			8
Scapula	16339.0											2
Humerus	5640.0				1							2
Radius/Ulna	3465.0				2					1		2
Front Flipper	1899.0				1	1			1			2
Femur	3520.0											2
Tibia/Fibula	1615.0			1								2
Rear Flipper	1210.0		1		1		1					2

Note:

No infant specimens included

MMUI modified from Savelle et al. 1996

Table 6.12 Otariid Skeletal Part Abundances: Modified Meat Utility Index Values (MMUI), Minimum Animal Units (MAU) in Midden Layers, and the Abundances in a Whole Skeleton.

Otariid Skeletal Part	MMUI	RRJ	RRH	RRG	RRE	RRC	RRA	CP3	CP2	Uy M1/2A	"Null" Assemb.
Cranium	15942.0			1						1	1
Cervical Vert.	3440.4										7
Thoracic Vert	1649.5	2	1	1						1	15
Lumbar Vert	1102.4					1				1	5
Sacrum	452.0										3
Caudal Vert	193.7										7
Innominate	1356.0		1				1				2
Rib	1814.4	4			1	2	1			6	14
Sternebra	1733.0	2	2		1					1	8
Scapula	16339.0		1							2	2
Humerus	5640.0		1				1			6	2
Radius/Ulna	3465.0				1		1			1	2
Front Flipper	1899.0		1	1							2
Femur	3520.0					1				2	2
Tibia/Fibula	1615.0	1	1		1	1				1	2
Rear Flipper	1210.0	1			1						2

Note:

MMUI modified from Savelle et al. 1996

No infant specimens included

Table 6.13 Porpoise Skeletal Part Abundances: Modified Meat Utility Index Values (MMUI), Minimum Animal Units (MAU) in House Floor Layers, and the Abundances in a Whole Skeleton.

Porpoise Skeletal Part	MMUI	RRK	RRI	RRF	RRD	RRB	CP HF1B	Uy HF11	Uy HF7	Uy HF10	CP HF3A	"Null" Assemb.
Cranium	346.9	1		1			3		1			1
Cervical Vert.	89.4											7
Thoracic Vert	105.5			3	1		7				2	13
Lumbar Vert	131.3					1	1					14
Caudal Vert	56.7			1			3					31
Rib	62.9											13
Sternum	384.2											1
Scapula	418.5					1						2
Flipper	106.6						1	1				2

Note:

MMUI modified from Savelle and Friesen (1996)

No infant specimens included

Table 6.14 Porpoise Skeletal Part Abundances: Modified Meat Utility Index Values (MMUI), Minimum Animal Units (MAU) in Midden Layers, and the Abundances in a Whole Skeleton.

Porpoise Skeletal Part	MMUI	RRJ	RR H	RR G	RR E	RR C	RR A	CP3	CP2	Uy M1/2 A	"Null" Assemblage
Cranium	346.9	1	1						1	1	1
Cervical Vert.	89.4		7								7
Thoracic Vert	105.5	3	5	1					3	1	13
Lumbar Vert	131.3	1	3			1					14
Caudal Vert	56.7	2	1								31
Rib	62.9										13
Sternum	384.2										1
Scapula	418.5										2
Flipper	106.6										2

Note:

MMUI modified from Savelle and Friesen (1996)

No infant specimens included

6.15 Mean Harbor Seal Skeletal Part Utility and Standard Deviation (F = 1.170, p = 0.317; F_{welch} = 2.244, p = 0.058), t-Values and Probabilities Compared to a Null Assemblage for House Floor Assemblages.

Site	Layer	Mean MMUI	Std. Deviation	t-value	*p*	Significant at 0.10
Crag Point	3A	243.10	264.32	-1.104	0.468	
Uyak	10	432.98	186.64	-0.375	0.712	
Uyak	7	426.79	217.12	-0.296	0.776	
Uyak	11	750.83	728.82	1.754	0.097	*
Crag Point	1B	985.96	967.25	2.418	0.026	*
Rice Ridge	B	625.86	669.04	1.468	0.153	
Rice Ridge	D	831.69	922.76	1.986	0.060	*
Rice Ridge	F	757.26	813.70	2.392	0.022	*
Rice Ridge	I	548.18	244.22	1.400	0.189	
Rice Ridge	K	984.79	634.00	2.388	0.048	*
"Null" Assemblage		*449.50*	*564.72*	-	-	

6.16 Mean Harbor Seal Skeletal Part Utility and Standard Deviation (F = 2.137, p = 0.041; F_{welch} = 1.949, p = 0.082), t-Values and Probabilities Compared to a Null Assemblage for Midden Assemblages.

Site	Layer	Mean MMUI	Std. Deviation	t-value	*p*	Significant at 0.10
Uyak	1A/2	517.45	573.39	0.984	0.328	
Crag Point	2	763.30	732.25	1.286	0.235	
Crag Point	3	0.00	0.00	-	-	
Rice Ridge	A	751.29	673.10	1.268	0.245	
Rice Ridge	C	1100.84	1050.68	2.841	0.010	*
Rice Ridge	E	1135.79	1186.22	2.314	0.035	*
Rice Ridge	G	866.42	897.02	2.277	0.032	*
Rice Ridge	H	912.97	1016.62	2.955	0.005	*
Rice Ridge	J	701.81	613.62	2.535	0.016	*
"Null" Assemblage		*449.50*	*564.72*	-	-	

6.17 Mean Otariid Skeletal Part Utility and Standard Deviation (F = 1.674, p = 0.200), t-Values and Probabilities Compared to a Null Assemblage for House Floor Assemblages.

Site	Layer	Mean MMUI	Std. Deviation	t-value	*p*	Significant at 0.10
Crag Point	3A	193.70	-	-	-	
Uyak	10	3465.00	-	-	-	
Uyak	7	1815.47	83.01	-12.183	0.007	*
Uyak	11	1814.40	-	-	-	
Crag Point	1B	1210.00	-	-	-	
Rice Ridge	B	1856.70	59.82	-12.827	0.050	*
Rice Ridge	D	3135.80	1712.17	0.962	0.391	
Rice Ridge	F	1615.00	-	-	-	
Rice Ridge	I	1784.64	964.60	-1.425	0.227	
Rice Ridge	K	9691.20	8839.97	1.167	0.451	
"Null" Assemblage		*2399.27*	*3017.19*	-	-	

6.18 Mean Otariid Skeletal Part Utility and Standard Deviation (F = 1.220, p = 0.261; F_{welch} = 1.989, p = 0.155), t-Values and Probabilities Compared to a Null Assemblage for MiddenAssemblages.

Site	Layer	Mean MMUI	Std. Deviation	t-value	*p*	Significant at 0.10
Uyak	1A/2	4997.79	4857.52	2.509	0.020	*
Crag Point	2	-	-	-	-	
Crag Point	3	-	-	-	-	
Rice Ridge	A	3068.85	1938.66	0.691	0.539	
Rice Ridge	C	1973.24	912.36	-1.044	0.355	
Rice Ridge	E	1967.48	868.76	-1.111	0.329	
Rice Ridge	G	6469.83	8180.71	0.868	0.477	
Rice Ridge	H	3995.56	5180.14	0.872	0.412	
Rice Ridge	J	1684.76	183.98	-12.282	<0.000	*
"Null" Assemblage		*2399.27*	*3017.19*	-	-	

6.19 Mean Porpoise Skeletal Part Utility and Standard Deviation (F = 0.558, p = 0.781), t-Values and Probabilities Compared to a Null Assemblage for House Floor Assemblages.

Site	Layer	Mean MMUI	Std. Deviation	t-value	*p*	Significant at 0.10
Crag Point	3A	49.20	0.00	-	-	
Uyak	10	-	-	-	-	
Uyak	7	18.90	-	-	-	
Uyak	11	5.80	-	-	-	
Crag Point	1B	52.03	29.75	-5.919	<0.000	*
Rice Ridge	B	52.40	67.32	-0.947	0.517	
Rice Ridge	D	49.20	-	-	-	
Rice Ridge	F	51.54	25.76	-3.989	0.016	*
Rice Ridge	I	-	-	-	-	
Rice Ridge	K	18.90	-	-	-	
"Null" Assemblage		*97.53*	*72.40*	-	-	

6.20 Mean Porpoise Skeletal Part Utility and Standard Deviation (F = 1.057, p = 0.407), t-Values and Probabilities Compared to a Null Assemblage for Midden Assemblages.

Site	Layer	Mean MMUI	Std. Deviation	t-value	*p*	Significant at 0.10
Uyak	1A/2	34.05	21.43	-4.188	0.149	
Crag Point	2	41.63	15.15	-7.376	0.005	*
Crag Point	3	-	-	-	-	
Rice Ridge	A	-	-	-	-	
Rice Ridge	C	100.00	-	-	-	
Rice Ridge	E	-	-	-	-	
Rice Ridge	G	49.20	-	-	-	
Rice Ridge	H	40.37	38.09	-6.185	<0.000	*
Rice Ridge	J	64.13	30.19	-2.925	0.026	*
"Null" Assemblage		*97.53*	*72.40*	-	-	

Table 6.21 Sea Otter Vertebrae and Limb Element Abundances from House Floor Assemblages

Skeletal Part	RR-K	RR-I	RR-F	RR-D	RR-B	CP HF1B	Uy HF11	Uy HF7	Uy HF10	CP HF3A
Cervical Vert.	1		13	9	1					
Thoracic Vert	5	5	6	8	4					
Lumbar Vert	4	5	7	5	2					
Humerus	4	1	6		1					
Radius			5		2					
Ulna	4	2	10		4					
Femur	4	3	4	1						
Tibia	3	1	6	2	3					
Fibula	2		1	1						

Note: Calculations are for minimum number of elements (MNE); No infant specimens included

Table 6.22 Sea Otter Vertebrae and Limb Element Abundances from Midden Assemblages

Skeletal Part	RR-J	RR-H	RR-G	RR-E	RR-C	RR-A	CP3	CP2	UyM1/2A
Cervical Vert.	5	10	1	2	7				
Thoracic Vert	8	8	5	4	2				
Lumbar Vert	5	13	3	3	4				
Humerus	6	10	3	4	2				3
Radius	8	6	3	2	6				
Ulna	5	10	4	2	2				1
Femur	10	6	4	5	4				1
Tibia	7	7	2	2	4				
Fibula	2	4	1						

Note: Calculations are for minimum number of elements (MNE); No infant specimens included

Table 6.23 Ratio of Sea Otter Vertebrae and Limb Elements (χ^2_{total} = 15.80, p = 0.003; χ^2_{trend} = 2.51, p = 0.113; $\chi^2_{departure}$ = 13.29, p = 0.004) Vertebrae Index Values for House Floor Assemblages, and Value for a "Null" Assemblage

Site	Layer	Vertebrae MNE	Limb Bone MNE	Total MNE	Vertebrae Index
Rice Ridge	B	7	10	17	0.412
Rice Ridge	D	22	4	26	0.846
Rice Ridge	F	26	32	58	0.448
Rice Ridge	I	10	7	17	0.588
Rice Ridge	K	10	17	27	0.370
Total		*75*	*70*	*145*	0.517
"Null" Assemb.		27	12	39	0.692

Table 6.24 Ratio of Sea Otter Vertebrae and Limb Elements (χ^2_{total} = 4.65, p = 0.460; χ^2_{trend} = 0.00, p = 0.960; $\chi^2_{departure}$ = 4.65; p = 0.325) and Vertebrae Index Values for Midden Assemblages, and Value for a "Null" Assemblage

Site	Layer	Vertebrae MNE	Limb Bone MNE	Total MNE	Vertebrae Index
Uyak	1A/2	0	5	5	0.000
Crag Point	2	0	0	0	-
Crag Point	3	0	0	0	-
Rice Ridge	A	0	0	0	-
Rice Ridge	C	13	18	31	0.419
Rice Ridge	E	9	15	24	0.375
Rice Ridge	G	9	17	26	0.346
Rice Ridge	H	31	43	74	0.419
Rice Ridge	J	18	38	56	0.321
Total		*80*	*136*	*216*	0.370
"Null" Assemb.		27	12	39	0.692

Table 6.25 Mean Harbor Seal Skeletal Part Density and Standard Deviation (F = 1.143, p = 0.337), t-Values and Probabilities Compared to a Null Assemblage for House Floor Assemblages.

Site	Layer	Mean Density	Std. Deviation	t-value	*p*	Significant at 0.10
Uyak	10	0.48	0.08	-2.134	0.046	*
Uyak	7	0.47	0.13	-1.337	0.211	
Uyak	11	0.51	0.07	-0.995	0.329	
Crag Point	1B	0.52	0.14	-0.046	0.963	
Rice Ridge	B	0.52	0.14	-0.027	0.979	
Rice Ridge	D	0.54	0.14	0.711	0.485	
Rice Ridge	F	0.55	0.14	1.486	0.144	
Rice Ridge	I	0.52	0.14	-0.052	0.959	
Rice Ridge	K	0.58	0.14	1.277	0.230	
"Null" Assemblage		*0.52*	*0.13*	-	-	

Table 6.26 Mean Harbor Seal Skeletal Part Density and Standard Deviation (F = 6.952, p<0.001), t-Values and Probabilities Compared to a Null Assemblage for Midden Assemblages.

Site	Layer	Mean Density	Std. Deviation	t-value	*p*	Significant at 0.10
Uyak	1A/2	0.48	0.10	-4.665	0.000	*
Crag Point	2	0.48	0.10	-1.036	0.335	
Rice Ridge	A	0.62	0.16	1.439	0.224	
Rice Ridge	C	0.63	0.15	3.982	0.000	*
Rice Ridge	E	0.51	0.08	-0.598	0.560	
Rice Ridge	G	0.54	0.15	0.793	0.433	
Rice Ridge	H	0.57	0.15	2.412	0.019	*
Rice Ridge	J	0.57	0.15	2.641	0.010	*
"Null" Assemblage		*0.52*	*0.13*	-	-	

Table 6.27 Ratio of Cut-Marked and Non-Cut-Marked Sea Otter Specimens from House Floor Contexts, both Limb (χ^2_{total} = 42.32, p<0.001; χ^2_{trend} = 24.68, p<0.001; $\chi^2_{departure}$ = 17.64, p = 0.001) and Axial (χ^2_{total} = 19.68, p = 0.001; χ^2_{trend} = 13.63, p<0.001; $\chi^2_{departure}$ = 6.05, p = 0.109), and Proportions of Cut-Marked Bones

Site	Layer	Cut Limb NISP	Non-Cut Limb NISP	Total Limb NISP	Cut Limb Index	Cut Axial NISP	Non-Cut Axial NISP	Total Axial NISP	Cut Axial Index
Crag Point	3A	0	0	0	-	0	0	0	-
Uyak	10	0	2	2	0.000	2	1	3	0.667
Uyak	7	0	0	0	-	1	0	1	1.000
Uyak	11	0	2	2	0.000	0	3	3	0.000
Crag Point	1B	0	1	1	0.000	0	0	0	-
Rice Ridge	B	17	22	39	0.436	10	23	33	0.303
Rice Ridge	D	12	87	99	0.121	6	52	58	0.103
Rice Ridge	F	15	135	150	0.100	8	93	101	0.079
Rice Ridge	I	6	60	66	0.091	2	51	53	0.038
Rice Ridge	K	1	56	57	0.018	1	29	30	0.033
Total		*51*	*365*	*416*	0.123	*30*	*252*	*282*	0.106

Table 6.28 Ratio of Cut-Marked and Non-Cut-Marked Sea Otter Specimens from Midden Contexts, both Limb (χ^2_{total} = 30.46, p<0.001; χ^2_{trend} = 6.22, 0.013; $\chi^2_{departure}$ = 24.24, p<0.001) and Axial (χ^2_{total} = 2.77, p = 0.735; χ^2_{trend} = 0.03, p = 0.874; $\chi^2_{departure}$ = 2.74, p = 0.601), and Proportions of Cut-Marked Bones

Site	Layer	Cut Limb NISP	Non-Cut Limb NISP	Total Limb NISP	Cut Limb Index	Cut Axial NISP	Non-Cut Axial NISP	Total Axial NISP	Cut Axial Index
Uyak	1A/2	1	4	5	0.200	0	4	4	0.000
Crag Point	2	0	0	0	-	0	0	0	-
Crag Point	3	0	0	0	-	0	0	0	-
Rice Ridge	A	2	8	10	0.200	1	5	6	0.167
Rice Ridge	C	5	76	81	0.062	3	44	47	0.064
Rice Ridge	E	13	34	47	0.277	3	47	50	0.060
Rice Ridge	G	7	65	72	0.097	2	51	53	0.038
Rice Ridge	H	25	188	213	0.117	18	185	203	0.089
Rice Ridge	J	7	196	203	0.034	10	140	150	0.067
Total		*60*	571	*631*	*0.095*	*37*	*476*	*513*	*0.072*

Table 6.29 Ratio of Cut-Marked and Non-Cut-Marked Harbor Seal Specimens from House Floor Contexts, both Limb (χ^2_{total} = 17.53, p = 0.025; χ^2_{trend} = 0.00, p = 0.987; $\chi^2_{departure}$ = 17.53, p = 0.014) and Axial (χ^2_{total} = 32.13, p<0.001; χ^2_{trend} = 3.29, p = 0.074; $\chi^2_{departure}$ = 28.94, p<0.001), and Proportions of Cut-Marked Bones

Site	Layer	Cut Limb NISP	Non-Cut Limb NISP	Total Limb NISP	Cut Limb Index	Cut Axial NISP	Non-Cut Axial NISP	Total Axial NISP	Cut Axial Index
Crag Point	3A	0	0	0	-	2	0	2	1.000
Uyak	10	4	37	41	0.098	6	35	41	0.146
Uyak	7	1	18	19	0.053	2	11	13	0.154
Uyak	11	1	34	35	0.029	0	26	26	0.000
Crag Point	1B	8	17	25	0.320	4	11	15	0.267
Rice Ridge	B	6	26	32	0.188	2	28	30	0.067
Rice Ridge	D	4	27	31	0.129	0	21	21	0.000
Rice Ridge	F	9	72	81	0.111	3	46	49	0.061
Rice Ridge	I	0	7	7	0.000	1	8	9	0.111
Rice Ridge	K	0	11	11	0.000	1	2	3	0.333
Total		*33*	*249*	*282*	0.117	*21*	188	*209*	*0.100*

Table 6.30 Ratio of Cut-Marked and Non-Cut-Marked Harbor Seal Specimens from Midden Contexts, both Limb (χ^2_{total} = 6.57, p = 0.583; χ^2_{total} = 0.38, p = 0.539; $\chi^2_{departure}$ = 6.19, p = 0.517) and Axial (χ^2_{total} = 22.88, p = 0.004; χ^2_{trend} = 0.11, p = 0.742; $\chi^2_{departure}$ = 22.77, p = 0.002), and Proportions of Cut-Marked Bones

Site	Layer	Cut Limb NISP	Non-Cut Limb NISP	Total Limb NISP	Cut Limb Index	Cut Axial NISP	Non-Cut Axial NISP	Total Axial NISP	Cut Axial Index
Uyak	1A/2	6	53	59	0.102	5	97	102	0.049
Crag Point	2	5	20	25	0.200	6	18	24	0.250
Crag Point	3	4	44	48	0.083	1	33	34	0.029
Rice Ridge	A	1	14	15	0.067	1	10	11	0.091
Rice Ridge	C	9	44	53	0.170	1	17	18	0.056
Rice Ridge	E	1	24	25	0.040	5	15	20	0.250
Rice Ridge	G	4	40	44	0.091	2	16	18	0.111
Rice Ridge	H	6	49	55	0.109	2	40	42	0.048
Rice Ridge	J	3	35	38	0.079	1	38	39	0.026
Total		*39*	*323*	*362*	*0.108*	*24*	*284*	*308*	*0.078*

Table 6.31 Ratios of Adult and Sub-Adult Sea Mammal Specimens from House Floor Assemblages (see text for statistical comparison of ratios).

			Sea Otter				Harbor Seal		
Site	**Layer**	**Adult NISP**	**Sub-Adult NISP**	**Total Aged NISP**	**Adult Index**	**Adult NISP**	**Sub-Adult NISP**	**Total Aged NISP**	**Adult Index**
Crag Point	3A	0	0	0	-	0	2	2	0.000
Uyak	10	3	2	5	0.600	27	51	78	0.346
Uyak	7	1	0	1	1.000	6	26	32	0.188
Uyak	11	4	1	5	0.800	5	38	43	0.116
Crag Point	1B	1	0	1	1.000	11	24	35	0.314
Rice Ridge	B	36	23	59	0.610	12	33	45	0.267
Rice Ridge	D	80	71	151	0.530	24	15	39	0.615
Rice Ridge	F	137	89	226	0.606	45	51	96	0.469
Rice Ridge	I	57	37	94	0.606	5	10	15	0.333
Rice Ridge	K	49	16	65	0.754	7	5	12	0.583
Total		*368*	*239*	*607*	*0.606*	*142*	*255*	*397*	*0.358*

			Otariid				Porpoise		
Site	**Layer**	**Adult NISP**	**Sub-Adult NISP**	**Total Aged NISP**	**Adult Index**	**Adult NISP**	**Sub-Adult NISP**	**Total Aged NISP**	**Adult Index**
Crag Point	3A	1	0	1	1.000	0	1	1	0.000
Uyak	10	0	4	4	0.000	0	0	0	-
Uyak	7	1	3	4	0.250	0	1	1	0.000
Uyak	11	5	1	6	0.833	0	3	3	0.000
Crag Point	1B	0	1	1	0.000	5	14	19	0.263
Rice Ridge	B	2	1	3	0.667	1	2	3	0.333
Rice Ridge	D	5	5	10	0.500	1	1	2	0.500
Rice Ridge	F	2	1	3	0.667	1	3	4	0.250
Rice Ridge	I	6	1	7	0.857	0	0	0	-
Rice Ridge	K	6	1	7	0.857	0	0	0	-
Total		*28*	*18*	*46*	*0.609*	*8*	*25*	*33*	*0.242*

Table 6.32 Ratios of Adult and Sub-Adult Sea Mammal Specimens from Midden Assemblages (see text for statistical comparison of ratios).

Site	Layer	Sea Otter				Harbor Seal			
		Adult NISP	Sub-Adult NISP	Total Aged NISP	Adult Index	Adult NISP	Sub-Adult NISP	Total Aged NISP	Adult Index
Uyak	1A/2	5	3	8	0.625	53	116	169	0.314
Crag Point	2	0	0	0	-	10	30	40	0.250
Crag Point	3	0	0	0	-	39	38	77	0.506
Rice Ridge	A	4	13	17	0.235	4	19	23	0.174
Rice Ridge	C	66	46	112	0.589	20	31	51	0.392
Rice Ridge	E	59	35	94	0.628	21	20	41	0.512
Rice Ridge	G	76	39	115	0.661	29	26	55	0.527
Rice Ridge	H	249	141	390	0.638	40	50	90	0.444
Rice Ridge	J	245	93	338	0.725	47	21	68	0.691
Total		*704*	*370*	1074	0.655	*263*	*351*	614	0.428

Site	Layer	Otariid				Porpoise			
		Adult NISP	Sub-Adult NISP	Total Aged NISP	Adult Index	Adult NISP	Sub-Adult NISP	Total Aged NISP	Adult Index
Uyak	1A/2	14	16	30	0.467	0	2	2	0.000
Crag Point	2	0	3	3	0.000	9	12	21	0.429
Crag Point	3	5	1	6	0.833	21	21	42	0.500
Rice Ridge	A	4	2	6	0.667	0	0	0	-
Rice Ridge	C	4	3	7	0.571	1	0	1	1.000
Rice Ridge	E	4	2	6	0.667	0	0	0	-
Rice Ridge	G	4	0	4	1.000	0	1	1	0.000
Rice Ridge	H	82	4	86	0.953	12	7	19	0.632
Rice Ridge	J	17	10	27	0.630	4	3	7	0.571
Total		*134*	*41*	175	0.766	*47*	*46*	93	0.505

Table 6.33 Width Measurements Taken on Pacific Cod Angulars

Site	Layer	Context	Deposit Age (Mean Calib. BP)	Mean Angular Width (mm)	Max. Angular Width (mm)	Std. Dev.	Angular Sample Size
Uyak	HF10	Floor	1056	7.84	8.69	0.77	5
Uyak	HF7	Floor	1211	7.58	10.02	1.01	10
Uyak	HF11	Floor	1277	9.49	9.93	0.44	3
Crag Point	HF3A	Floor	825	9.05	10.83	1.52	5
Crag Point	2	Midden	1972	7.49	8.32	1.17	2
Crag Point	HF1B	Floor	2182	9.05	11.96	1.51	28
Rice Ridge	A	Midden	4603	8.56	10.00	0.88	9
Rice Ridge	B	Floor	4410	8.11	10.62	1.41	58
Rice Ridge	C	Midden	5817	8.95	11.44	1.17	21
Rice Ridge	D	Floor	5910	7.76	8.83	1.24	3
Rice Ridge	F	Floor	5660	10.33	11.05	0.55	5
Rice Ridge	G	Midden	6840	-	-	-	0
Rice Ridge	H	Midden	6860	9.21	9.21	-	1
Rice Ridge	I	Floor	6850	-	-	-	0
Rice Ridge	J	Midden	6952	12.09	14.52	3.44	2
Rice Ridge	K	Floor	6877	12.68	12.68	-	1

Table 6.34 Width Measurements Taken on Pacific Cod Dentaries

Site	Layer	Context	Deposit Age (Mean Calib. BP)	Mean Dentary Width (mm)	Max. Dentary Width (mm)	Std. Dev.	Dentary Sample Size
Uyak	HF10	Floor	1056	4.56	5.73	0.86	4
Uyak	HF7	Floor	1211	4.45	4.71	0.33	5
Uyak	HF11	Floor	1277	5.50	5.50	-	1
Crag Point	HF3A	Floor	825	4.49	5.25	0.58	12
Crag Point	2	Midden	1972	4.15	4.36	0.30	2
Crag Point	HF1B	Floor	2182	4.94	6.34	0.67	22
Rice Ridge	A	Midden	4603	4.67	5.47	0.41	6
Rice Ridge	B	Floor	4410	4.68	5.69	0.44	46
Rice Ridge	C	Midden	5817	4.57	5.79	0.63	20
Rice Ridge	D	Floor	5910	4.84	4.84	0.01	2
Rice Ridge	F	Floor	5660	-	-	-	0
Rice Ridge	G	Midden	6840	6.45	7.22	0.59	4
Rice Ridge	H	Midden	6860	5.64	6.60	0.91	3
Rice Ridge	I	Floor	6850	-	-	-	0
Rice Ridge	J	Midden	6952	8.33	8.33	-	1
Rice Ridge	K	Floor	6877	6.18	6.18	-	1

Table 6.35 Width Measurements Taken on Pacific Cod Maxillae

Site	Layer	Context	Deposit Age (Mean Calib. BP)	Mean Maxilla Width (mm)	Max. Maxilla Width (mm)	Std. Dev.	Maxilla Sample Size
Uyak	HF10	Floor	1056	6.62	7.55	0.63	4
Uyak	HF7	Floor	1211	6.93	7.74	0.54	9
Uyak	HF11	Floor	1277	7.51	8.11	0.59	5
Crag Point	HF3A	Floor	825	6.94	8.33	0.88	8
Crag Point	2	Midden	1972	8.27	8.61	0.48	2
Crag Point	HF1B	Floor	2182	7.88	10.36	1.07	24
Rice Ridge	A	Midden	4603	6.65	6.65	-	1
Rice Ridge	B	Floor	4410	6.75	8.52	0.78	33
Rice Ridge	C	Midden	5817	7.54	8.76	1.09	3
Rice Ridge	D	Floor	5910	8.20	8.27	0.10	2
Rice Ridge	F	Floor	5660	-	-	-	0
Rice Ridge	G	Midden	6840	-	-	-	0
Rice Ridge	H	Midden	6860	8.80	8.80	-	1
Rice Ridge	I	Floor	6850	-	-	-	0
Rice Ridge	J	Midden	6952	-	-	-	0
Rice Ridge	K	Floor	6877	-	-	-	0

Table 6.36 Width Measurements Taken on Pacific Cod Premaxillae

Site	Layer	Context	Deposit Age (Mean Calib. BP)	Mean Premax Width (mm)	Max. Premax Width (mm)	Std. Dev.	Premaxilla Sample Size
Uyak	HF10	Floor	1056	6.43	7.69	0.89	6
Uyak	HF7	Floor	1211	6.32	7.51	0.66	7
Uyak	HF11	Floor	1277	7.56	8.46	0.78	5
Crag Point	HF3A	Floor	825	6.13	7.48	1.02	5
Crag Point	2	Midden	1972	7.35	8.23	0.77	3
Crag Point	HF1B	Floor	2182	6.99	9.81	1.07	35
Rice Ridge	A	Midden	4603	6.64	7.43	0.64	8
Rice Ridge	B	Floor	4410	5.93	8.23	0.83	69
Rice Ridge	C	Midden	5817	6.79	9.52	1.43	15
Rice Ridge	D	Floor	5910	6.92	6.92	-	1
Rice Ridge	F	Floor	5660	7.90	7.90	-	1
Rice Ridge	G	Midden	6840	-	-	-	0
Rice Ridge	H	Midden	6860	-	-	-	0
Rice Ridge	I	Floor	6850	7.74	8.07	0.47	2
Rice Ridge	J	Midden	6952	8.18	9.81	1.19	4
Rice Ridge	K	Floor	6877	-	-	-	0

Table 6.37 Correlation Coefficients Between Sea Mammal Index and Cod Skeletal Element Measurements

Correlation	Pearson's Correlation Coeff.	sig.	Number of Assemblages	Spearman's rho (nonparametric)	sig.
Sea Mammal Index and Mean Angular Width	0.620	0.018	14	0.449	0.107
Sea Mammal Index and Mean Dentary Width	0.778	0.001	14	0.695	0.006
Sea Mammal Index and Mean Maxilla Width	0.649	0.031	11	0.405	0.216
Sea Mammal Index and Mean Premaxilla Width	0.757	0.003	13	0.792	0.001

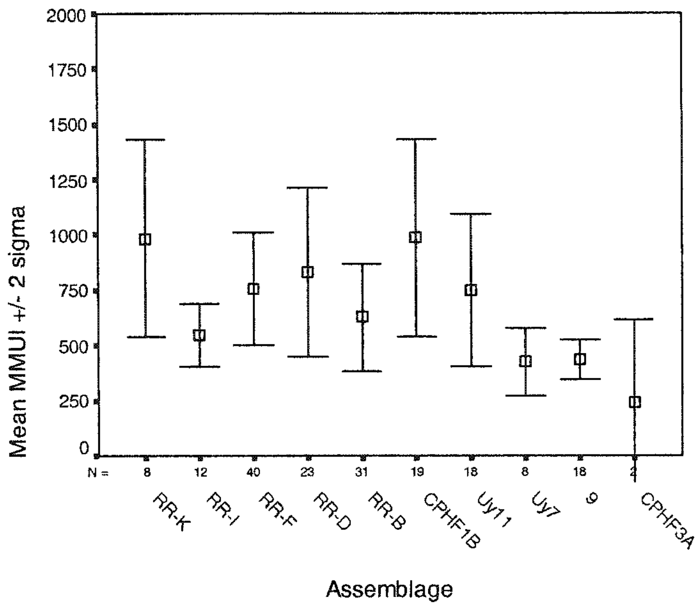


Fig. 6.1 Mean Utility and 2σ Range of Harbor Seal Skeletal Elements in House Floor Assemblages

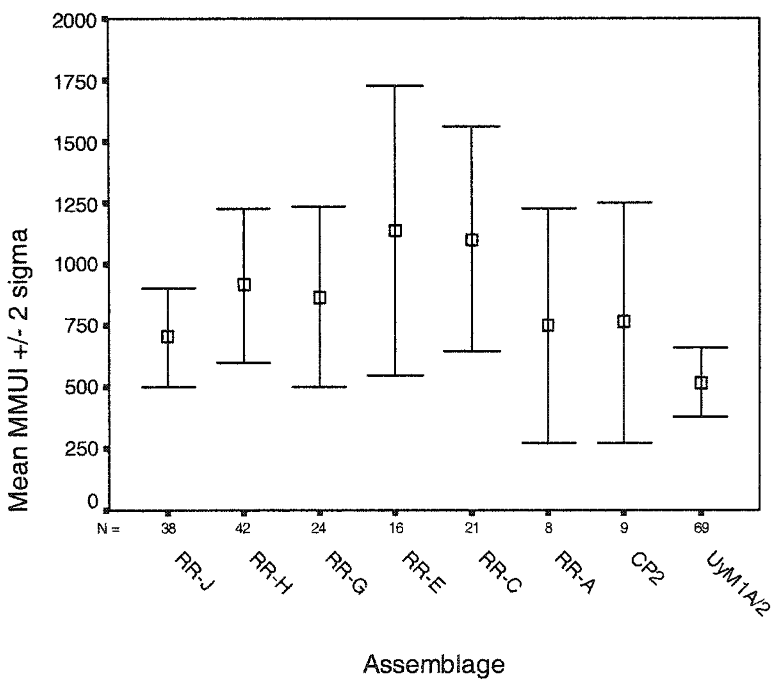


Fig. 6.2 Mean Utility and 2σ Range of Harbor Seal Skeletal Elements in Midden Assemblages

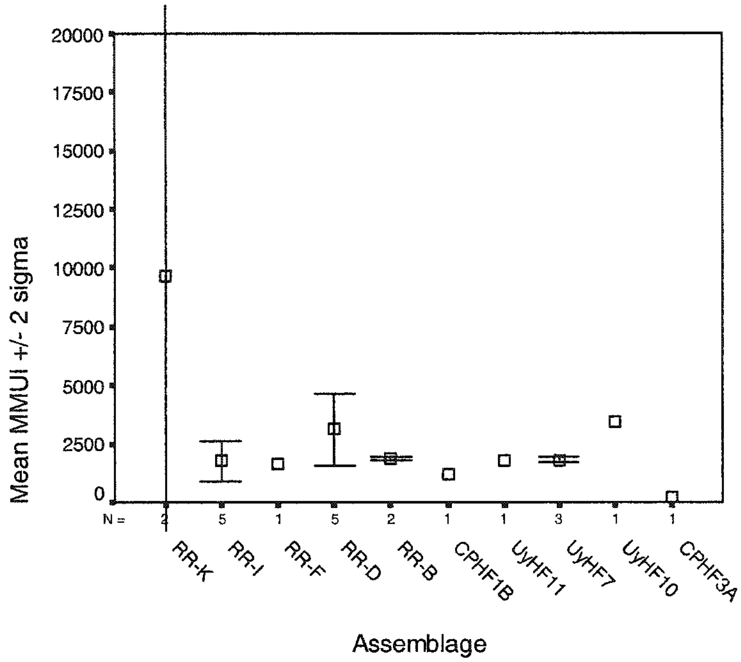


Fig. 6.3 Mean Utility and 2σ Range of Otariid Skeletal Elements in House Floor Assemblages

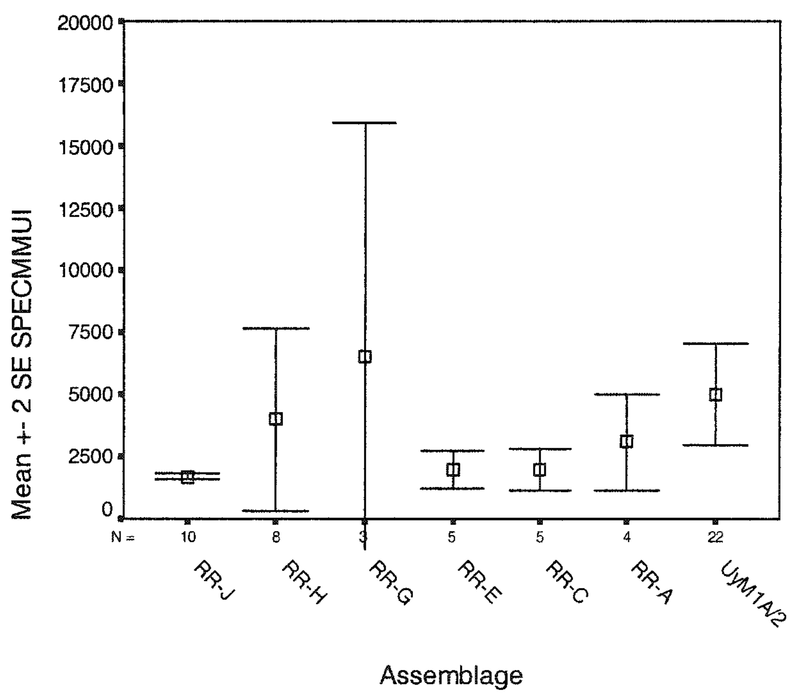


Fig. 6.4 Mean Utility and 2σ Range of Otariid Skeletal Elements in Midden Assemblages

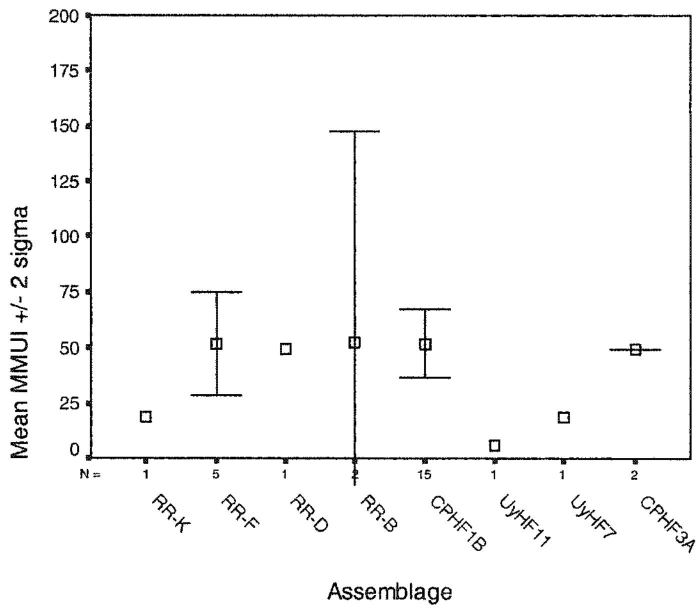


Fig. 6.5 Mean Utility and 2σ Range of Porpoise Skeletal Elements in House Floor Assemblages

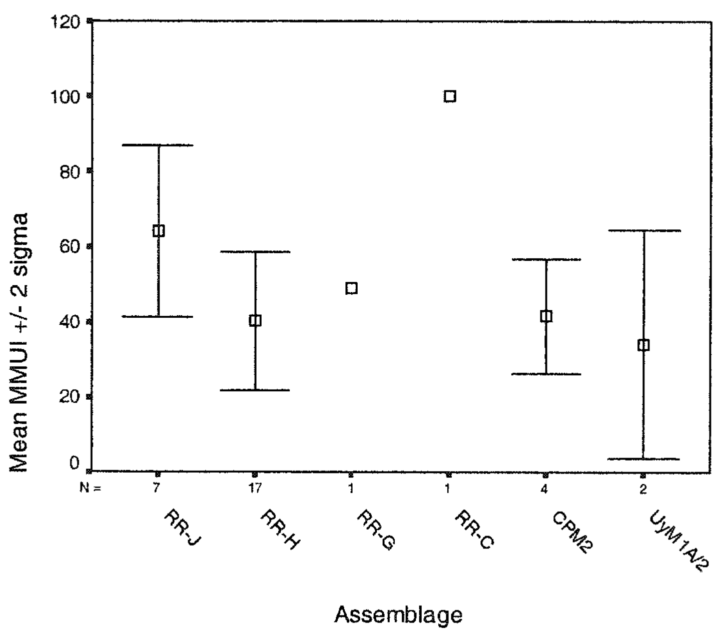


Fig. 6.6 Mean Utility and 2σ Range of Porpoise Skeletal Elements in Midden Assemblages

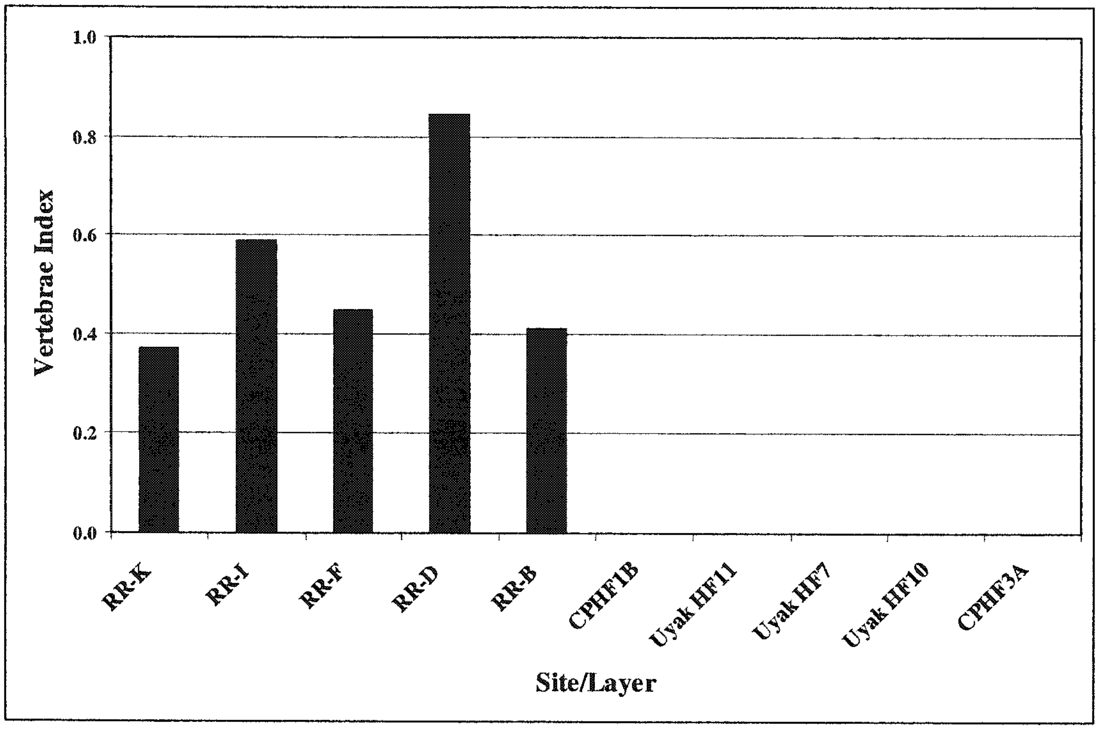


Fig. 6.7 Vertebrae Index Values for Sea Otter Remains from House Floor Assemblages

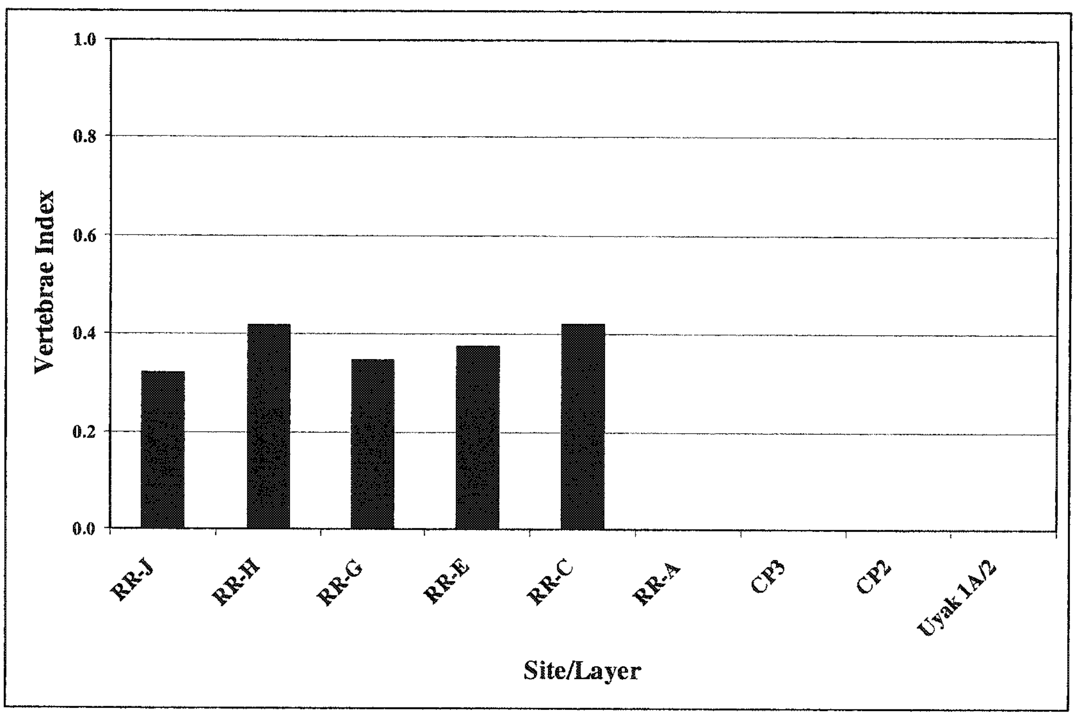


Fig. 6.8 Vertebrae Index Values for Sea Otter Remains from Midden Assemblages

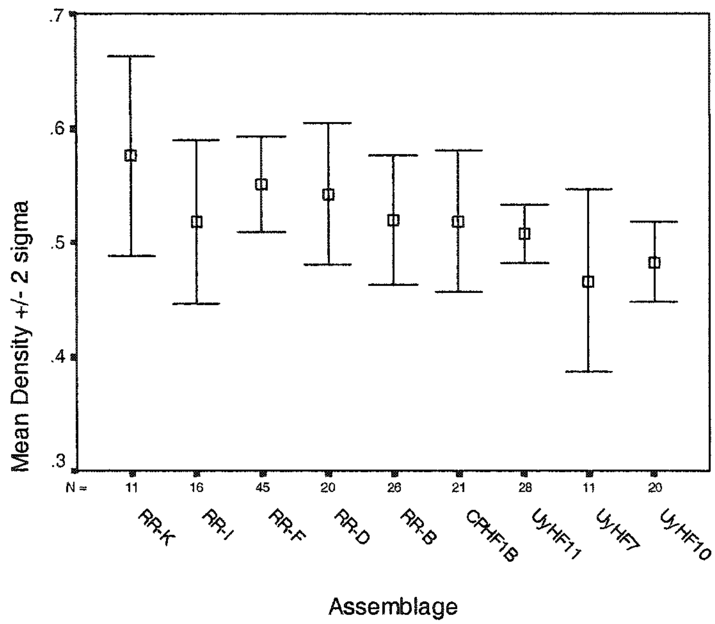


Fig. 6.9 Mean Harbor Seal Skeletal Part Density and 2σ Range for House Floor Assemblages

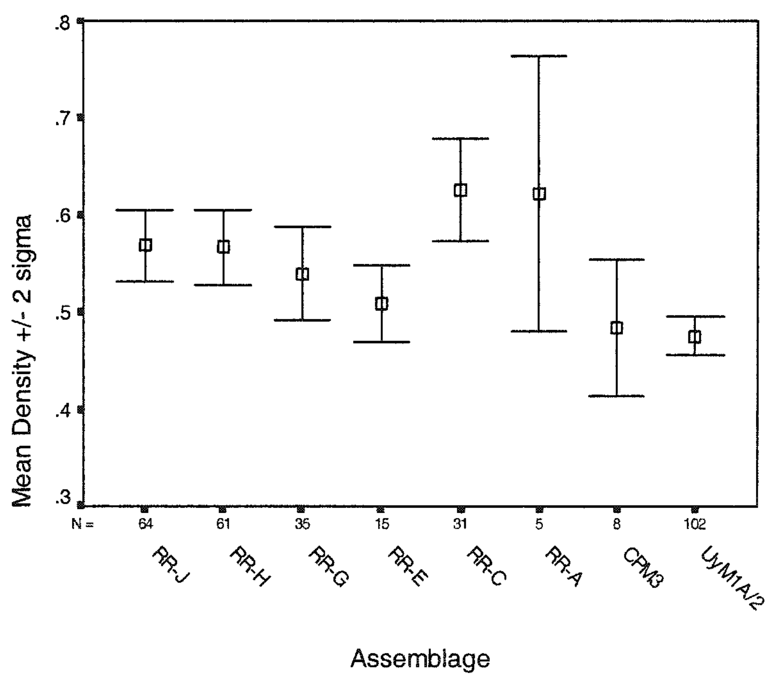


Fig. 6.10 Mean Harbor Seal Skeletal Part Density and 2σ Range for Midden Assemblages

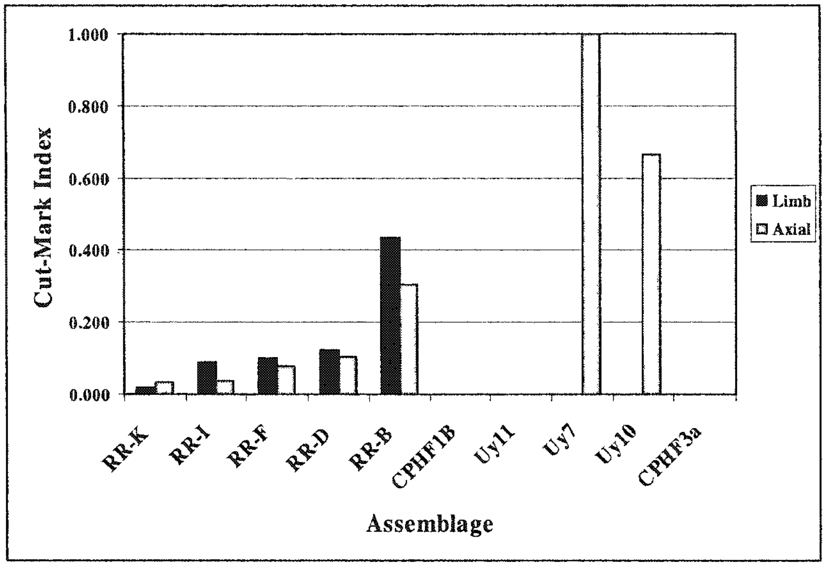


Fig. 6.11 Cut-Mark Index Values for Sea Otter Remains from House Floor Assemblages

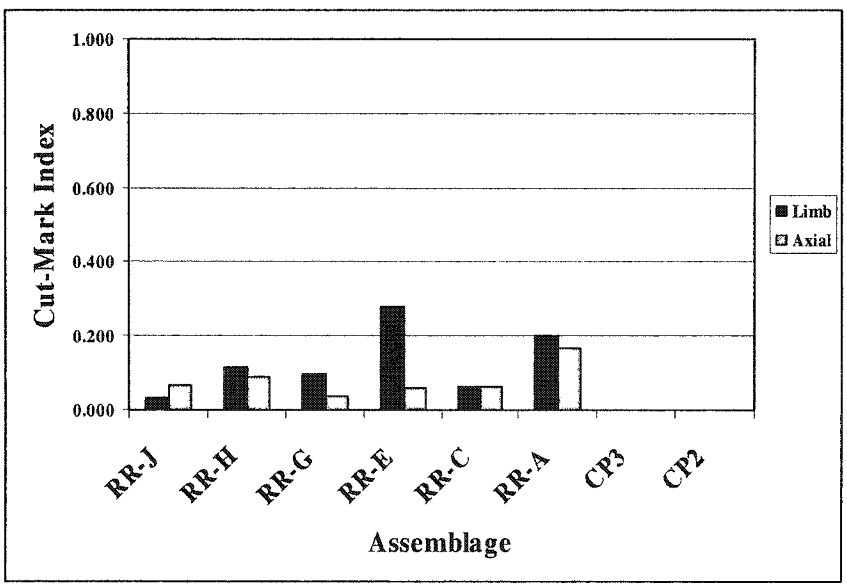


Fig. 6.12 Cut-Mark Index Values for Sea Otter Remains from Midden Assemblages

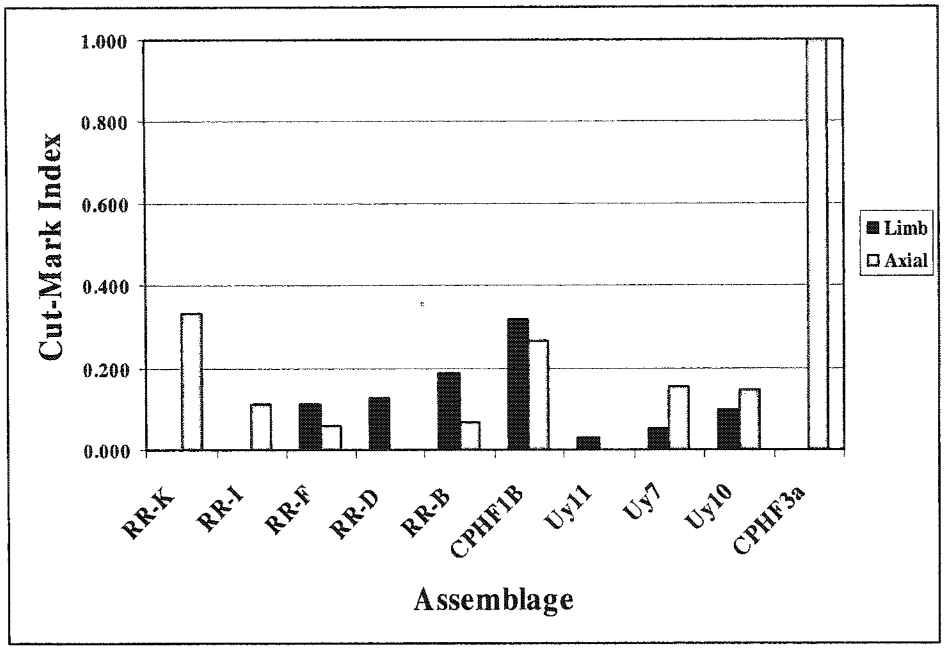


Fig. 6.13 Cut-Mark Index Values for Harbor Seal Remains from House Floor Assemblages

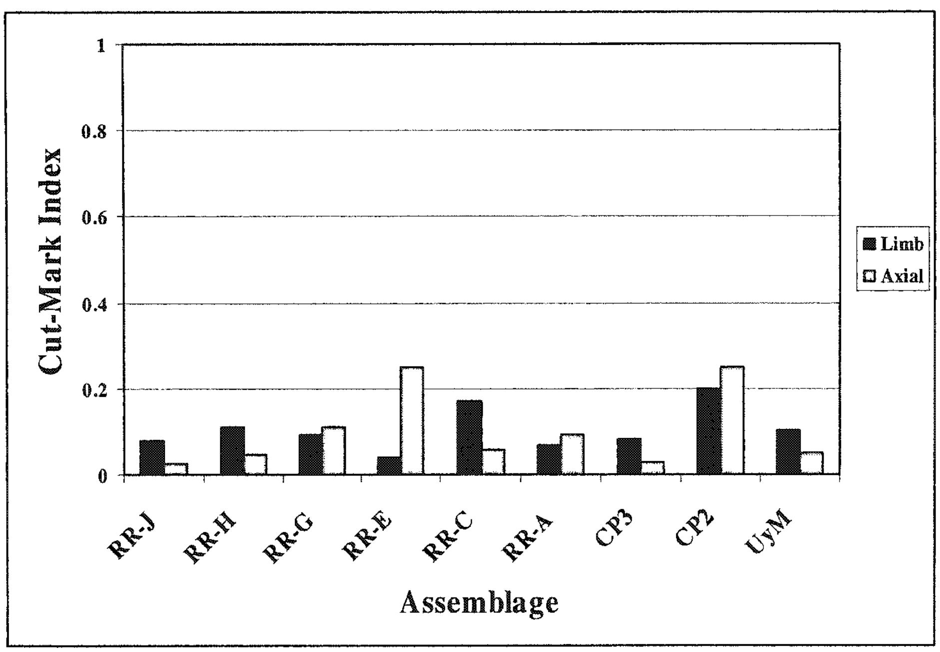


Fig. 6.14 Cut-Mark Index Values for Harbor Seal Remains from Midden Assemblages

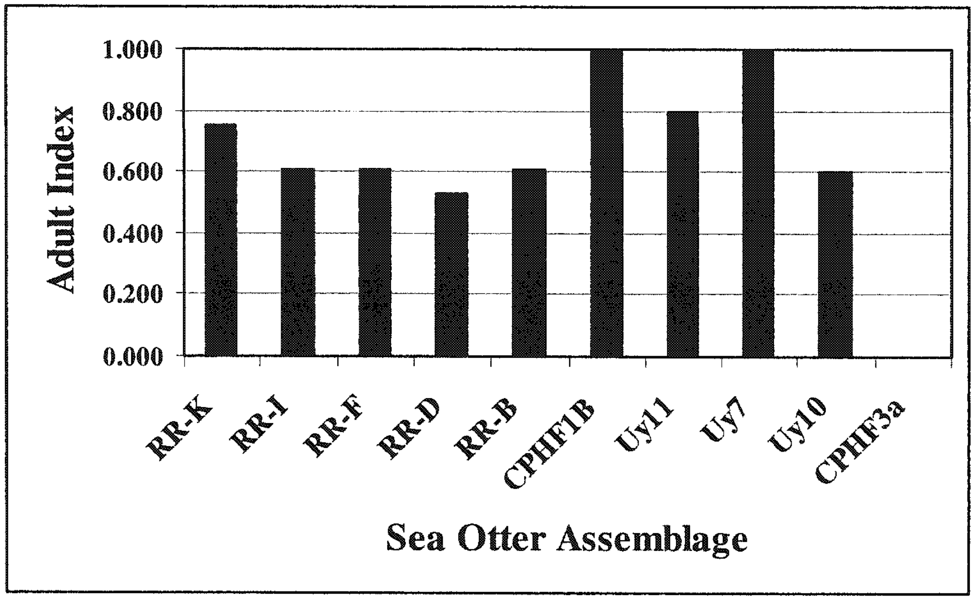


Fig. 6.15 Adult Specimen Index Values for Sea Otter Remains from House Floor Assemblages

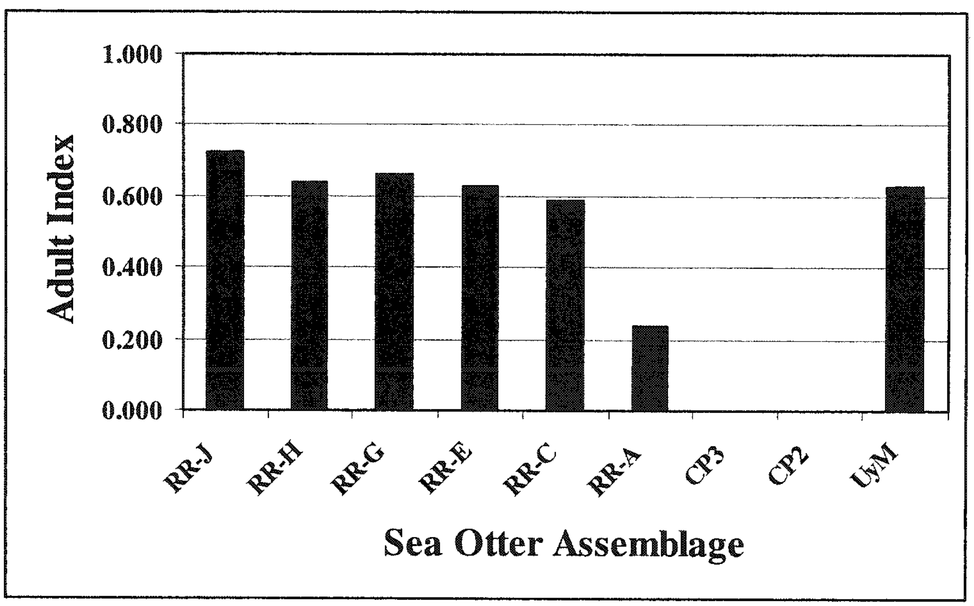


Fig. 6.16 Adult Specimen Index Values for Sea Otter Remains from Midden Assemblages

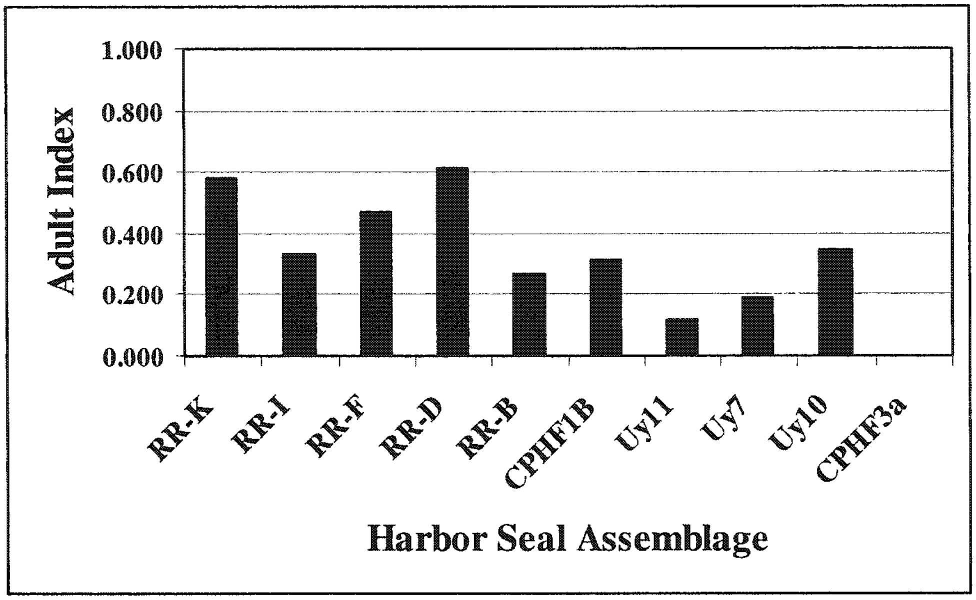


Fig. 6.17 Adult Specimen Index Values for Harbor Seal Remains from House Floor Assemblages

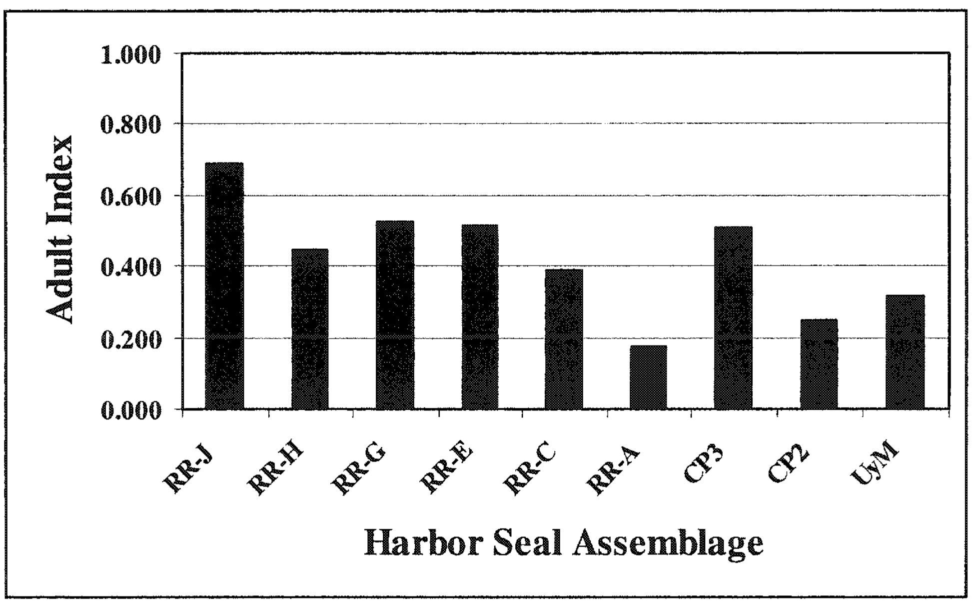


Fig. 6.18 Adult Specimen Index Values for Harbor Seal Remains from Midden Assemblages

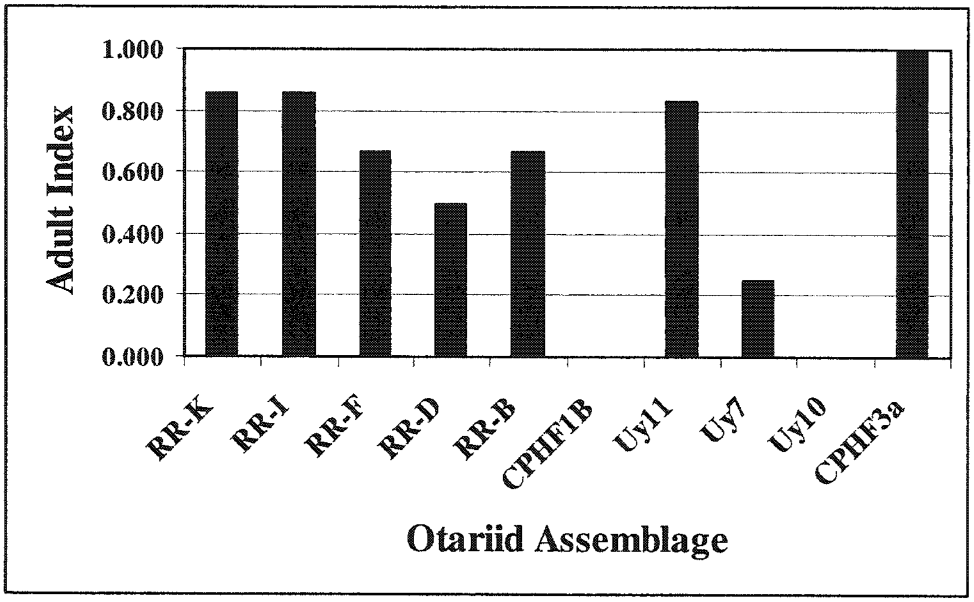


Fig. 6.19 Adult Specimen Index Values for Otariid Remains from House Floor Assemblages

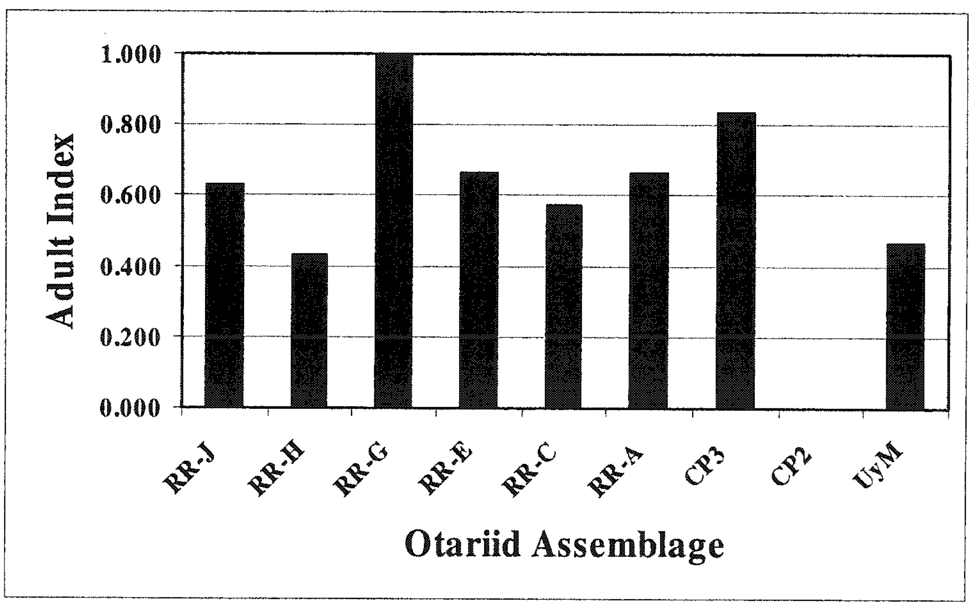


Fig. 6.20 Adult Specimen Index Values for Otariid Remains from Midden Assemblages

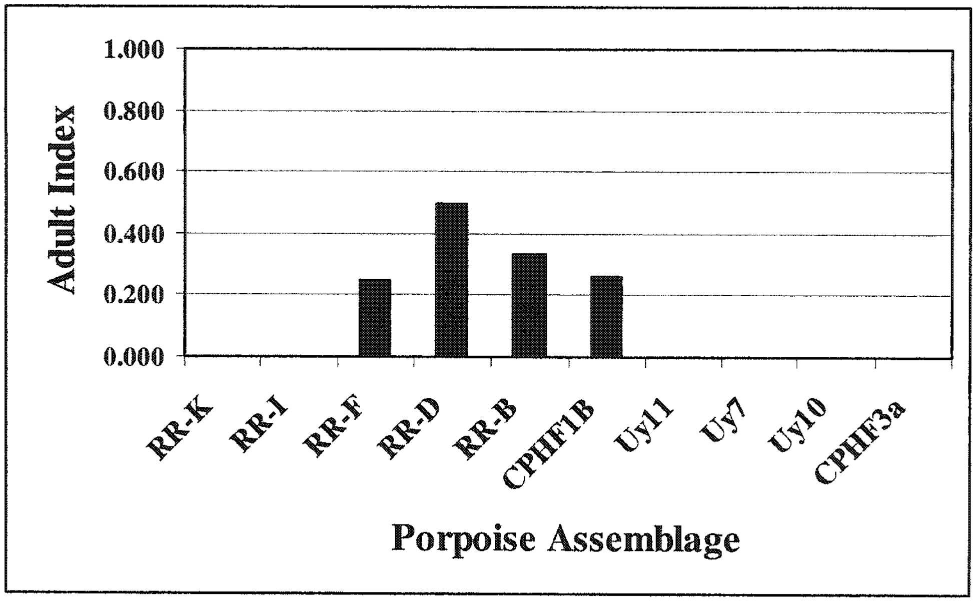


Fig. 6.21 Adult Specimen Index Values for Porpoise Remains from House Floor Assemblages

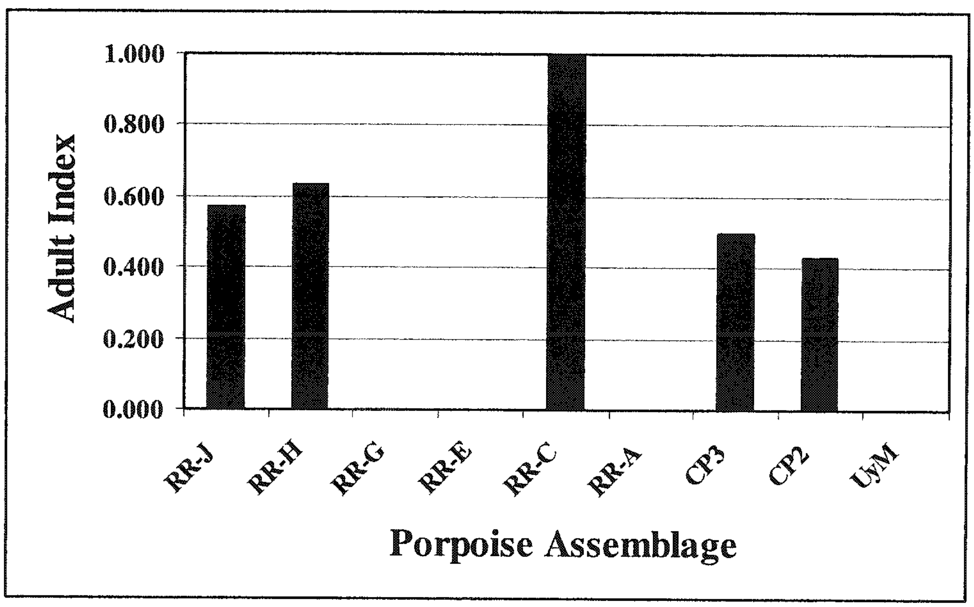


Fig. 6.22 Adult Specimen Index Values for Porpoise Remains from Midden Assemblages

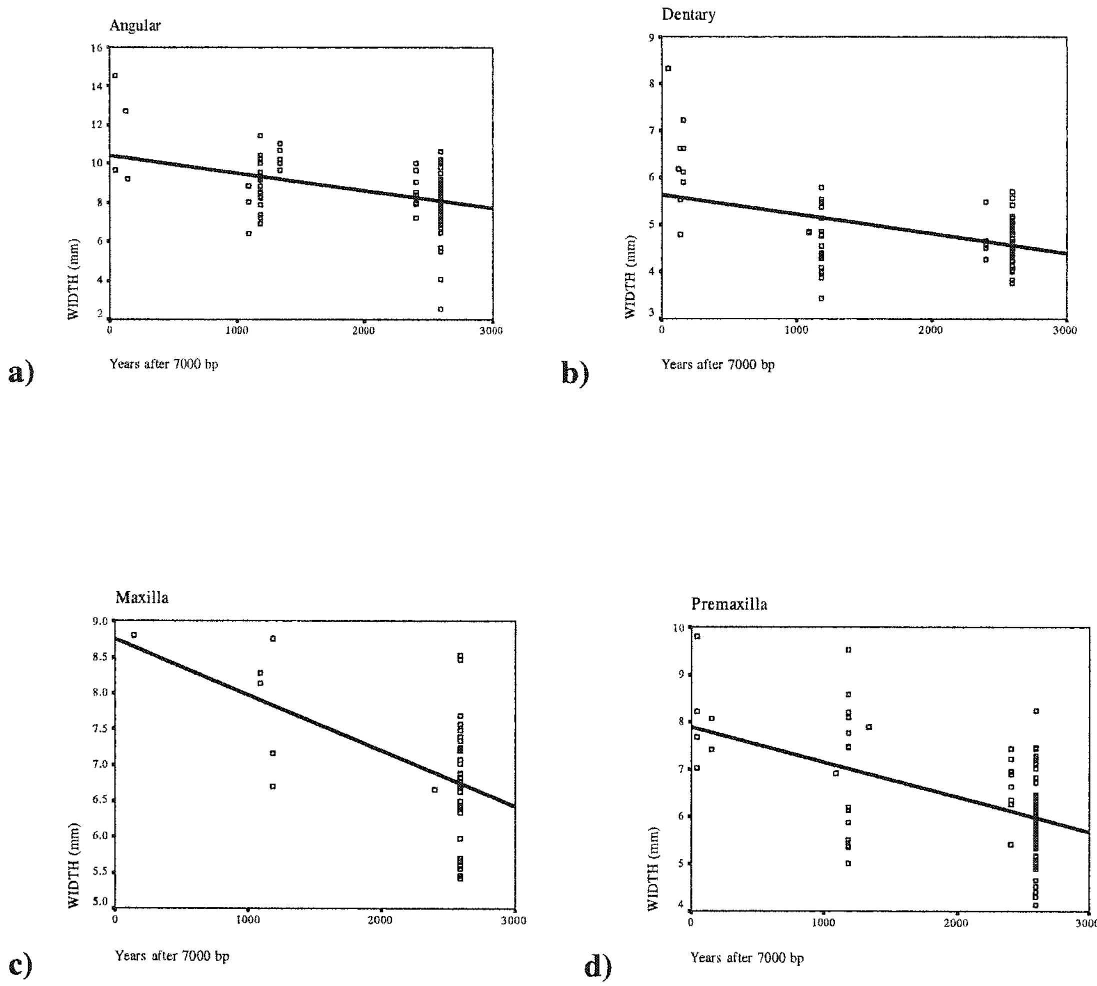


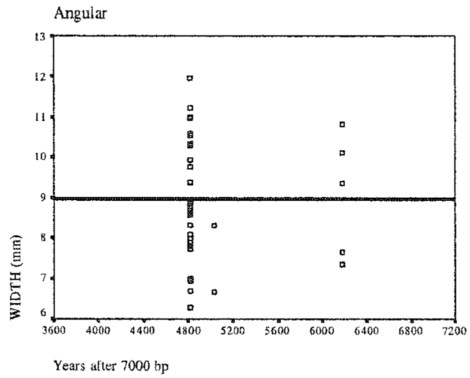
Fig. 6.23 Width Measurements on Pacific Cod Elements from the Rice Ridge site:

a) Angular: $y=10.411-(8.92E-04)x$; $r^2=0.1817$; $t_{slope}= -4.666$, $p<0.001$

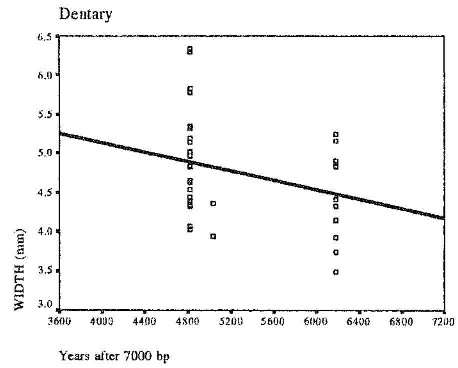
b) Dentary: $y=5.637-(4.12E-04)x$; $r^2=0.2186$; $t_{slope}= -4.761$, $p<0.001$

c) Maxilla: $y=8.749-(7.76E-04)x$; $r^2=0.2749$; $t_{slope}= -3.795$, $p=0.001$

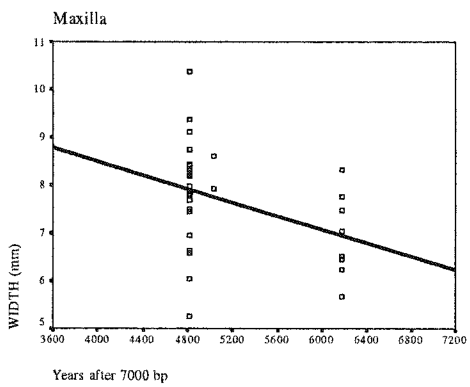
d) Premaxilla: $y=7.899-(7.43E-04)x$; $r^2=0.2587$; $t_{slope}= -5.849$, $p<0.001$



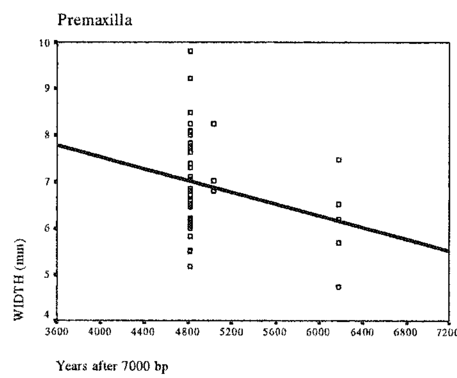
a)



b)



c)



d)

Fig. 6.24 Width Measurements on Pacific Cod Elements from the Crag Point site:
a) Angular: $y=8.698-(1.24E-06)x$; $r^2=0.0000$; $t_{slope}= -0.002$, $p=0.998$
b) Dentary: $y=6.353-(3.04E-04)x$; $r^2=0.0869$; $t_{slope}= -1.799$, $p=0.081$
c) Maxilla: $y=11.327-(7.08E-04)x$; $r^2=0.1450$; $t_{slope}= -2.330$, $p=0.026$
d) Premaxilla: $y=10.034-(6.26E-04)x$; $r^2=0.0658$; $t_{slope}= -1.699$, $p=0.097$

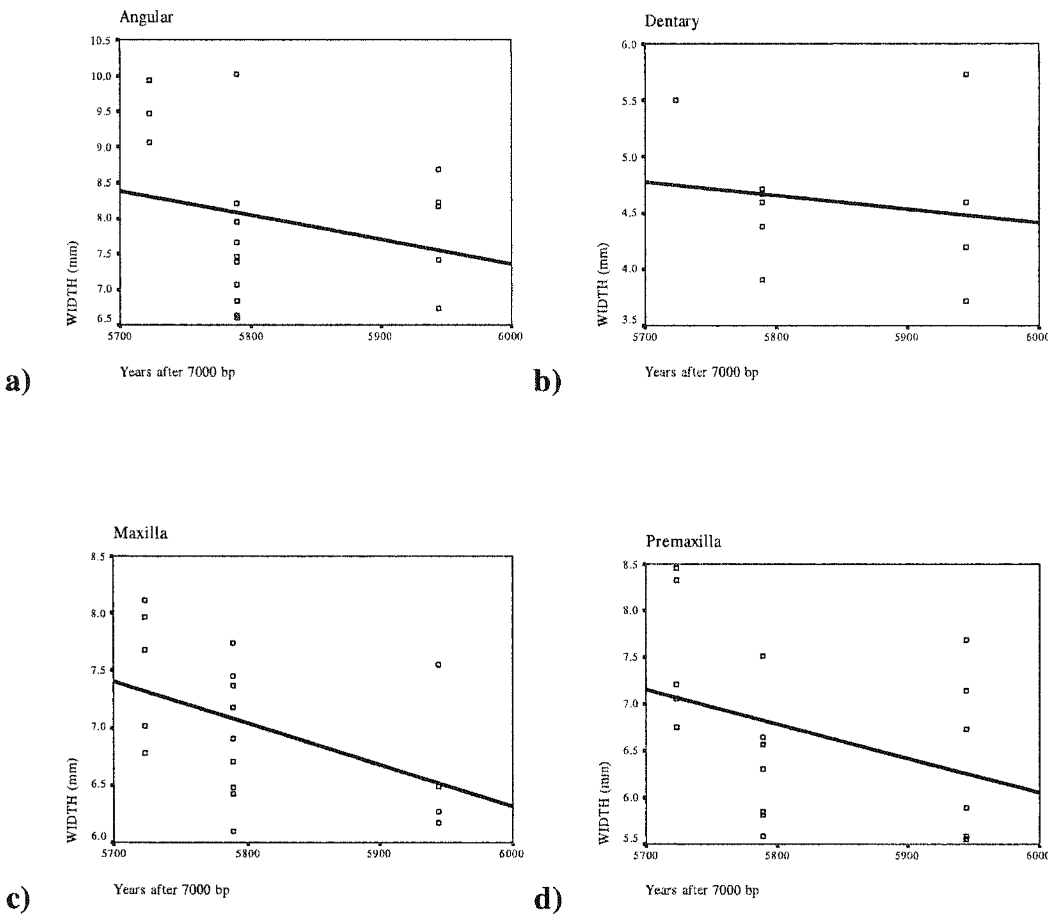


Fig. 6.25 Width Measurements on Pacific Cod Elements from the Uyak site:
a) Angular: y=28.138-(3.46E-03)x; r^2=0.0671; t_{slope}= -1.073, p=0.299
b) Dentary: y=11.619-(1.20E-03)x; r^2=0.0282; t_{slope}= -0.482, p=0.643
c) Maxilla: y=28.064-(3.62E-03)x; r^2=0.2163; t_{slope}= -2.101, p=0.052
d) Premaxilla: y=28.063-(3.67E-03)x; r^2=0.1394; t_{slope}= -1.610, p=0.127

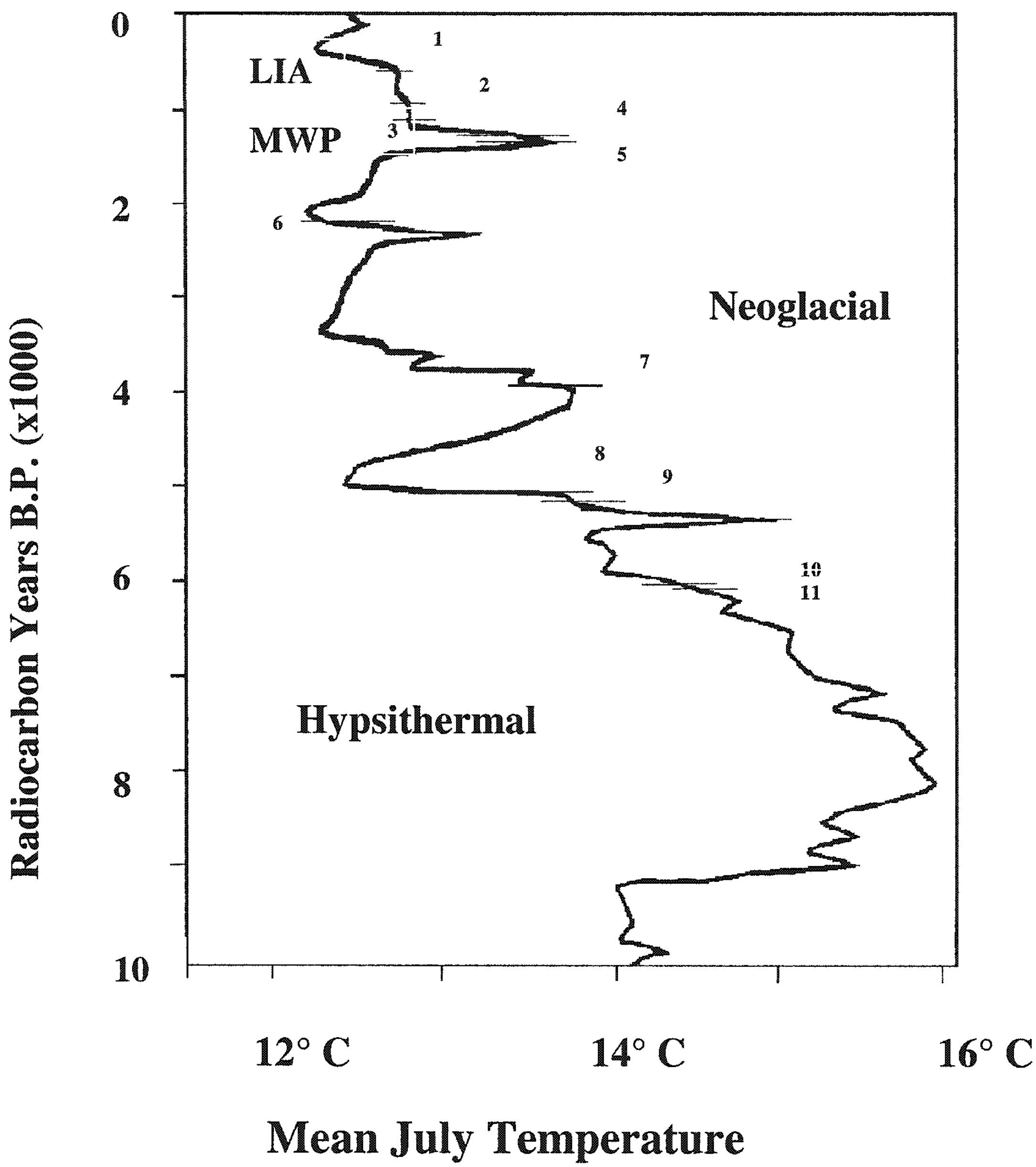


Fig. 6.26 Mean July Temperature Reconstruction for the Holocene (adapted from Heusser et al. 1985; Mann et al. 1998). Kodiak Faunal Assemblages from Floor Deposits as Follows: **1**=Settlement Point House; **2**=Crag Point House 3A; **3**=Uyak House 10; **4**=Uyak House 7; **5**=Uyak House 11; **6**=Crag Point House 1B; **7**=Rice Ridge Floor B; **8**=Rice Ridge House D; **9**=Rice Ridge House F; **10**=Rice Ridge House I; **11**=Rice Ridge House K.

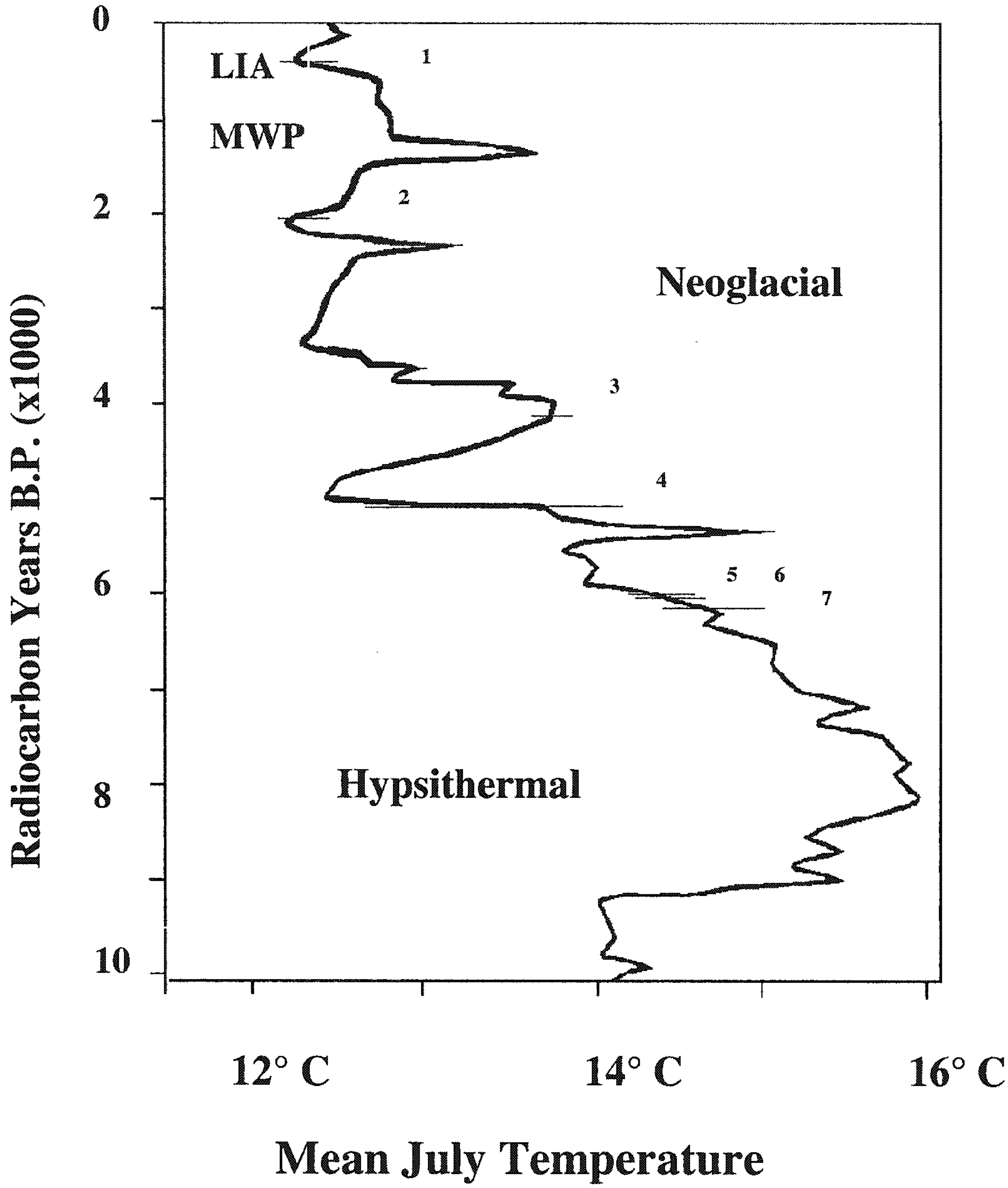


Fig. 6.27 Mean July Temperature Reconstruction for the Holocene (adapted from Heusser et al. 1985; Mann et al. 1998). Kodiak Faunal Assemblages from Midden Deposits as Follows: **1**=Settlement Point Midden; **2**=Crag Point Midden Layer 2; **3**=Rice Ridge Midden Layer A; **4**=Rice Ridge Midden Layer C; **5**=Rice Ridge Midden Layer G; **6**=Rice Ridge Midden Layer H; **7**=Rice Ridge Midden Layer J.

Chapter 7:

Subsistence Change and Cultural Complexity Discussion and Conclusions

In this final chapter, I review and discuss the results of my dissertation research. This is the first attempt to rigorously examine whether or not intensification of fish occurred in relation to sea mammal hunting along the Alaskan Pacific coast and the possibility that depression of both sea mammal and fish populations coincided with these subsistence changes. Not surprisingly, this work has answered some questions and raised many others. Along with a brief review of the problem orientation and hypotheses I test to address the issue of resource intensification and its relationship with cultural complexity, I discuss the results of analysis of the Kodiak faunal assemblages. Following this review, I conclude by examining some issues that remain unanswered and presented themselves during the course of research.

Resource Intensification and Depression

Complexity models for the north Pacific frequently posit resource intensification, usually of fish such as salmon, as a causal mechanism for the initial development of cultural complexity. The rationale for the use of intensification often incorporates the rich ethnohistoric record for the area that indicates intensive use of maritime resources, especially salmon, by Native Americans shortly before and during contact with Euroamericans (e.g., Coupland 1988; Matson and Coupland 1995). Additional archaeological evidence of intensive salmon use is found in shell middens across the region, suggesting the importance of salmon for at least the past few thousand years (e.g., Cannon 1991; Hoffman et al. 1999; Matson 1976). Yet as important of a role intensification is afforded in many complexity models, whether or not such subsistence change actually occurred has remained untested, along with its possible causes. In this dissertation almost 15,000 vertebrate remains from three archaeological sites on Kodiak Island, Alaska were analyzed to perform such tests.

Resource Intensification

I explicitly test the hypothesis that resource intensification occurred on Kodiak Island, using predictions based on the prey and patch choice models of foraging theory. To test whether or not intensification occurred within the near-shore marine resource patch, I examined the proportions of sea mammal and marine fish remains in each assemblage. Sea mammals are considered higher-ranking than marine fish in terms of net energetic returns, so an increase in the proportion of marine fish to sea mammals over time is interpreted as resource intensification. Sea mammal index values indicate a decreasing proportion of sea mammals in the assemblages over time compared to marine fish, and chi-squared tests of the linear trends in the data also support the hypothesis that intensification of marine fish increased.

To test whether or not intensification in the riverine patch occurred, I examined the proportion of salmonid and fox remains in each assemblage. Here, salmon are considered higher-ranking than fox despite their seasonally-restricted life histories. Intensification in the riverine patch is identified by a decrease in proportion of salmon to fox in the assemblages across time. Unfortunately, the consistently low numbers of fox remains in most all of the assemblages seriously hamper the use of this index in these samples, and the possibility that foxes were hunted for furs instead of food confuses the use of this species in te index as well. Use of other terrestrial taxa such as brown bear is also hampered by sample size problems. Therefore, whether or not intensification of non-salmonid riverine resources occurred over time is not clear from this study. Another test using larger samples of exclusively terrestrial resources, such as ptarmigan (*Lagopus* sp.) remains, may offer a more robust means of exploring inland resource intensification.

Finally, to test whether or not Alutiiq hunters and fishers were spending more effort harvesting salmon instead of hunting sea mammals or fishing for marine fish in the near-shore environment, I examined the proportion of sea mammal and salmonid remains in each assemblage. The hypothesis that intensification of salmon harvesting relative to sea mammal hunting did occur is supported by changes in the marine patch index over time and statistical examination of the ratios of sea mammal and salmon remains in each assemblage. The trend towards intensification is noticeable during the Ocean Bay period, while the Kachemak assemblages show fluctuating proportions of sea mammal and salmon remains, especially in the midden contexts.

Before concluding that resource intensification in its different manifestations occurred at these sites, I examined several possible confounding factors. Differential fragmentation of specimens from a particular species relative to others can possibly account for patterns of relative abundance between assemblages. Measures of fragmentation were made on the remains of both sea mammals and fish, and the changes in fragmentation between assemblages, when present, cannot account for changes in the proportions of particular taxa. Other taphonomic processes such as carnivore gnawing and burning of bones are occasionally present but do not appear to play a major structuring role in the assemblages either.

Finally, I examined the chronology of technological innovation seen in the archaeological record of the Kodiak archipelago and compared it to changing prey and patch choices inferred from the faunal assemblages. If trends in those foraging choices occurred during or after the introduction of mass-harvest technology that would increase the profitability of marine fish or salmon relative to sea mammals, then those changes in hunting and fishing suggest technological intensification (Fitzhugh 2001, 2003) and not intensification as a decrease in foraging efficiency (e.g., Beaton 1991; Boserup 1965). Greater use of both marine fish and salmon, however, clearly occurs much earlier than the appearance in the archaeological record of artifacts assumed to be related to the mass-harvesting and processing of fish, such as net weights and ground slate *ulus*. This first general hypothesis, that intensification of both marine fish and salmon occurred on the Kodiak archipelago, is not only supported from this study but the trends of intensification appear to take hold at a very early time.

Resource Depression

The second main hypothesis that this dissertation explicitly tests is that resource depression of high- and low-ranked prey types occurred on the Kodiak archipelago, reducing hunting encounters with sea mammals over time and decreasing the average body size of fish that were being harvested with increasing intensity. Foraging theory predicts that resource depression of large bodied, slow-reproducing, high-ranked prey such as resident sea mammals occurred as human population density on the archipelago increased and hunters targeted sea mammals as the most profitable food prey. The raw materials sea mammals provide in terms of skins, bone, and fat would make them even more of an essential resource. With decreasing encounters with sea mammals, foraging efforts would have shifted to a greater emphasis on salmon and marine fish, which would exhibit characteristics of increased harvest pressure as well.

The first line of evidence used to test whether or not resource depression of sea mammals occurred is skeletal part representation. For species with published meat utility indices, an increase in the mean utility of skeletal parts represented in the faunal assemblages is expected to occur over time if hunters traveled further from central camps and villages to access those populations. Of these species, which included phocid seals, otariid seals and sea lions, and porpoises, only phocid seal remains were recovered in samples large enough to statistically infer whether or not their mean utility did change over time. The assemblages from midden contexts do show a statistically significant increase in mean utility over time, followed by a decline. A simple index created for sea otters that follows the same rationale as the meat utility indices for other taxa suggests an increase in the mean utility of sea otter parts brought back to the Rice Ridge site over time. Mean density of these remains does increases with depth however, and therefore may be another structuring agent of the assemblages.

A second line of evidence that may indicate that sea mammal encounters were occurring with increasing rarity over time is the frequency of cut-marks on high-ranked prey. The proportion of cut-marked specimens of a particular prey type is expected to increase as they become scarce on the landscape and are butchered more intensively when they are captured. The cut-mark data from the two most abundant high-ranked mammal species, sea otter and harbor seal, do show some increase in the frequency of cut-marks as predicted by the resource depression model. Sea otter in particular show a marked increase over time in proportions of assemblages that exhibit cut-marks, inferred as a trend towards greater intensity of butchering. There is less evidence for the ratios of cut-marked and non-cut-marked harbor seal bones changing over time, however.

The final line of evidence used to test whether or not sea mammal populations were being depressed is age structure data. A reduction in the proportion of adult specimens of a particular sea mammal taxon is expected in this case. Sea otters and harbor seals are the species that have the greatest abundance at the sites, and therefore may have been targeted most heavily, and also come the closest to following the predictions put forth in the resource depression model. Sea otter remains from the Rice Ridge assemblages show a decline in proportion of adult specimens over time, and statistically the ratios of adult to sub-adult specimens significantly change over time in a declining trend. The harbor seal remains from the midden layers at Rice Ridge closely follow the model as well with a statistically significant decrease in the ratio of adult to sub-adult specimens, although the house floor remains do not.

As shown in Chapter 5, both marine fish within the same general patch as sea mammals and salmon from the riverine patch were harvested with increasing intensity over time compared to sea mammals. Although their life histories and reproductive habits are much different from sea mammals, probably making them much less sensitive to harvest pressure, they may still undergo such pressure in the wake of resource intensification on an island gradually being populated with a larger human presence. Although there are methodological barriers that prevent examination of possible depression of salmon populations, the ability to identify Pacific cod to species and their abundance in archaeofaunal assemblages on the Kodiak archipelago from a very early time make them ideal to test this hypothesis. Measurements taken on cod jaw elements from these assemblages indicate that mean body size of cod being caught decreased significantly over the course of 6000 years, correlating with an increase in their harvest compared to sea mammal hunting over that same time span.

Human harvest pressure is not the only mechanism that may reduce the abundance of sea mammals on the landscape or the body sizes and population dynamics of fish. Climate change offers another explanation for the patterns seen in the faunal remains that indicate possible resource depression. Comparison of the chronology of faunal assemblages from Rice Ridge, Crag Point, and Uyak with reconstruction of summer temperatures for the past 10,000 years suggests that in general they were deposited under cooler conditions over time. However, it is not clear whether that trend would affect sea mammal, salmon, or marine fish populations in a detrimental manner. Until the relationship between paleoclimate reconstructions, species-specific responses to climate change, and the variability found in the archaeofaunal record on Kodiak can be reconciled, climate change cannot be ruled out as a possible cause of resource depression of either sea mammals or fish suggested by the research presented in this dissertation.

Resource Intensification as a Cause of Cultural Complexity on Kodiak

The third hypothesis that I address in this dissertation elucidates the role of resource intensification in an established model of the evolution of cultural complexity (Fitzhugh 2003). I do not test the validity of intensification in that role *per se*, but instead note that indications of intensification (in this case labor intensification, or a decrease in foraging efficiency) must be chronologically situated prior to the appearance of technological innovations that would increase the efficiency of harvesting small-bodied prey. Labor intensification must occur prior to the appearance of archaeological correlates of complexity as well before it can be considered as a causal mechanism. For this case study, the hypothesis that intensification had such priority requires that subsistence trends described in Chapter 5 began before the appearance of mass-harvesting technology and the archaeological correlates of cultural complexity around the archipelago. The amount of time that can be expected to elapse between the subsistence shifts of resource intensification and an increase in sociocomplexity of a population, however, is not addressed here.

Despite all indications pointing to very successful maritime adaptations by Kodiak's earliest human occupants 8,000 years ago or earlier, significant changes in the archaeological record in the region suggest dramatic technological and socio-political change during the Kachemak period from about 3,500-1,000 radiocarbon years BP. These changes, taken as a group, are considered by most archaeologists working in the region as an indication of the ability to efficiently harvest, process, and store large quantities of small-bodied prey such as fish and shellfish, and increasing sociocultural complexity amongst the Alutiit (e.g., Clark 1984a; Dumond 1987; Fitzhugh 2002, 2003; Steffian 2002).

The specific archaeological phenomena brought together in many models as a suite of proxy indicators of cultural complexity are quite varied, and often are more indicative of processes associated with, but not analogous to, complexity. For example, shifts in house size and structure as well as settlement patterns may be closely related to increasing population size, but less so to increasing social complexity. A change from simple one room semi-subterranean houses prior to the

Koniag period to multi-room houses after the Kachemak-Koniag transition has been inferred as an indication of a shift in family residence patterns from nuclear to extended households (Jordan and Knecht 1988) and towards expanding corporate households (Maschner and Hoffman 2003). Fitzhugh (2003:210) further hypothesizes that changes in mean house size and size variation in village sites into the Developed Koniag phase is indicative of increasingly complex social relations within communities.

Other archaeological phenomena are closely tied to subsistence in terms of both mass-harvesting and storage of certain foods. Along with implications these innovations have on the efficiency of subsistence pursuits, such innovations affect the social environments of the communities that incorporate them as well. Mass-harvesting and storage technology are often asserted to be indications of economic specialization, which is considered another facet of cultural complexity possibly leading to asymmetrical control over food resources (e.g., Fitzhugh 2003; Hoffman et al. 1999; Testart 1982). The appearance of mass-harvesting tools first occurs on Kodiak during the Early Kachemak phase, along with the first significant use of inland riverine settings (Clark 1997; Saltonstall et al. 2001). Storage features such as clay-lined pits first occur during the Kachemak period as well, soon followed by slate box features (Saltonstall 1997; Steffian 1992a).

Archaeological correlates that perhaps relate closest to an increase in cultural complexity are those indicative of social inequality, warfare and ceremonial ritual. Any of these phenomena could have occurred during the Ocean Bay period, however the generally poor organic preservation at these early sites makes detection of artifacts indicating these phenomena difficult. Labrets are objects of personal adornment that were often made of stone (but see Knecht 1995), and are associated with displays of status (e.g., Holmberg 1985:38). Steffian and Saltonstall (2001) argue that shifts in labret design between the Late Kachemak and Early Koniag phases is indicative of a shift in function of the labrets from a marker of group membership to an indication of personal status. Fitzhugh (2003) notes a settlement shift of Koniag sites on Sitkalidak Island that includes an increase in strategically-located defensive sites that are smaller and more scarce during the preceding Late Kachemak phase and entirely absent across the archipelago prior to the Late Kachemak period. Despite the possibility of one or more correlates occurring earlier than their visibility in the archaeological record may suggest, one can reasonably infer that Alutiiq social structure involved inter- and intra-village competition, social inequality, and displays of status emergent in the Late Kachemak phase and more fully developed in the subsequent Koniag period.

The results of my analyses strongly support the hypothesis that labor intensification, in this case of marine fish and salmon, occurred before technological intensification or the appearance of correlates of cultural complexity. Decreasing foraging efficiency began in the early deposits of the Rice Ridge site, corresponding to Stages I and II in Fitzhugh's (2003) model, and continued before the development of fish netting technology during the Kachemak period corresponding to Stage III. Indications that encounters with sea mammals, especially sea otters and harbor seals, were becoming increasingly scarce also occur before the Kachemak period. Just as intensification can be considered a prerequisite condition for the development of subsistence-related technological innovations and cultural complexity, resource depression of higher-ranked sea mammal populations may have played a role in foraging decisions shifting towards a focus on fish. Ultimately, population growth and increasing human population density on the archipelago seems to have occurred up to the Early Kachemak phase (Fitzhugh 2003), and would likely have been a major factor in an increase in human harvest pressure placed on the profitable, slow-reproducing resident sea mammal populations in the area.

Future Directions of Prehistoric Subsistence Research on Kodiak

In this dissertation, I have modeled and demonstrated strong support for the occurrence of resource depression and intensification on Kodiak, but many questions have been raised that will require refinement of the models and methods presented here, as well as the usual need for "more data".

Modeling Prey and Patch Choices

The research presented here is the first application of a resource depression model derived from foraging theory that uses the Kodiak archipelago as a case study area. Consequently, there are many other ways of modeling both decreases in foraging efficiency and resource depression by examining different prey types and patch designations. Here, I have conceptualized sea mammals as a whole (excluding cetaceans larger than porpoises) to be the most profitable prey choice available to Alutiiq foragers compared to both marine fish within the same broad patch designation and salmon from a different patch.

Intensification may have occurred within these prey types or other prey types as well. For example, a shift from selective hunting of sea lion rookeries to a greater focus on sea otter and harbor seal populations may indicate resource intensification as well. Also, prey types not addressed here offered subsistence choices that have the potential to refine the resource depression model, most notably birds and shellfish. Analysis of the bird remains from Rice Ridge offers the hope that they can be incorporated soon (Susan Bender, personal communication 2003). The use of shellfish in a similar model will require additional excavation or use of data from other sites, since the mollusk remains from Rice Ridge, Crag Point, and Uyak were sampled much less systematically than the vertebrate remains. Shellfish are an ideal prey type to test the hypothesis that low-ranked prey underwent depression with intensified use, because they were most likely a low-return, labor-intensive resource and are morphologically sensitive to harvest pressure (e.g., Jerardino 1997; Mannino and Thomas 2001, 2002).

Methodological Issues and Resource Depression

The methods used to test whether depression of certain prey occurred offer a reasonable attempt when used in combination and samples are large enough, but how the specific methods are used and their results are interpreted need to be strengthened.

As mentioned in Chapter 6, meat utility indices created for certain sea mammal taxa (Diab 1998; Lyman et al. 1992; Savelle and Friesen 1996; Savelle et al. 1996) are a useful quantitative tool to test hypotheses about butchery and transport decisions. However, they are based upon associated meat weight alone and sometimes contradict ethnographic data on body part ranking and butchery decisions by hunters (e.g., Mishler 2001). Not only will utility indices be improved with further refinement based on ethnographic, ethnohistoric and experimental research that take into account other currencies besides caloric yield from meat, but similar indices can be developed for other species such as sea otter. Similarly, more experimental research needs to be done to investigate the relationship between cut-marks, butchery intensity, and prey scarcity.

Finally, this dissertation assumes that harvest pressure placed upon sea mammal species that do not form rookeries will result in a decrease in mean age of the individuals in the population. Specific effects need to be elucidated, as well as the effects that increased harvest pressure will have on otariid populations harvested at rookeries. Archaeofaunal samples with otariid sample sizes greater than those presented here are obviously required to evaluate these predictions.

Climate Change

Another area in which the relationship between theory, predictions, and empirical data need to be evaluated further is the role of climate change in prey availability and human foraging decisions. The research described in Chapter 6 suggests that certain sea mammal species were undergoing depression, possibly from human harvest pressure. However, changes in climate over time can not be ruled out as a possible explanation for decreasing encounters with these animals. To more fully integrate the role of climate in explanations of the history of subsistence on Kodiak, better coordination of paleoclimatic data, knowledge of animal behavior and biology, and archaeological data is required. The climatic reconstruction used in Chapter 6 holds general support across the north Pacific, but reconstruction of Kodiak's paleoclimate using local data has not yet occurred. Fitzhugh (personal communication 2003) is currently addressing this issue with isotopic data from shell remains from various sites on Kodiak Island. Also, the responses of animal populations to changes in climate and human harvest activities have been explored on a very short-term ecological temporal scale across the Pacific and for most animal species. Until there is congruence of temporal scales between paleoclimatic reconstructions, studies of animal population dynamics and archaeological data, the role of climate change in resource depression can be speculated upon not rigorously evaluated.

Faunal Assemblages

Finally, as in most cases in which zooarchaeological data are used from sites excavated primarily to answer non-subsistence questions, the samples used here may be adequate but are not ideal. With the exception of the Settlement Point data, the remains from the sites presented here were recovered using ¼" mesh screens which tend to under-represent small-bodied taxa such as fish (but presumably did so consistently between the sites examined). Besides the assemblages, what is known about the archaeological sites themselves is based on aggregated information regarding site function and seasonal occupation. In this dissertation I assume that these parameters remain consistent between the assemblages that I analyze, based on artifact and structural data associated with each assemblage. Further analyses of the Rice Ridge, Uyak, Crag Point, and Settlement Point sites in terms of site function and seasonality, and additional samples of faunal material recovered from mesh screens finer than ¼", may strengthen the arguments presented in this dissertation.

Also, there is a large temporal gap in the sequence of these assemblages corresponding to the Early Kachemak phase, about 3500-2500 radiocarbon years BP. This span of time is underrepresented in the archaeological record of the archipelago, yet it is also a critical period in understanding Alutiiq prehistory in general (Clark 1997; Fitzhugh 2003). It is the only phase prior to initial Russian colonization that is hypothesized as representing a population plateau or even a possible decline (Fitzhugh 2003), while settlement patterns apparently shift towards a greater use of inland riverine settings during the Early Kachemak phase as well (Saltonstall et al. 2001). My research indicates a decrease in foraging efficiency prior to the Early Kachemak phase and greater variability of subsistence trends during the Late Kachemak and Koniag phases. Obviously, a comparable faunal sample or samples dating to the Early Kachemak phase may clarify the transition from a steady trend of fish intensification during the Ocean Bay period and greater use of fish resources using mass-harvesting technology during the Kachemak and Koniag periods.

Conclusions

This dissertation has accomplished its intended goals of testing the hypotheses that resource intensification and depression occurred on the Kodiak archipelago. Faunal data from several sites were applied to an explicit resource depression model for the first time in the region. Given the broad range of subsistence choices available to Native Americans who lived along the north Pacific coast, and the importance of foraging pursuits to social organization amongst these groups, models from foraging theory are an appropriate explanatory tool to bridge the gap between complex hunter-gatherers and their prey. In conjunction with a new radiocarbon sequence for the Rice Ridge site, this research also gives the first picture of subsistence change from Ocean Bay times onward. In this way, it complements existing zooarchaeological research already done for the Kachemak-Koniag transition and the Koniag period (Partlow 2000). And finally, like most dissertations, this research has raised as many questions as it attempted to answer and will hopefully shape future archaeological inquiries in the region.

Bibliography

Ainley, David G., William J. Sydeman, and Richard H. Parrish
1991 Upwelling, Offshore Transport, and the Availability of Rockfish in Central California. In *Proceedings of the Seventh Annual Pacific Climate (PACLIM) Workshop, April 1990.* Edited by J.L. Betancourt and V.L. Tharp. pp. 131-136. Technical Report 26. California Department of Water Resources. Interagency Ecological Studies Program.

Allen, Glover M.
1939 Dog Skulls from Uyak Bay, Kodiak Island. *Journal of Mammalogy* 20:336-340.

Ames, Kenneth M.
1981 The evolution of social ranking on the Northwest Coast of North America. *American Antiquity* 46:789-805.

2002 Going by Boat: The Forager-Collector Continuum at Sea. In *Beyond Foraging and Collecting: Evolutionary Change in Hunter-Gatherer Settlement Systems*. Edited by B. Fitzhugh and J. Habu, pp. 19-52. Kluwer-Academic, New York.

Ames, Kenneth M. and Herbert D.G. Maschner
1999 *Peoples of the Northwest Coast: Their Archaeology and Prehistory.* Thames and Hudson, New York.

Amorosi, T.
1987 The Karluk and Uyak archaeofaunas: An approach towards the paleoeconomy of Kodiak Island, Alaska. Paper presented at the 52nd annual meeting of the Society for American Archaeology, Toronto.

Anderson, Pactricia M., Patrick J. Bartlein, Linda B. Brubaker, K. Gajewski, and James C. Ritchie
1991 Vegetation-Pollen-Climate Relationships for the Arcto-Boreal Region of North America and Greenland. *Journal of Biogeography* 18:565-582.

Anderson, Patricia M. and Linda B. Brubaker
1993 Holocene Vegetation and Climate Histories of Alaska. In *Global Climates Since the Last Glacial Maximum*, edited by H. Wright, J.E. Kutzbach, T. Webb, W.F. Ruddiman, A.F. Street-Perrott and P.J. Bartlein, pp. 386-400. University of Minnesota Press, Minneapolis.

Arndt, Allan, Win Van Neer, Bart Hellemans, Johan Robben, Filip Volckaert and Marc Waelkens
2003 Roman Trade Relationships at Sagalassos (Turkey) Elucidated by Ancient DNA of Fish Remains. *Journal of Archaeological Science* 30(9):1095-1105.

Arnold, Jeanne E.
1992 Complex hunter-gatherer-fishers of prehistoric California: Chiefs, specialists, and maritime adaptations of the Channel Islands. *American Antiquity* 57:60-84.

1993 Labor and the Rise of Complex Hunter-Gatherers. *Journal of Anthropological Archaeology* 12:75-119.

1996 Archaeology of Complex Hunter-Gatherers. *Journal of Archaeological Method and Theory* 3(2):77-126.

Bass, William M.
1987 *Human Osteology: A Laboratory and Field Manual*, 3rd Edition. Missouri Archaeological Society, Columbia.

Bayham, Frank E.
1979 Factors influencing the Archaic pattern of animal utilization. *Kiva* 44:219-235.

Beacham, Terry D.
1983 Variability in Meadian Size and Age at Sexual Maturity of Atlantic Cod, *Gadus morhua*, on the Scotian Shelf in the Northwest Atlantic Ocean. *Fishery Bulletin* 81(2):303-321.

Bean, Tarleton H.
1890 *Report on the Salmon and Salmon Rivers of Alaska.* Government Printing Office, Washington.

Beaton, J. M.
1991 Extensification and Intensification in Central California Prehistory. *Antiquity* 65:947-951.

Bettinger, Robert L.
1991a *Hunter-Gatherers: Archaeological and Evolutionary Theory*. Plenum Press, New York.

1991b Aboriginal Occupation at High Altitude: Alpine Villages in the White Mountains of Eastern California. *American Anthropologist* 93:656-679.

Binford, Lewis R.

1978 *Nunamiut Ethnoarchaeology*. Academic Press, New York.

1981 *Bones: Ancient Men and Modern Myths*. Academic Press, London.

Bjørnstad, Ottar N., Jean-Marc Fromentin, Nils Chr. Stenseth, and Jakob Gjøsæter

1999 Cycles and Trends in Cod Populations. *Proceedings of the National Academy of Sciences of the United States of America* 96:5066-5071.

Blair, G. R., D. E. Rogers, and T. P. Quinn

1993 Variation in Life History Characteristics and Morphology of Sockeye Salmon in the Kvichak River System, Bristol Bay, Alaska. *Transactions of the American Fisheries Society* 122:550-559.

Boone, James L. and Eric A. Smith

1997 Is It Evolution Yet? A Critique of Evolutionary Archaeology. *Current Anthropology* 39:S141-S174.

Borque, Bruce J.

1995 *Diversity and Complexity in Prehistoric Maritime Societies*. Plenum, New York.

Boserup, Ester

1965 *The Conditions of Agricultural Growth: The Economics of Agrarian Exchange under Population Pressure*. Aldine, Chicago.

Bradley, Raymod S.

1999 *Paleoclimatology: Reconstructing Climates of the Quaternary*. San Diego: Academic Press.

Bray, Tamara L. and Thomas W. Killion (editors)

1994 *Reckoning with the Dead: The Larsen Bay Repatriation and the Smithsonian Institution*. Smithsonian Institution Press, Washington.

Broughton, John M.

1994 Declines in Mammalian Foraging Efficiency During the Late Holocene, San Francisco Bay, California. *Journal of Anthropological Archaeology* 13:371-401.

1995 Resource Depression and Intensification During the Late Holocene, San Francisco Bay: Evidence from the Emeryville Shellmound Vertebrate Fauna. Ph.D. Dissertation, University of Washington, Seattle.

1997 Widening Diet Breadth, Declining Foraging Efficiency, and Prehistoric Harvest Pressure: Ichtyofaunal Evidence from the Emeryville Shellmound, California. *Antiquity* 71:845-862.

2002a Prey Spatial Structure and Behavior Affect Archaeological Tests of Optimal Foraging Models: Examples from the Emeryville Shellmound Vertebrate Fauna. *World Archaeology* 34(1):60-83.

2002b Pre-Columbian Impact on California Vertebrates: Evidence from Old Bones and Implications for Wilderness Policy. In *Wilderness and Political Ecology: Aboriginal Influences and the Original State of Nature,* edited by C.E. Kay and R.T. Simmons, pp. 44-71. University of Utah Press, Salt Lake City.

Broughton, John M. and Donald K. Grayson

1993 Diet Breadth, Adaptive Change, and the White Mountain Faunas. *Journal of Archaeological Science* 20:331-336.

Broughton, John M. and James F. O'Connell

1999 On Evolutionary Ecology, Selectionist Archaeology, and Behavioral Archaeology. *American Antiquity* 64:153-165.

Brown, Christopher L. and Carl E. Gustafson

1990 *A Key to Postcranial Skeletal Remains of Cattle/Bison, Elk and Horse.* Washington State University Laboratory of Anthropology Reports of Investigations 57, Pullman

Butler, Virginia L.

2000 Resource Depression on the Northwest Coast of North America. *Antiquity* 74:649-661.

2001 Changing fish use on Mangaia, southern Cook Islands: Resource depression and the prey choice model. *International Journal of Osteoarchaeology* 11:88-100

Butler, Virginia L. and Nancy J. Bowers

1998 Ancient DNA from Salmon Bone: A Preliminary Study. *Ancient Biomolecules* 2:17-26.

Butler, Virginia L. and James C. Chatters
1994 The Role of Bone Density in Structuring Prehistoric Salmon Bone Assemblages. *Journal of Archaeological Science* 21(3):413-424.

Cannon, Aubrey
1991 *The Economic Prehistory of Namu: Patterns in Vertebrate Fauna.* Archaeology Press, Simon Fraser University, Burnaby.

1995 The Ratfish and Marine Resource Deficiencies on the Northwest Coast. *Canadian Journal of Archaeology* 19:49-60.

2000 Settlement and Sea Levels on on the Central Coast of British Columbia: Evidence from Shell Midden Cores. *American Antiquity* 65(1): 67-77.

Cannon, Michael D.
2000 Large Mammal Relative Abundance in Pithouse and Pueblo Period Archaeofaunas from Southwestern New Mexico: Resource Depression Among the Mimbres Mogollon? *Journal of Anthropological Archaeology* 19(3):317-347.

2001a Large mammal resource depression and agricultural intensification: an empirical test in the Mimbres Valley, New Mexico. Ph.D. Dissertation, University of Washington, Seattle.

2001b Archaeofaunal Relative Abundance, Sample Size, and Statistical Methods. *Journal of Archaeological Science* 28(2):185-195.

2003 A Model of Central Place Forager Prey Choice and an Application to Faunal Remains from the Mimbres Valley, New Mexico. *Journal of Anthropological Archaeology* 22(1):1-25.

Casteel, Richard W.
1976 *Fish Remains in Archaeology and Paleo-environmental Studies.* Academic Press, London.

Caughley, Graeme
1977 *Analysis of Vertebrate Populations.* John Wiley and Sons, London.

Chambers, A. L.
1992 Seal Bone Mineral Density: Its Effect on Specimen Survival in Archaeological Sites. Undergraduate Honors Thesis, University of Missouri, Columbia.

Charnov, Eric
1976 Optimal Foraging: The Marginal Value Theorem. *Theoretical Population Biology* 9:474-478.

Charnov, Eric, Gordon H. Orians, and K. Hyatt
1976 Ecological Implications of Resource Depression. *American Naturalist* 110:247-259.

Chatters, James C., Virginia L. Butler, Michael J. Shott, David M. Anderson, and Duane A. Neitzel
1995 A Paleoscience Approach to Estimating the Effects of Climatic Warming on Salmonid Fisheries of the Columbia River Basin. In *Climate Change and Northern Fish Populations*. Edited by R.J. Beamish. pp. 489-496. Ottawa: National Research Council of Canada.

Clark, Donald W.
1966 Two Late Prehistoric Pottery-Bearing Sites on Kodiak Island, Alaska. *Arctic Anthropology* 3(2):157-184.

1970 The Late Kachemak Tradition at Three Saints and Crag Point, Kodiak Island, Alaska. *Arctic Anthropology* 6:73-111.

1974a *Koniag Prehistory*. Tubinger Monographien zur Urgeschichte Vol. 1. Verlag W. Kolhammer, Stuttgart.

1974b *Contributions to the Later Prehistory of Kodiak Island, Alaska.* Archaeological Survey of Canada, Mercury Series 20. Canadian Museum of Man, Ottawa.

1979 *Ocean Bay: An Early North Pacific Maritime Culture*. Archaeological Survey of Canada, Mercury Series 86. Canadian Museum of Man, Ottawa.

1982 An Example of Technological Change in Prehistory: The Origin of a Regional Ground Slate Industry in South-Central Coastal Alaska. *Arctic Anthropology* 19:103-126.

1984a Prehistory of the Pacific Eskimo Region. In *Arctic, Handbook of North American Indians, Vol. 5*, edited by D. Damas, pp. 136-148. Smithsonian Institution Press, Washington.

1984b Pacific Eskimo: Historical Ethnography. In *Arctic, Handbook of North American Indians, Vol. 5*, edited by D. Damas, pp. 185-197. Smithsonian Institution Press, Washington.

1986 Archaeological and historical evidence for an 18th-century "blip" in the distribution of the northern fur seal at Kodiak Island, Alaska. *Arctic* 39(1):39-42.

1997 *The Early Kachemak Phases on Kodiak Island at Old Kiavak.* Archaeological Survey of Canada, Mercury Series 155. Canadian Museum of Civilization, Ottawa.

Cohen, Mark N.

1981 Pacific Coast Foragers: Affluent or Overcrowded? *Senri Ethnological Studies* 9:275-295.

Colley, Sarah M.

1990 The Analysis and Interpretation of Archaeological Fish Remains. In *Archaeological Method and Theory* 2, edited by M.B. Schiffer, pp. 207-254. University of Arizona Press, Tucson.

Colten, Roger H. and Jeanne E. Arnold

1998 Prehistoric Marine Mammal Hunting on California's Northern Channel Islands. *American Antiquity* 63:679-701.

Coupland, Gary

1988 Prehistoric economic and social change in the Tsimshian area. In *Prehistoric Economies of the Northwest Coast*, edited by B. Isaac, pp. 211-243. Research in Economic Anthropology vol. 3. JAI Press, Greenwich.

Croes, Dale R. and Steve Hackenberger

1988 Hoko River Archaeological Complex: Modeling Prehistoric Northwest Coast Economic Evolution, edited by B. Isaac, pp. 19-85. Research in Economic Anthropology vol. 3. JAI Press, Greenwich.

Crowell, Aron C.

1994 Koniag Eskimo poison-dart whaling. In *Anthropology of the North Pacific Rim*, edited by W.W. Fitzhugh and V. Chaussonnet, pp. 217-242. Smithsonian Institution Press, Washington.

1997 *Archaeology and the Capitalist World System: A Study from Russian America.* Plenum Press, New York.

Crowell, Aron C. and April Laktonen
2001 *Súgucihpet* – "Our Way of Living". In *Looking Both Ways: Heritage and Identity of the Alutiiq People,* edited by A.L. Crowell, A.F. Steffian, and G.L. Pullar. pp. 137-187. University of Alaska Press, Fairbanks.

Cwynar, Les C. and Ray W. Spear
1991 Reversion of Forest to Tundra in the Central Yukon. *Ecology* 72:202-212.

Damas, David (editor)
1984 *Handbook of North American Indians Volume 5: Arctic.* Smithsonian Institution Press, Washington.

Davydov, Gavriil I.
1977 *Two Voyages to Russian America: 1802-1807.* Limestone Press, Kingston.

de Laguna, Frederica
1934 *The Archaeology of Cook Inlet, Alaska.* University Museum Press, Philadelphia.

1956 *Chugach Prehistory: The Archaeology of Prince William Sound, Alaska.* University of Washington Publications in Archaeology, Seattle.

DeLong, Robert L. and George A. Antonelis
1991 Impact of the 1982-1983 El Niño on the Northern Fur Seal Population at San Miguel Island, California. In *Pinnipeds and El Niño: Responses to Environmental Stress.* Edited by F. Trillmich and K.A. Ono. pp. 75-83. Berlin: Springer-Verlag.

Deo, Jennie N.
2003 Fueling the Fire of Kodiak Prehistory. Paper presented at the 68th Annual Meeting of the Society for American Archaeology, Milwaukee, WI.

Diab, Mark C.
1998 Economic utility of the ringed seal (*Phoca hispida*): Implications for arctic archaeology. *Journal of Archaeological Science* 25:1-26.

Donta, Christopher
1993 Koniag Ceremonialism: An Archaeological and Ethnographic Analysis of Sociopolitical Complexity and Ritual among the Pacific Eskimo. Ph.D. Dissertation, Bryn Mawr College, Bryn Mawr.

Dumond, Don E.
1987 *The Eskimos and Aleuts*, 2nd Edition. Thames and Hudson, London.

1988a The Alaska Peninsula as Superhighway: A Comment. In *The Late Prehistoric Development of Alaska's Native Peoples*, edited by R.D. Shaw, R.K. Herritt and D.E. Dumond, pp. 379-388. Aurora vol. 4, Alaska Anthropological Association, Anchorage.

1988b Trends and Traditions in Alaskan Prehistory: A New Look at an Old View of the Neo-Eskimo. In *The Late Prehistoric Development of Alaska's Native Peoples*, edited by R.D. Shaw, R.K. Herritt and D.E. Dumond, pp. 17-26. Aurora vol. 4, Alaska Anthropological Association, Anchorage.

1994 The Uyak Site in Prehistory. In *Reckoning with the Dead: The Larsen Bay Repatriation and the Smithsonian Institution*, edited by T.L. Bray and T.W. Killion, pp. 43-53. Smithsonian Institution Press, Washington.

Dumond, Donald and G. Richard Scott
1991 *The Uyak Site on Kodiak Island: Its Place in Prehistory.* University of Oregon Anthropological Papers 44, University of Oregon, Eugene.

Dyson-Hudson, Rada and Eric A. Smith
1978 Human territoriality: An ecological reassessment. *American Anthropologist* 80:21-41.

Egeland, Charles P.
2003 Carcass Processing Intensity and Cutmark Creation: An Experimental Approach. *Plains Anthropologist* 48:39-51.

Erlandson, Jon M.
1988 The role of shellfish in prehistoric economies: A protein perspective. *American Antiquity* 53(1):102-109.

Erlandson, Jon M. and Madonna L. Moss
1999 The Systematic Use of Radiocarbon Dating in Archaeological Surveys in Coastal and Other Erosional Environments. *American Antiquity* 64:431-443.

Erlandson, Jon M., A. Crowell, C. Wooley and J. Haggarty
1992 Spatial and temporal patterns in Alutiiq paleodemography. *Arctic Anthropology* 29:42-62.

Etnier, Michael A.
2002 The effects of human hunting on northern fur seal (*Callorhinus ursinus*) migration and breeding distributions in the Late Holocene. Ph.D. dissertation, University of Washington, Seattle.

Finney, Bruce P., I. Gregory-Eaves, J. Sweetman, M.S.V. Douglas, and J.P. Smol
2000 Impacts of Climatic Change and Fishing on Pacific Salmon Abundance Over the Past 300 Years. *Science* 290:795-799.

Finney, Bruce P., I. Gregory-Eaves, M.S.V. Douglas, and J.P. Smol
2002 Fisheries productivity in the northeastern Pacific Ocean over the past 2,200 years. *Nature* 416:729-733.

Fitzhugh, J. Benjamin
1995 Clams and the Kachemak: Seasonal Shellfish Use on Kodiak Island, Alaska (1200-800 B.P.). *Research in Economic Anthropology* 16:129-176.

1996 Evolution of Complex Hunter-Gatherers in the North Pacific: An Archaeological Case Study from Kodiak Island, Alaska. Ph.D. Dissertation, University of Michigan, Ann Arbor.

2001 Risk and Invention in Human Technological Evolution. *Journal of Anthropological Archaeology* 20(2):125-167.

2002 Residential and Logistical Strategies in the Evolution of Complex Hunter-Gatherers on the Kodiak Archipelago. In *Beyond Foraging and Collecting: Evolutionary Change in Hunter-Gatherer Settlement Systems*, edited by B. Fitzhugh and J. Habu, pp. . Kluwer Academic, New York.

2003 *The Evolution of Complex Hunter-Gatherers: Archaeological Evidence from the North Pacific*. Kluwer Academic/Plenum, New York.

Fitzhugh, William W. and Aron Crowell (editors)
1988 *Crossroads of Continents: Cultures of Siberia and Alaska*. Smithsonian Institution Press, Washington.

Fladmark, Knut R.
1975 *A Paleoecological Model for Northwest Coast Prehistory.* Archaeological Survey of Canada, Mercury Series 43. Canadian Museum of Man, Ottawa.

Forsell, Douglas J. and Patrick J. Gould
1981 *Distribution and Abundance of Marine Birds and Mammals Wintering in the Kodiak Area of Alaska.* United States Fish and Wildlife Service, Coastal Ecosystems Project, Washington.

Francis, Robert C. and Steven R. Hare
1994 Decadal-Scale Regime Shifts in the Large Marine Ecosystems of the Northeast Pacific: A Case for Historical Science. *Fisheries Oceanography* 3:279-291.

Froese, R. and D. Pauly (editors)
2002 FishBase. World Wide Web Publication. http://www.fishbase.org

Gamble, Lynn H.
2002 Archaeological Evidence for the Origin of the Plank Canoe in North America. *American Antiquity* 67(2):301-315.

Gentry, Roger L.
1991 El Niño Effects on Adult Northern Fur Seals at the Pribilof Islands. In *Pinnipeds and El Niño: Responses to Environmental Stress.* Edited by F. Trillmich and K.A. Ono. pp. 84-93. Berlin: Springer-Verlag.

Gilbert, B. Miles
1990 *Mammalian Osteology.* Missouri Archaeological Society, Columbia.

Gilpin, Lou M.
1995 Holocene Paleoseismicity and Coastal Tectonics of the Kodiak Islands, Alaska. Ph.D. Dissertation, University of California, Santa Cruz, CA.

Grayson, Donald K.
1984 *Quantitative Zooarchaeology: Topics in the Analysis of Archaeological Faunas.* Academic Press, Orlando.

1989 Bone transport, bone destruction, and reverse utility curves. *Journal of Archaeological Science* 16:643-652.

2001 The Archaeological Record of Human Impacts on Animal Populations. *Journal of World Prehistory* 15:1-68.

Grayson, Donald K. and Michael D. Cannon
1999 Human paleoecology and foraging theory in the Great Basin. In *Models for the Millenium: The Current Status of Great Basin Anthropological Research*, edited by C. Beck. University of Utah Press, Salt Lake City.

Grayson, Donald K. and Françoise Delpech
1998 Changing Diet Breadth in the Early Upper Palaeolithic of Southwestern France. *Journal of Archaeological Science* 25:1119-1129.

Grayson, Donald K., Françoise Delpech, Jean-Phillipe Rigaud, and Jan F. Simek
2001 Explaining the development of dietary dominance by a single ungulate taxon at Grotte XVI, Dordogne, France. *Journal of Archaeological Science* 28:115-125.

Griggs, R. F.
1922 *The Valley of Ten Thousand Smokes*. National Geographic Society, Washington.

1934 The edge of the forest in Alaska and the reasons for its position. *Ecology* 15(2):80-96.

Groot, Cornelius and Leo Margolis (editors)
1991 *Pacific Salmon Life Histories*. University of British Columbia Press, Vancouver.

Gross, M. R.
1985 Disruptive Selection for Alternative Life Histories in Salmon. *Nature* 313:47-48.

Guiot, J., J. A. Pons, J. L. de Beaulieu, and M. Reille
1989 A 140,000-Year Climate Reconstruction from Two European Pollen Records. *Nature* 338:309-313.

Haag, William G.
1948 An Osteometric Analysis of Some Aboriginal Dogs. *University of Kentucky Reports in Anthropology*, Volume 7, Number 3.

Haedrich, Richard L. and Johanne Fischer
1996 Stability and Change of Exploited Fish Communities in a Cold Ocean Continental Shelf Ecosystem. *Senckenbergiana Maritima* 27(3/6):237-243.

Hames, Raymond B. and William T. Vickers
1982 Optimal diet breadth theory as a model to explain variability in Amazonian hunting. *American Ethnologist* 9:358-378.

Hamilton, W. J. and K. E. F. Watt
1970 Refuging. *Annual Review of Ecology and Systematics* 1:263-286.

Hamon, Troy R.
1995 Artificial Selection in the Wild: Selection on Spawner Morphology of Wild Sockeye Salmon (*Oncorhynchus nerka*) by a Gillnet Fishery. M.S. Thesis, University of Washington, Seattle.

Hampton, Monty A., Paul R. Carlson, Homa J. Lee, and Richard A. Feely
1986 Geomorphology, Sediment, and Sedimentary Processes. In *The Gulf of Alaska: Physical Environment and Biological Resources*, edited by D.W. Hood and S.T. Zimmerman. pp. 93-143. National Oceanic and Atmospheric Administration, Anchorage.

Hansen, Barbara C. S and Daniel R. Engstrom
1996 Vegetation History of Pleasant Island, Southeastern Alaska Since 13,000 yr B.P. *Quaternary Research* 46:161-175.

Hanson, Diane K.
1995 Subsistence During the Late Prehistoric Occupation of Pender Canal, British Columbia (DeRt-1). *Canadian Journal of Archaeology* 19:29-48.

Hart, John L.
1973 *Pacific Fishes of Canada*. Bulletin 180. Fisheries Research Board of Canada, Ottawa.

Hausler-Knecht, Philomena
1991 Expanded View of the Ocean Bay Period: Preliminary Findings from the Rice Ridge (KOD-363) Site. Paper presented at the 18th Annual Meeting of the Alaska Anthropological Association, Anchorage, AK.

1993 Early Prehistory of the Kodiak Archipelago. Paper Presented at NSF-JSPS Seminar *The Origins, Development, and Spread of North Pacific-Bering Sea Maritime Cultures*, Honolulu, HI.

Hawkes, Kristen
1993 Why Hunter-Gatherers Work: An Ancient Version of the Problem of Public Goods. *Current Anthropology* 34(4):341-361.

Hawkes, Kristen, Kim Hill, and James F. O'Connell
1982 Why hunters gather: Opitmal foraging and the Ache of eastern Paraguay. *American Ethnologist* 9:379-398.

Hayden, Brian
1981 Research and Development in the Stone Age: Technological Transitions among Hunter-Gatherers. *Current Anthropology* 22:519-548.

Heizer, Robert F.
1943 Aconite Poison Whaling in Asia and America: An Aleutian Transfer to the New World. *Bureau of American Ethnology Bulletin* 133, pp. 415-468. Smithsonian Institution, Washington.

1956 *Archaeology of the Uyak Site, Kodiak Island, Alaska.* University of California Anthropological Records Vol. 17. University of California, Berkeley.

Heusser, C. J.
1983 Pollen diagrams from the Shumagin Islands and adjacent Alaska Peninsula, Southwestern Alaska. *Boreas* 12:279-295.

Heusser, C. J., L. E. Heusser, and D. M. Peteet
1985 Late-Quaternary Climatic Change on the American North Pacific Coast. *Nature* 315:482-485.

Hewes, G. W.
1973 Indian fisheries productivity in pre-contact times in the Pacific salmon area. *Northwest Anthropological Research Notes* 7:133-155.

Hildebrandt, William R. and Terry L. Jones
1992 Evolution of Marine Mammal Hunting: A View from the California and Oregon Coasts. *Journal of Anthropological Archaeology* 11:360-401.

2002 Depletion of Prehistoric Pinniped Populations along the California and Oregon Coasts: Were Humans the Cause? In *Wilderness and Political Ecology: Aboriginal Influences and the Original State of Nature,* edited by C.E. Kay and R.T. Simmons, pp. 72-110. University of Utah Press, Salt Lake City.

Hildebrandt, William R. and Kelly R. McGuire
2002 The Ascendance of Hunting During the California Middle Archaic: An Evolutionary Perspective. *American Antiquity* 67(2):231-256.

Hill, Kim, Hillard Kaplan, Kristen Hawkes and Ana Hurtado
1987 Foraging decisions among Aché hunter-gatherers: New data and implications for optimal foraging models. *Ethology and Sociobiology* 8:1-36.

Hillson, Simon
1992 *Mammal Bones and Teeth: An Introductory Guide to Methods of Identification*. Simon Hillson, London.

Hoffman, Brian W., Jessica M. C. Czederpiltz and Megan A. Partlow
1999 Heads or Tails: The Zooarchaeology of Aleut Salmon Storage on Unimak Island, Alaska. *Journal of Archaeological Science* 27(8):699-708.

Hoffman, Kirsten
1987 The Crag Point Site: A Preliminary Report on the 1986 Excavations. Senior Thesis, University of Alaska, Fairbanks.

Holmberg, Heinrich J.
1985 *Holmberg's Ethnographic Sketches*. Translated by F. Jaensch. The University of Alaska Press, Fairbanks.

Hopkins, D. M. and P. A. Smith
1981 Dated wood from Alaska and the Yukon: Implications for forest refugia in Beringia. *Quaternary Research* 15:217-249.

Hrdlicka, Aleš
1944 *The Anthropology of Kodiak Island*. Wistar Institute of Anatomy and Biology, Philadelphia.

Hurtado, A. Magdalena, Kristen Hawkes, Kim Hill, and Hillard Kaplan
1985 Female Subsistence Strategies Among the Aché of Eastern Paraguay. *Human Ecology* 13:1-28.

Ingram, B. Lynn
1998 Differences in Radiocarbon Age between Shell and Charcoal from a Holocene Shellmound in Northern California. *Quaternary Research* 49:102-110.

Jakobsson, J., O.S. Astthorson, R.J.H. Beverton, B. Bjoernsson, N. Daan, K.T. Frank, J. Meincke, B. Rothschild, S. Sundby, and S. Tilseth (editors)
1994 *Cod and Climate Change: Proceedings of a Symposium Held in Reykjavik, 23-27 Audust, 1993*. Copenhagen: International Council for the Exploration of the Sea.

Jerardino, Antonieta
1997 Changes in Shellfish Species Composition and Mean Shell Size from a Late-Holocene Record of the West Coast of Southern Africa. *Journal of Archaeological Science* 24(11):1031-1044.

Jones, Terry L. and William R. Hildebrandt
1995 Reasserting a Prehistoric Tragedy of the Commons: Reply to Lyman. *Journal of Anthropological Archaeology* 14:78-98.

Jordan, Richard H.
1992 Paleoarctic Assemblage from Crag Point, Kodiak Island, Alaska. In *Contributions to the Anthropology of Southcentral and Southwestern Alaska*, edited by R.H. Jordan, F. deLaguna, and A.F. Steffian. pp. 127-140. Anthropological Papers of the University of Alaska 24(1-2).

Jordan, Richard H. and Richard A. Knecht
1988 Archaeological Research on Western Kodiak Island, Alaska: The Development of Koniag Culture. In *The Late Prehistoric Development of Alaska's Native People*, edited by R.D. Shaw, R.K. Herritt and D.E. Dumond, pp. 225-306. Aurora vol. 4, Alaska Anthropological Association, Anchorage.

Jørgensen, Terje
1990 Long-Term Changes in Age at Sexual Maturity of Northeast Arctic Cod (*Gadus morhua* L.). *Journal du Conseil International pour l'Exploration de la Mer* 46:235-248.

Kaplan, Hillard and Kim Hill
1992 The Evolutionary Ecology of Food Acquisition. In *Evolutionary Ecology and Human Beahvior*, edited by E.A. Smith and B. Winterhalder, pp. 167-201. Aldine, Chicago.

Karlstrom, T. N. V.
1969 *Quaternary Geology of the Kenai Lowland and Glacial History of the Cook Inlet Region, Alaska.* U. S. Geological Survey Professional Paper 443. United States Department of the Interior, Washington.

Kay, C. E.
1994 Aboriginal Overkill: The Role of Native Americans in Structuring Western Ecosystems. *Human Nature* 5:359-398.

Keeley, Lawrence H.
1988 Hunter-gatherer economic complexity and "population pressure": A cross-cultural analysis. *Journal of Anthropological Archaeology* 7:373-411.

Kellogg, Remington
1925 *Additions to the Tertiary History of the Pelagic Mammals on the Pacific Coast of North America.* Contributions to Paleontology, Carnegie Publications 348. Carnegie Institution, Washington.

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

1996 Foraging and Fishing. In *Prehistoric Hunter-Gatherer Fishing Strategies*, edited my M.G. Plew, pp. 208-214. Boise State University, Boise.

Kennett, Douglas J., B. Lynne Ingram, Jon M. Erlandson and Phillip Walker
1997 Evidence for Temporal Fluctuations in Marine Radiocarbon Reservoir Ages in the Santa Barbara Channel, Southern California. *Journal of Archaeological Science* 24(11):1051-1059.

Kennett, Douglas J. and James P. Kennett
2000 Competitive and Cooperative Responses to Climatic Instability in Coastal Southern California. *American Antiquity* 65(2):379-395.

Kenyon, Karl W.
1969 The Sea Otter in the Eastern Pacific Ocean. *North American Fauna* 68. Washington: U.S. Bureau of Sport Fisheries and Wildlife.

Ketchen, Keith S.
1961 Observations on the Ecology of the Pacific Cod (*Gadus macrocephalus*) in Canadian Waters. *Journal of the Fisheries Research Board of Canada* 18(4):513-558.

Knecht, Richard A.
1995 *Late Prehistory of the Alutiiq People: Culture Change on the Kodiak Archipelago from 1200-1750 AD.* Unpublished Ph.D. dissertation, Department of Anthropology, Bryn Mawr College, Bryn Mawr.

Kopperl, Robert E.
2001 Herring Use in Southern Puget Sound: Analysis of Fish Remains at 45-KI-437. *Northwest Anthropological Research Notes* 35(1):1-20.

Kramer, Donald E. and Victoria M. O'Connell
1995 *Guide to Northeast Pacific Rockfishes.* Marine Advisory Bulletin 25. Alaska Sea Grant, Fairbanks.

Kramer, Donald E., William H. Barss, Brian C. Paust and Barry E. Bracken
1995 *Guide to Northeast Pacific Flatfishes.* Marine Advisory Bulletin 47. Alaska Sea Grant, Fairbanks.

Krebs, J. R. and N. B. Davies
1993 *An Introduction to Behavioural Ecology.* Blackwell Scientific Publications, London.

Kreutzer, Lee A.
1992 Bison and Deer Bone Mineral Densities: Comparisons and Implications for the Interpretation of Archaeological Faunas. *Journal of Archaeological Science* 19:271-294.

Kroeber, Alfred L. and S. A. Barrett
1960 *Fishing among the Indians of Northwestern California.* Anthropological Records 21(1). University of California Press, Berkeley.

Kurlansky, Mark
1997 *Cod: A Biography of the Fish that Changed the World.* Walker and Company, New York.

Leach, B. Foss and J. Davidson
1999 Estimating fish size from archaeological bones within one family: A detailed look at three species of Labridae. Paper presented at the 10th Annual Meeting of the ICAZ Fish Remains Working Group, New York.

2001 Use of Size-Frequency Diagrams to Characterize Prehistoric Fish Catches and to Assess Human Impact on Inshore Fisheries. *International Journal of Osteoarchaeology* 11:150-162.

Leach, B. Foss, J. Davidson, and L. M. Horwood
1997 The Estimation of Live Fish Size from Archaeological Cranial Bones of the New Zealand Blue Cod *Parapercis colias*. *International Journal of Osteoarchaeology* 7:481-496.

Lightfoot, Kent G., Thomas A. Wake and Ann M. Schiff
1991 *The Archaeology and Ethnohistory of Fort Ross, California: Volume 1, Introduction*. Contributions of the University of California Archaeological Research Facility 49, Berkeley.

Love, Milton
1996 A Checklist of Marine and Estuarine Fishes of the Northeast Pacific, from Alaska to Baja California. World Wide Web Publication http://id-www.ucsb.edu/lovelab/l_long.html University of California, Santa Barbara.

Love, Milton S., Mary Yoklavich and Lyman Thorsteinson
2002 *The Rockfishes of the Northeast Pacific*. University of California Press, Berkeley.

Lubinski, Patrick
1996 Fish Heads, Fish Heads: An Experiment on Differential Bone Preservation in a Salmonid Fish. *Journal of Archaeological Science* 23(2):175-181.

Lyman, R. Lee
1984 Bone Density and Differential Survivorship of Fossil Classes. *Journal of Anthropological Archaeology* 3:259-299.

1985 Bone Frequencies: Differential Transport, *In Situ* Destruction, and the MGUI. *Journal of Archaeological Science* 12(3):221-236.

1987 Archaeofaunas and Butchery Studies: A Taphonomic Perspective. *Advances in Archaeological Method and Theory* 10:249-337.

1989 Seal and Se Lion Hunting: A Zooarchaeological Study from the Southern Northwest Coast of North America. *Journal of Anthropological Archaeology* 8:68-99.

1991 *Prehistory of the Oregon Coast: The Effects of Excavation Strategies and Assemblage Size on Archaeological Inquiry*. Academic Press, San Diego.

1992 Anatomical Considerations of Utility Curves in Zooarchaeology. *Journal of Archaeological Science* 19(1):7-22.

1994 *Vertebrate Taphonomy*. Cambridge University Press, Cambridge.

1995 On the Evolution of Marine Mammal Hunting on the West Coast of North America. *Journal of Anthropological Archaeology* 14:45-77.

2003 The Influence of Time Averaging and Space Averaging on the Application of Foraging Theory in Zooarchaeology. *Journal of Archaeological Science* 30(5):595-610.

Lyman, R. Lee, James M. Savelle, and Peter Whitridge
1992 Derivation and application of a Meat Utility Index for Phocid seals. *Journal of Archaeological Science* 19:531-555.

MacArthur, R. H. and E. R. Pianka
1966 On optimal use of a patchy environment. *American Naturalist* 95:195-199.

Macer, C. T. and J. G. Shepherd
1987 The Effect of Species and Fishery Interactions on the Assessment of Some North Sea Gadoids. *Fisheries Research* 5:303-317.

Madsen, David B., L. Eschler and T. Eschler
1999 Winter Cattail Collecting Experiments. *Utah Archaeology* In Press.

Madsen, David B. and Dave N. Schmitt
1998 Mass collecting and the diet breadth model: A Great Basin example. *Journal of Archaeological Science* 25:445-455.

Mann, Daniel H.
1998 Geological and Paleonvironmental Investigations. In *Archaeology and Coastal Dynamics of Kenai Fjords National Park, Alaska*, edited by A. Crowell and D. Mann, pp. 31-51. Research/Resources Management Report ARRCR/CRR-98/34. National Park Service, Anchorage.

Mann, Daniel H., Aron L. Crowell, Thomas D. Hamilton, and Bruce P. Finney
1998 Holocene geologic and climatic history around the Gulf of Alaska. *Arctic Anthropology* 35:112-131.

Mannino, Marcello A. and Kenneth D. Thomas
2001 Intensive Mesolithic Exploitation of Coastal Resources? Evidence from a Shell Deposit on the Isle of Portland (Southern England) for the Impact of Human Foraging on Populations of Intertidal Rocky Shore Molluscs. *Journal of Archaeological Science* 28(10):1101-1114.

2002 Depletion of a Resource? The Impact of Prehistoric Human Foraging on Intertidal Mollusc Communities and Its Significance for Human Settlement, Mobility and Dispersal. *World Archaeology* 33(3):452-474.

Mantua, Nathan J., Steven R. Hare, Yuan Zhang, John M. Wallace, and Robert C. Francis
1997 A Pacific Interdecadal Climate Oscillation with Impacts on Salmon Production. *Bulletin of the American Meteorological Society* 78(6):1069-1079.

Marean, Curtis W.
1991 Measuring the Post-Depositional Destruction of Bone in Archaeological Assemblages. *Journal of Archaeological Science* 18:677-694.

Marean, Curtis W. and Lillian M. Spencer
1992 Impact of Carnivore Ravaging on Zooarchaeological Measures of Element Abundance. *American Antiquity* 56(4):645-658.

Maschner, Herbert D. G. and Brian W. Hoffman
2003 The Development of Large Corporate Households along the North Pacific Rim. *Alaska Journal of Anthropology* 1(2):44-61.

Mason, Owen K. and S. Craig Gerlach
1995 The Archaeological Imagination, Zoological Data, the Origins of Whaling in the Western Arctic, and "Old Whaling" and Choris Cultures. In *Hunting the Largest Animals*, edited by A.P. McCartney, pp. 1-31. Canadian Circumpolar Institute, Edmonton.

Mason, Owen K. and James W. Jordan
1993 Heightened north Pacific storminess during synchronous late Holocene erosion of northwest Alaska beach ridges. *Quaternary Research* 40:55-69.

Matson, R. G.
1976 *The Glenrose Cannery Site.* National Museum of Man, Ottawa.

Matson, R. G. and Gary Coupland
1995 *The Prehistory of the Northwest Coast.* Academic Press, San Diego.

McCartney, Alan P.
1984 Prehistory of the Aleutian Region. In *Handbook of North American Indians Volume 5, Arctic*, edited by D. Damas, pp. 119-135. Smithsonian Institution Press, Washington.

1995 Whale Size Selection by Precontact Hunters of the North American Western Arctic and Subarctic. In *Hunting the Largest Animals*, edited by A.P. McCartney, pp. 83-108. Canadian Circumpolar Institute, Edmonton.

McCartney, Alan P., H. Okada, A. Okada, and William Workman
1998 Introduction, In North Pacific and Bering Sea Maritime Societies: The Archaeology of Prehistoric and Early Historic Coastal Peoples. *Arctic Anthropology* 35 Special Issue.

McCutcheon, Patrick T.
1992 Burned Archaeological Bone. In *Deciphering a Shell Midden*, edited by J. K. Stein, pp. 347-370. Academic Press, San Diego.

McEvoy, Arthur F.
1991 Indian and Non-Indian Fisheries for Klamath River Salmon: Environment and Culture Change on the Northwestern California Frontier. In *New Dimensions in Ethnohistory: Papers of the Second Laurier Conference on Ethnohistory and Ethnology.* Edited by B. Gough and L. Christie, pp. 191-212. Hull: Canadian Museum of Civilization.

Mecklenburg, Catherine W., T. Anthony Mecklenburg, and Lyman K. Thosteinson
2002 *Fishes of Alaska.* Bethesda: American Fisheries Society.

Metcalfe, Duncan and Kevin T. Jones
1988 A Reconsideration of Animal Body-Part Utility Indices. *American Antiquity* 53(3):486-504.

Metcalfe, Duncan and K. Renee Barlow
1992 A model for exploring the optimal tradeoff between field processing and transport. *American Anthropologist* 94:340-356.

Mills, Robin O.
1994 Radiocarbon Calibration of Archaeological Dates from the Central Gulf of Alaska. *Arctic Anthropology* 31:126-149.

Mills, S. and J. Beatty
1979 The propensity interpretation of fitness. *Philosophy of Science* 46:263-286.

Mishler, Craig
2001 *Black ducks and salmon bellies: An ethnography of Old Harbor and Ouzinkie, Alaska.* U.S. Minerals Management Service, Technical Memorandum 7. Alaska Department of Fish and Game, Division of Subsistence, Anchorage.

Monks, Gregory G.
1987 Prey as Bait: The Deep Bay Example. *Canadian Journal of Archaeology* 11:119-142.

2001 Quit Blubbering: An Examination of Nuu'chah'nulth (Nootkan) Whale Butchery. *International Journal of Osteoarchaeology* 11:136-149.

Morrow, James E.
1979 *Preliminary Keys to Otoliths of Some Adult Fishes of the Gulf of Alaska,Bering Sea, and Beuafort Sea.* NOAA Technical Report, NMFS Circular 420.

Moss, Madonna L. and Jon M. Erlandson
1992 Forts, Refuge Rocks, and Defensive Sites: The Antiquity of Warfare along the North Pacific Coast of North America. *Arctic Anthropology* 29:73-90.

Moss, Madonna L., J. M. Erlandson, and R. Stuckenrath
1990 Wood stake weirs and salmon fishing on the Northwest Coast: Evidence from Southeast Alaska. *Canadian Journal of Archaeology* 14:143-158.

Moyle, P. B. and J. J. Cech
1996 *Fishes: An Introduction to Ichthyology.* Prentice Hall, Upper Saddle River.

Murie, Olaus J.
1959 *Fauna of the Aleutian Islands and Alaska Peninsula.* United States Fish and Wildlife Service, Washington.

Nagaoka, Lisa A.
1998 Resource depletion, extinction, and subsistence change in southern New Zealand. Poster presented at the 63rd annual meeting of the Society for American Archaeology, Seattle.

2001 Using Diversity Indices to Measure Changes in Prey Choice at the Shag River Mouth Site, Southern New Zealand. *International Journal of Osteoarchaeology* 11:101-111.

2002 The Effects of Resource Depression on Foraging Efficiency, Diet Breadth, and Patch Use in Southern New Zealand. *Journal of Anthropological Archaeology* 21:419-442.

National Oceanic and Atmospheric Administration
1997 *Kodiak Island and Shelikof Strait, Alaska: Environmentally Sensitive Areas.* Set of four seasonal maps. U.S. Department of Commerce, NOAA, Seattle.

National Research Council
1996 *Upstream: Salmon and Society in the Pacific Northwest.* Report by the Committee on Protection and Management of Pacific Northwest Anadromous Salmonids, Board on Environmental Studies and Toxocology, and Commission on Life Sciences. National Academy Press, Washington.

Nelson, Robert E. and Richard H. Jordan
1988 A post-glacial pollen record from western Kodiak Island, Alaska. *Arctic* 41:59-63.

O'Connell, James F.
1995 Ethnoarchaeology Needs a General Theory of Behavior. *Journal of Archaeological Research* 3:205-255.

O'Connell, James F. and Kristen Hawkes
1981 Alyawara Plant Use and Optimal Foraging Theory. In *Hunter-Gatherer Foraging Strategies*, edited by B. Winterhalder and E.A. Smith, pp. 99-125. University of Chicago Press, Chicago.

O'Connell, James F., Kristen Hawkes, and Nicholas Blurton Jones
1988 Hadza hunting, butchering and bone transport and their archaeological implications. *Journal of Anthropological Research* 44:113-161.

1990 Reanalysis of large animal body part transport among the Hadza. *Journal of Archaeological Science* 17:301-316.

OCSEAP
1986 Marine Fishes: Resources and Environments. In *The Gulf of Alaska: Physical Environment and Biological Resources*, edited by D.W. Hood and S.T. Zimmerman. pp. 399-415. National Oceanic and Atmospheric Administration, Anchorage.

Orians, Gordon H. and Nolan E. Pearson
1979 On the theory of central place foraging. In *Analysis of Ecological Systems*, edited by D.J. Horn, R.D. Mitchell and G.R. Stairs, pp. 154-177. Ohio State University Press, Columbus.

Partlow, Megan
2000 Salmon Instensification and Changing Household Organization in the Kodiak Archipelago. Ph.D. Dissertation, University of Wisconsin, Madison.

Pellat, Marlow G. and Rolf W. Mathewes
1997 Holocene Tree Line and Climate Change on the Queen Charlotte Islands, Canada. *Quaternary Research* 48:88-99.

Péwé, T. L.
1975 *Quaternary Geology of Alaska.* U. S. Geological Survey Professional Paper 835. United States Department of the Interior, Washington.

Pisias, Nicklas G.
1978 Paleoceanography of the Santa Barbara Basin During the Last 8,000 Years. *Quaternary Research* 10:366-384.

Porcasi, Judith F. and Harumi Fujita
2000 The Dolphin Hunters: A Specialized Prehistoric Maritime Adaptation in the Southern California Channel Islands and Baja California. *American Antiquity* 65:543-566.

Quinn, Thomas P.
1994 Anthropogenic Influences on Fish Populations of the Georgia Basin. Part I, Salmonids. In *Review of the Marine Environment and Biota of Strait of Georgia, Puget Sound, and Juan de Fuca Strait.* Edited by R.C.H. Wilson, R.J. Beamish, F. Aitkens and J. Bell, pp. 219-229. Ottawa: Fisheries and Oceans, Canada.

Quinn, Thomas P. and Chris J. Foote
1994 The Effects of Body Size and Sexual Dimorphism on the Reproductive Behaviour of Sockeye Salmon, *Oncorhynchus nerka*. *Animal Behaviour* 48:751-761.

Rätz, Hans-Joachim and Manfred Stein
1999 Variation in Growth and Recruitment of Atlantic Cod (*Gadus morhua*) off Greenland During the Second Half of the Twentieth Century. *Journal of Northwest Atlantic Fisheries Science* 25:161-170.

Rausch, R. L.
1969 Origin of the terrestrial mammalian fauna of the Kodiak Archipelago. In *The Kodiak Island Refugium: Its Geology, Flora, Fauna, and History*, edited by T.N.V. Karlstrom and G.E. Ball, pp. 216-235. Boreal Institute, University of Alberta, Edmonton.

Reeves, Randall R., Brent S. Stewart, Phillip J. Clapham, and James A. Powell
2002 *National Audubon Society Guide to Marine Mammals of the World.* New York: Knopf.

Reidman, Marianne and James A. Estes
1991 *The Sea Otter (*Enhydra lutris*): Behavior, Ecology, and Natural History.* Washington: U.S. Department of the Interior, Fish and Wildlife Service.

Robinson, Stephen W. and Gail Thompson
1980 Radiocarbon Corrections for Marine Shell Dates with Application to Southern Pacific Northwest Prehistory. *Syesis* 14:46-57.

Rogers, Donald E.
1986 Pacific Salmon. In *The Gulf of Alaska: Physical Environment and Biological Resources*, edited by D.W. Hood and S.T. Zimmerman. pp. 399-415. National Oceanic and Atmospheric Administration, Anchorage.

Rogers, Donald E., Brenda J. Rogers, and Rick J. Rosenthal
1987 The Nearshore Fishes. In *The Gulf of Alaska: Physical Environment and Biological Resources*, edited by D.W. Hood and S.T. Zimmerman. pp. 399-415. National Oceanic and Atmospheric Administration, Anchorage.

Roppel, Patricia
1986 *Salmon from Alaska.* Alaska Historical Commission, Anchorage.

Rosenberg, Michael
1998 Cheating at musical chairs: Territoriality and sedentism in an evolutionary context. *Current Anthropology* 39:653-682.

Rousselot, Jean-Loup
1994 Watercraft in the North Pacific: A Comparative View. In *Anthropology of the North Pacific Rim*, edited by W.W. Fitzhugh and V. Chaussonnet, pp. 243-258. Smithsonian Institution Press, Washington.

Sabin, Ann L. and Nicklas G. Pisias
1996 Sea surface temperature changes in the northeastern Pacific Ocean during the past 20,000 years and their relationship to climate change in northwestern North America. *Quaternary Research* 46:48-61.

Saltonstall, Patrick G.
1997 *Archaeology at Settlement Point: 1997 Preliminary Report.* Prepared For the Afognak Native Corporation, Kodiak.

Saltonstall, Patrick G. and Gary Carver
2002 Earthquakes, Subsidence, Prehistoric Site Attrition and the Archaeological Record: A View from the Settlement Point Site, Kodiak Archipelago, Alaska. In *Natural Disasters and Cultural Change*. Edited by R. Torrence and J. Grattan, pp. 172-192. Routledge, London.

Saltonstall, Patrick G., Robert E. Kopperl, and Amy F. Steffian
2001 4000 Years of Fishing: Archaeological Investigations Along Buskin River, Kodiak Island, Alaska. Paper presented at the 28th annual meeting of the Alaska Anthropological Association, Fairbanks, Alaska.

Saltonstall, Patrick G. and Amy F. Steffian
2002 Archaeological Reconnaissance on the Shores of Red Lake and Red River, Kodiak Archipelago, Alaska. Report Prepared for United States Fish and Wildlife Service, Anchorage. Alutiiq Museum and Archaeological Repository, Kodiak.

Samuels, Stephan R.
1991 *House Structure and Floor Midden.* Ozette Archaeological Project Research Reports, Volume 1. Washington State University Department of Anthropology Reports of Investigations 63, Pullman.

Savelle, James M. and T. Max Friesen
1996 An Odontocete (Cetacea) Meat Utility Index. *Journal of Archaeological Science* 23:713-721.

Savelle, James M., T. Max Friesen, and R. Lee Lyman
1996 Derivation and application of an Otariid Utility Index. *Journal of Archaeological Science* 23:705-712.

Schalk, Randall F.
1977 The structure of an anadromous fish resource. In *For Theory Building in Archaeology*, edited by L. Binford, pp. 207-243. Academic Press, New York.

Schoener, T. W.
1979 Generality of the size-distance relation in models of optimal feeding. *American Naturalist* 114(6):902-914.

Shipman, Pat, Giraud Foster, and Margaret Schoeninger
1984 Burnt Bones and Teeth: An Experimental Study of Color, Morphology, Crystal Structure and Shrinkage. *Journal of Archaeological Science* 11:307-325.

Shipman, Pat and Jennie Rose
1983 Evidence of Butchery Activities at Torralba and Ambrona: An Evaluation Using Microscopic Techniques. *Journal of Archaeological Science* 10:465-474.

Shubin, Valerii O.
1994 Aleut in the Kurile Islands 1820-1870. In *Anthropology of the North Pacific Rim*, edited by W. Fitzhugh and V. Chaussonnet, pp. 337-345. Smithsonian Institution Press, Washington.

Simenstad, Charles A., James A. Estes, and Karl W. Kenyon
1978 Aleuts, Sea Otters, and Alternate Stable-State Communities. *Science* 200:403-411.

Simms, Steven R.
1987 *Behavioral Ecology and Hunter-Gatherer Foraging: An Example from the Great Basin.* BAR International Series 381. British Archaeological Reports, Oxford.

Simon, James K.
1992 Mortuary Practices of the Late Kachemak Tradition in Southcentral Alaska: A Perspective from the Crag Point Site, Kodiak Island. *Arctic Anthropology* 29:130-149.

Smith, Eric A.
1991 *Inujjuamiut Foraging Strategies: Evolutionary Ecology of an Arctic Hunting Economy.* Aldine, Chicago.

Smith, Eric A. and Rebecca L. Bliege Bird
2000 Turtle Hunting and Tombstone Opening: Public Generosity as Costly Signaling. *Evolution and Human Behavior* 21(4):245-261.

Smith, Eric A, and Bruce Winterhalder
1992 Natural Selection and Decision-Making. In *Evolutionary Ecology and Human Beahvior*, edited by E.A. Smith and B. Winterhalder, pp. 25-60. Aldine, Chicago.

Sosis, Richard
2000 Costly Signaling and Torch Fishing on Ifaluk Atoll. *Evolution and Human Behavior* 21(4):223-244.

Steffian, Amy F.
1992a Fifty Years after Hrdlicka: Further Investigations at the Uyak Site, Kodiak Island, Alaska. In *Contributions to the Anthropology of Southcentral and Southwestern Alaska*, edited by R.H. Jordan, F. deLaguna, and A.F. Steffian. pp. 141-164. Anthropological Papers of the University of Alaska 24(1-2).

1992b Archaeological Coal in the Gulf of Alaska: A View from Kodiak Island. *Arctic Anthropology* 29(2):111-129.

2002 Cumilalhet – "Our Ancestors". In *Looking Both Ways: Heritage and Identity of the Alutiiq People*, edited by A.L. Crowell, A.F. Steffian, and G.L. Pullar. pp. 99-136. University of Alaska Press, Fairbanks.

Steffian, Amy F, Elizabeth P. Eufemio, and Patrick G. Saltonstall
1998 Archaeology of the Blisky Site: A Prehistoric Camp on Near Island, Kodiak Archipelago, Alaska. Report prepared for the Kodiak Island Borough. Alutiiq Museum and Archaeological Repository, Kodiak.

2002 Early Sites and Microblade Technologies from the Kodiak Archipelago. *University of Alaska Anthropological Papers*, in press.

Steffian, Amy F. and Patrick G. Saltonstall
2001 Markers of Identity: Labrets and Social Organization in the Kodiak Archipelago. *Alaska Journal of Anthropology* 1(1):1-20.

Stein, Barbara R.
1989 Bone Density and Adaptation in Semiaquatic Mammals. *Journal of Mammalogy* 70(3):467-476.

Stein, Julie K.
2000 Exploring Coast Salish Prehistory: The Archaeology of San Juan Island. University of Washington Press, Seattle.

Stein, Julie K., Laura S. Phillips and Jennie N. Deo
2003 Big Sites - Short Time: Accumulation Rates in Archaeological Sites. *Journal of Archaeological Science* 30(3):297-316.

Stephens, David W. and John R. Krebs
1986 *Foraging Theory*. Princeton University Press, Princeton.

Stuiver, Minze and Paula J. Reimer
1986 A Computer Program for Radiocarbon Age Calibration. *Radiocarbon* 28:980-1021.

1993 Extended ^{14}C Data Base and Revised CALIB 3.0 ^{14}C Age Calibration Program. *Radiocarbon* 35:215-230.

Stuiver, Minze, Paula J. Reimer, E. Bard, W. E. Beck, G. S. Burr, K. A. Hughen, B. Kromer, F. G. McCormac, J. v.d. Plicht, and M. Spurk
1998 INTCAL98 Radiocarbon Age Calibration. *Radiocarbon* 40:1041-1083.

Suttles, Wayne (editor)
1990 *Handbook of North American Indians Volume 7: Northwest Coast.* Smithsonian Institution Press, Washington.

Tennison, David C.
2000 Archaeological Wood Analysis in the Kodiak/Shelikof Region of the Gulf of Alaska: Searching for Spatial and Temporal Patterns. M.A. Thesis, University of Minnesota, St. Paul.

Testart, Alain
1982 The significance of food storage among hunter-gatherers: Residence patterns, population densities, and social inequalities. *Current Anthropology* 23:523-537.

Thomas, David Hurst
2000 *Skull Wars: Kennewick Man, Archaeology, and the Battle for Native American Identity.* Basic Books, New York.

Todd, Lawrence C. and David J. Rapson
1988 Long Bone Fragmentation and Interpretation of Faunal Assemblages: Approaches to Comparative Analysis. *Journal of Archaeological Science* 15:307-325.

Trillmich, Fritz, Kathryn A. Ono, Daniel P. Costa, Robert L. DeLong, Steven D. Feldkamp, John M. Francis, Roger L. Gentry, Carolyn B. Heath, Burney J. Le Boeuf, Patricia Majluf, and Anne York
1991 The Effects of El Niño on Pinniped Populations in the Eastern Pacific. In *Pinnipeds and El Niño: Responses to Environmental Stress.* Edited by F. Trillmich and K.A. Ono. pp. 247-270. Berlin: Springer-Verlag.

United States Fish and Wildlife Service
1987 Kodiak National Wildlife Refuge. Final Comprehensive Conservation Plan, Wilderness Review, and Environmental Impact Statement. Report prepared by U.S. Fish and Wildlife Service, Anchorage.

Van Neer, Wim, Lembi Lõugas, and Adriann D. Rijnsdorp
1999 Reconstructing Age Distribution, Season of Capture, and Growth Rate of Fish from Archaeological Sites Based on Otoliths and Vertebrae. *International Journal of Osteoarchaeology* 9:116-130.

Veniaminov, Ioann
1984 *Notes on the Islands of the Unalashka District.* Limestone Press, Kingston.

Viereck, L. A., C. T. Dyrness, A. R. Batten and K. J. Wenzlick
1992 *Alaska Vegetation Classification.* United States Forest Service, Portland.

Viereck, Leslie A. and Elbert L. Little, Jr.
1994 *Alaska Trees and Shrubs,* 5th edition. University of Alaska Press, Fairbanks.

Wall, William P.
1983 The Correlation Between High Limb-Bone Density and Aquatic Habits in Recent Mammals. *Journal of Paleontology* 57(2):197-207.

Ware, Daniel M.
1991 Climate Forcing of Pacific Herring Recruitment and Growth in Southern British Columbia. In *Proceedings of the Seventh Annual Pacific Climate (PACLIM) Workshop, April 1990*. Edited by J.L. Betancourt and V.L. Tharp. pp. 127-131. Technical Report 26. California Department of Water Resources. Interagency Ecological Studies Program.

Ware, Daniel M. and Gordon A. McFarlane
1995 Climate-Induced Changes in Pacific Hake (*Merluccius productus*) Abundance and Pelagic Community Interactions in the Vancouver Island Upwelling System. In *Climate Change and Northern Fish Populations*. Edited by R.J. Beamish. pp. 509-521. Ottawa: National Research Council of Canada.

White, Tim D.
2000 *Human Osteology* 2nd Edition. Academic Press, San Diego.

Whitridge, Peter
1999 Prehistory of Inuit and Yupik whale use. *Revista de Arqueología Americana* 16:99-154.

Wigen, Rebecca J. and Barbara R. Stucki
1988 Taphonomy and Stratigraphy in the Interpretation of Economic Patterns at Hoko River Rockshelter. *Research in Economic Anthropology* 3:87-146.

Wiles, G. C. and P. E. Calkin
1994 Late Holocene, high-resolution glacial chronologies and climate, Kenai Mountains, Alaska. *Geological Society of America Bulletin* 106:281-303.

Wiles, G. C., P. E. Calkin, and A. Post
1995 Glacier fluctuations in the Kenai Fjords, Alaska, U.S.A.: An evaluation of controls on iceberg-calving glaciers. *Arctic and Alpine Research* 27:234-245.

Wiles, G. C., R. D. d'Arrigo, and G. C. Jacoby
1996 Temperature changes along the Gulf of Alaska and the Pacific Northwest Coast modeled from coastal tree rings. *Canadian Journal of Forest Research* 26:474-481.

Williams, T. and B. C. Bedford
1974 The Use of Otoliths for Age Determination. In *The Ageing of Fish*, edited by T.B. Bagenal, pp. 114-123. Unwin Brothers Limited, Surrey.

Wilson, Judith G. and James E. Overland
1988 Meteorology. In *The Gulf of Alaska: Physical Environment and Biological Resources*, edited by D.W. Hood and S.T. Zimmerman. pp. 31-54. National Oceanic and Atmospheric Administration, Anchorage.

Winterhalder, Bruce
1981 Optimal Foraging Strategies and Hunter-Gatherer Research in Anthropology: Theories and Models. In *Hunter-Gatherer Foraging Strategies*, edited by B. Winterhalder and E.A. Smith, pp. 13-35. University of Chicago Press, Chicago.

Winterhalder, Bruce and Carol Goland
1997 An evolutionary ecology perspective on diet choice and plant domestication. In *People, Plants, and Landscapes: Studies in Paleothnobotany*, edited by K.J. Gremillion, pp. 123-160. University of Alabama Press, Tuscaloosa.

Winterhalder, Bruce and Eric A. Smith
1992 Evolutionary Ecology and the Social Sciences. In *Evolutionary Ecology and Human Behavior*, edited by E. A. Smith and B. Winterhalder, pp. 3-23. Aldine, Chicago.

Wynne, Kate
1997 *Guide to Marine Mammals of Alaska.* Alaska Sea Grant Marine Advisory Bulletin 44. University of Alaska, Fairbanks.

Yarborough, Linda F.
1995 Prehistoric Use of Cetacean Species in the Northern Gulf of Alaska. In *Hunting the Largest Animals*, edited by A.P. McCartney, pp. 63-82. Canadian Circumpolar Institute, Edmonton.

Yarborough, Michael R. and Linda F. Yarborough
1998 *Prehistoric Maritime Adaptations of Prince William Sound and the Pacific Coast of the Kenai Peninsula.* Arctic Anthropology 35(1):132-145.

Yesner, David R.
1987 Life in the "Garden of Eden". In *Food and Evolution*, edited by M. Harris and E. Ross. Temple University Press, Philadelphia.

1988 Effects of prehistoric human exploitation on Aleutian sea mammal populations. *Arctic Anthropology* 25:28-43.

1989 Osteological Remains from Larsen Bay, Kodiak Island, Alaska. *Arctic Anthropology* 26:96-106.

1992 Evolution of Subsistence in the Kachemak Tradition: Evaluating the North Pacific Maritime Stability Model. *Arctic Anthropology* 29:167-181.

York, Anne
1991 Sea Surface Temperatures and Theor. Relationship to the Survival of Juvenile Male Northern Fur Seals from the Pribilof Islands. In *Pinnipeds and El Niño: Responses to Environmental Stress*. Edited by F. Trillmich and K.A. Ono. pp. 94-106. Berlin: Springer-Verlag.

Zar, Jerrold H.
1996 *Biostatistical Analysis*, 3rd Edition. Prentice Hall, Upper Saddle River.

Zebdi, Abdelkrim and Jeremy S. Collie
1995 The Effect of Climate on Herring (*Clupea pallasi*) Population Dynamics in the Northeast Pacific Ocean. In *Climate Change and Northern Fish Populations*. Edited by R.J. Beamish. pp. 277-290. Ottawa: National Research Council of Canada.

Zimmerly, David W.
2000 *QAYAQ: Kayaks of Alaska and Siberia*. University of Alaska Press, Fairbanks.

Zohar, I., T. Dayan, and E. Spanier
1997 Predicting Grey Triggerfish Body Size from Bones. *International Journal of Osteoarchaeology* 7:150-156.

Appendix A: Comparative Skeletal Material

Fish

Taxon	Family	Common Name	Lgth (mm)	Origin	Cat. #
Agonus acipenserinus	Agonidae	Sturgeon Poacher	175	Case Inlet, WA	F59
Anarrichthys ocellatus	Anarhichadidae	Wolf-Eel	-	Seattle Aquarium, WA	F110
Anoplopoma fimbria	Anoplopomatidae	Sablefish	580	-	F47
Anoplopoma fimbria	Anoplopomatidae	Sablefish	-	-	F120
Bathylagus pacificus	Bathylagidae	Slender Blacksmelt	190	Bering Sea	F88
Bathylagus pacificus	Bathylagidae	Slender Blacksmelt	160	Bering Sea	F89
Bathylagus pacificus	Bathylagidae	Slender Blacksmelt	130	Bering Sea	F90
Bathylagus pacificus	Bathylagidae	Slender Blacksmelt	120	Bering Sea	F91
Porichthys notatus	Batrachoididae	Plainfin Midshpmn	245	Case Inlet, WA	F48
Porichthys notatus	Batrachoididae	Plainfin Midshpmn	154	Shilshole Beach, Seattle, WA	F49
Citharichthys sordidus	Bothidae	Pacific Sanddab	280	Case Inlet, WA	F75
Pampus sp.	Bramidae	Pomfret	290	Store Bought, Seattle, WA	F84
C. macrocheilus	Catostomidae	Large Scale Sucker	380	Willamette River, OR, Mile 65	F86
Micropterus salmoides	Centrarchidae	Largemouth Bass	-	-	F126
Hydrolagus colliei	Chimaeridae	Ratfish	438	Puget Sound, WA	F8
Hydrolagus colliei	Chimaeridae	Ratfish	575	Puget Sound, WA	F9
Oreochromis sp.	Cichlidae	Tilapia	270	Store Bought, Seattle, WA	F83
Alosa pseudoharengus	Clupeidae	Alewife	-	Long Lodge, Montsweag Bay, ME	F106
Clupea harangus p.	Clupeidae	Pacific Herring	320	Old Harbor, Kodiak Island, AK	F106
Sardinops sagax c.	Clupeidae	Pacific Sardine	197	Oregon Coast	F99
Sardinops sagax c.	Clupeidae	Pacific Sardine	242	Oregon Coast	F100
Sardinops sagax c.	Clupeidae	Pacific Sardine	262	Oregon Coast	F101
Sardinops sagax c.	Clupeidae	Pacific Sardine	276	Oregon Coast	F102
Chitonotus pugetensis	Cottidae	Roughback Sculpin	143	Case Inlet, WA	F24
Dasycottus setiger	Cottidae	Spinyhead Sculpin	215	Puget Sound, WA	F25
Enophrys bison	Cottidae	Buffalo Sculpin	212	Case Inlet, WA	F26
H. hemilepidotus	Cottidae	Red Irish Lord	310	North Puget Sound, WA	F27
H. hemilepidotus	Cottidae	Red Irish Lord	289	North Puget Sound, WA	F28
H. hemilepidotus	Cottidae	Red Irish Lord	450	Anton Larsen Bay, Kodiak Is, AK	F29
Hemilepidotus jordani	Cottidae	Yellow Irish Lord	-	-	F119
Leptocottus armatus	Cottidae	Pac. Staghorn Sculp	260	Elliot Bay, WA	F30
Leptocottus armatus	Cottidae	Pac. Staghorn Sculp	-	Edmonds, WA - Puget Sound	F31
M. polyacanthocephls	Cottidae	Great Sculpin	400	North Puget Sound, WA	F32
S. marmoratus	Cottidae	Cabezon	-	Neah Bay, WA	F92
Gila bicolor	Cyprinidae	Tui Chub	-	Oregon	F77
Rhinichthys osculus	Cyprinidae	Speckled Dace	-	-	F81
R. balteatus	Cyprinidae	Redside Shiner	-	-	F82
Cymatogaster aggregata	Embiotocidae	Shiner Surfperch	130	Shilshole Beach, Seattle, WA	F2
Cymatogaster aggregata	Embiotocidae	Shiner Surfperch	150	Case Inlet, WA	F33
Rhacochilus vacca	Embiotocidae	Pile Surfperch	250	Case Inlet, WA	F34

Engraulis mordax	Engraulidae	Northern Anchovy	117	San Francisco Bay, CA	F94
Engraulis mordax	Engraulidae	Northern Anchovy	130	San Francisco Bay, CA	F95
Engraulis mordax	Engraulidae	Northern Anchovy	140	San Francisco Bay, CA	F96
Engraulis mordax	Engraulidae	Northern Anchovy	155	San Francisco Bay, CA	F97
Esox spp.	Esocidae	Pike	-	-	F124
Gadus macrocephalus	Gadidae	Pacific Cod	-	Old Harbor, Kodiak Island, AK	F35
Gadus macrocephalus	Gadidae	Pacific Cod	-	Old Harbor, Kodiak Island, AK	F36
Gadus macrocephalus	Gadidae	Pacific Cod	-	Kodiak, AK	F56
Gadus macrocephalus	Gadidae	Pacific Cod	-	Kodiak, AK	F57
Gadus macrocephalus	Gadidae	Pacific Cod	-	Kodiak, AK	F58
Merluccius productus	Gadidae	Pacific Hake	271	Puget Sound, WA	F37
Merluccius productus	Gadidae	Pacific Hake	265	Puget Sound, WA	F38
Microgadus proximus	Gadidae	Pacific Tomcod	175	Case Inlet, WA	F41
Microgadus proximus	Gadidae	Pacific Tomcod	155	Case Inlet, WA	F42
Microgadus proximus	Gadidae	Pacific Tomcod	134	Case Inlet, WA	F43
T. chalcogramma	Gadidae	Walleye Pollock	350	Puget Sound, WA	F39
T. chalcogramma	Gadidae	Walleye Pollock	410	Shilshole Beach, Seattle, WA	F40
T. chalcogramma	Gadidae	Walleye Pollock	380	-	F118
Gasterosteus aculeatus	Gasterosteidae	3-spine Stickleback	-	-	F80
Gasterosteus aculeatus	Gasterosteidae	3-spine Stickleback	55	Afognak River Est, Afognak I., AK	F98
H. lagocephalus	Hexigrammidae	Rock Greenling	-	McDonald Lag., Sitkalidak Is, AK	F1
H. stelleri	Hexigrammidae	Whitespotted Glng	275	North Puget Sound, WA	F44
Ophidon elongatus	Hexigrammidae	Lingcod	-	Neah Bay, WA	F45
Ophidon elongatus	Hexigrammidae	Lingcod	-	Neah Bay, WA	F46
Ophidon elongatus	Hexigrammidae	Lingcod	-	-	F121
Ophidon elongatus	Hexigrammidae	Lingcod	-	-	F122
Lamna ditropis	Lamnidae	Salmon Shark	-	Monashka Bay, Kodiak Is., AK	F123
Mallotus villosus	Osmeridae	Capelin	147	Newfoundland, Canada	F103
Mallotus villosus	Osmeridae	Capelin	166	Newfoundland, Canada	F104
Mallotus villosus	Osmeridae	Capelin	182	Newfoundland, Canada	F105
Thaleichthys pacificus	Osmeridae	Eulachon	-	Cathlamet, Columbia River, OR	F107
Thaleichthys pacificus	Osmeridae	Eulachon	-	Cathlamet, Columbia River, OR	F108
Thaleichthys pacificus	Osmeridae	Eulachon	-	Cathlamet, Columbia River, OR	F109
Morone saxitilis	Percichthyidae	Striped Bass	370	Store Bought, Seattle, WA	F79
H. elassodon	Pleuronectidae	Flathead Sole	325	Elliot Bay, WA	F60
H. elassodon	Pleuronectidae	Flathead Sole	260	Elliot Bay, WA	F61
H. stenolepis	Pleuronectidae	Pacific Halibut	-	Neah Bay, WA	F62
H. stenolepis	Pleuronectidae	Pacific Halibut	sm	McDonald Lag., Sitkalidak Is, AK	F63
Lepidopsetta bilineata	Pleuronectidae	Rock Sole	248	North Puget Sound, WA	F64
Lepidopsetta bilineata	Pleuronectidae	Rock Sole	240	Case Inlet, WA	F65
Lepidopsetta bilineata	Pleuronectidae	Rock Sole	430	North Puget Sound, WA	F66
Lyopsetta exilis	Pleuronectidae	Slender Sole	202	Case Inlet, WA	F67
Microstomus pacificus	Pleuronectidae	Dover Sole	318	North Puget Sound, WA	F68
Microstomus pacificus	Pleuronectidae	Dover Sole	295	North Puget Sound, WA	F69
Parophrys vetulus	Pleuronectidae	English Sole	245	Case Inlet, WA	F70
Parophrys vetulus	Pleuronectidae	English Sole	310	North Puget Sound, WA	F71
Platichthys stellatus	Pleuronectidae	Starry Flounder	410	-	F72
Platichthys stellatus	Pleuronectidae	Starry Flounder	-	Kalsin Bay, Kodiak Is., AK	F114

P. proboscidium	Pleuronectidae	Long-Faced Dab	150	Marmot Bay, Afognak Island, AK	F85
P. coenosus	Pleuronectidae	C-O Sole	275	Case Inlet, WA	F73
P. melanostictus	Pleuronectidae	Sand Sole	292	Shilshole Beach, Seattle, WA	F74
R. hippoglossoides	Pleuronectidae	Greenland Turbot	-	-	F117
Reinhardtius stomias	Pleuronectidae	Arrowtooth Flnder	-	-	F115
Reinhardtius stomias	Pleuronectidae	Arrowtooth Flnder	-	-	F116
Bathyraja interrupta	Rajidae	Sandpaper Skate	460	Puget Sound, WA	F7
Raja binoculata	Rajidae	Big Skate	465	Puget Sound, WA	F5
Raja binoculata	Rajidae	Big Skate	370	Puget Sound, WA	F13
Raja rhina	Rajidae	Longnose Skate	560	Puget Sound, WA	F6
O. gorbuscha	Salmonidae	Pink Salmon	-	Karluk Lagoon, Kodiak Island, AK	F15
Oncorhynchus keta	Salmonidae	Chum Salmon	-	Red Cloud River, Kodiak Is., AK	F113
Oncorhynchus kisutch	Salmonidae	Coho Salmon	-	Karluk Lagoon, Kodiak Island, AK	F16
Oncorhynchus kisutch	Salmonidae	Coho Salmon	-	Kalsin Bay, Kodiak Is., AK	F111
Oncorhynchus kisutch	Salmonidae	Coho Salmon	-	Kalsin Bay, Kodiak Is., AK	F112
Oncorhynchus mykiss	Salmonidae	Rainbow Trout	550	Store Bought, Seattle, WA	F19
Oncorhynchus mykiss	Salmonidae	Rainbow Trout	-	Store Bought, Seattle, WA	F20
Oncorhynchus mykiss	Salmonidae	Rainbow Trout	-	Karluk Lagoon, Kodiak Island, AK	F21
Oncorhynchus mykiss	Salmonidae	Steelhead Trout	-	-	F22
Oncorhynchus nerka	Salmonidae	Sockeye Salmon	-	Karluk Lagoon, Kodiak Island, AK	F17
Oncorhynchus spp.	Salmonidae	Pacific Salmon	-	Store Bought, Seattle, WA	F11
Oncorhynchus spp.	Salmonidae	Pacific Salmon	-	-	F14
O. tsawytscha	Salmonidae	Chinook Salmon	-	Store Bought, Seattle, WA	F18
Salvelinus malma	Salmonidae	Dolly Varden	310	Marmot Bay, Afognak Island, AK	F23
Drum Family	Sciaenidae	Drum	-	-	F125
Sebastes babcocki	Scorpaenidae	Redbanded R-fish	600	Store Bought, Seattle, WA	F87
Sebastes brevispinis	Scorpaenidae	Silvergray Rockfish	-	Chiniak Bay, Kodiak Island, AK	F54
Sebastes melanops	Scorpaenidae	Black Rockfish	lg	Marmot Bay, Afognak Island, AK	F50
Sebastes melanops	Scorpaenidae	Black Rockfish	sm	Marmot Bay, Afognak Island, AK	F51
Sebastes pinniger	Scorpaenidae	Canary Rockfish	500	Store Bought, Seattle, WA	F93
Sebastes sp.	Scorpaenidae	Rockfish	-	-	F55
Sebastolobus altivelis	Scorpaenidae	L-spine Thornyhead	385	UW Fisheries Lab, Seattle, WA	F52
Sebastolobus altivelis	Scorpaenidae	L-spine Thornyhead	300	UW Fisheries Lab, Seattle, WA	F53
Squalus acanthias	Squalidae	Spiny Dogfish	540	Puget Sound, WA	F3
Squalus acanthias	Squalidae	Spiny Dogfish	520	Puget Sound, WA	F4
Squalus acanthias	Squalidae	Spiny Dogfish	595	Puget Sound, WA	F12
T. myops	Synodontidae	Snake Fish	380	Store Bought, Seattle, WA	F78
Lycodes sp.	Zoarcidae	Eelpout	170	Case Inlet, WA	F76

Mammals

Taxon	Common Name	Sex	Age	Source	Cat. #
Scapanus orarius	Coast Mole	M	Adult	Pers. Coll.	REK M5
Canis familiaris	Domestic Dog	M	Adult	Burke Museum	12542
Canis latrans	Coyote	F	Young Adult	Burke Museum	32821
Canis lupus	Gray Wolf	?	Adult	Burke Museum	19787
Vulpes vulpes	Red Fox	F	Adult	Pers. Coll.	REK M1
Enhydra lutris	Sea Otter	F	Adult	Burke Museum	38693
Enhydra lutris	Sea Otter	M	Juvenile	Burke Museum	38709
Enhydra lutris	Sea Otter	?	Infant	Burke Museum	-
Lontra canadensis	River Otter	M	Adult	K. Bovy	-
Lontra canadensis	River Otter	M	Young Adult	Alutiiq Museum	AM
Mustela erminea	Ermine	M	Adult	Alutiiq Museum	AM
Taxidea taxus	American Badger	M	Adult	Burke Museum	32614
Callorhinus ursinus	Northern Fur Seal	M	Adult	Burke Museum	12552
Callorhinus ursinus	Northern Fur Seal	M/F	Infant-Adult	NOAA NMML	Numerous
Eumetopias jubatus	Steller Sea Lion	M/F	Infant-Adult	NOAA NMML	Numerous
Phoca hispida	Ringed Seal	M	Juvenile	Burke Museum	34223
Phoca largha	Spotted Seal	M	Adult	Burke Museum	34221
Phoca vitulina	Harbor Seal	M	Young Adult	Burke Museum	51215
Phoca vitulina	Harbor Seal	M	Adult	Burke Museum	32053
Phoca vitulina	Harbor Seal	F	Infant	Burke Museum	39487
Ursus americanus	Black Bear	F	Adult	Burke Museum	12950
Ursus arctos	Brown Bear	M	Adult	Burke Museum	39422
Ursus arctos	Brown Bear	M	Young Adult	UW Anthro	-
Lagenorhynchus obliquidens	Pac. Whitesided Dolphin	M	Adult	Burke Museum	35358
Lagenorhynchus obliquidens	Pac. Whitesided Dolphin	M	Young Adult	Burke Museum	34528
Phocoena phocoena	Harbor Porpoise	F	Adult	Burke Museum	42014
Phocoena phocoena	Harbor Porpoise	M	Infant	Burke Museum	39488
Phocoenoides dalli	Dall's Porpoise	M	Adult	Burke Museum	12007
Cervus elaphus	Elk	F	Infant	Burke Museum	33288
Odocoileus hemionus	Mule Deer	M	Young Adult	Burke Museum	32087
Odocoileus hemionus	Mule Deer	M	Adult	Burke Museum	33346
Odocoileus hemionus	Mule Deer	M	Young Adult	Pers. Coll.	REK M4
Ovis canadensis	Bighorn Sheep	F	Adult	Burke Museum	39469
Marmota caligata	Hoary Marmot	M	Adult	Burke Museum	35529
Marmota flaviventris	Yellow-Bellied Marmot	F	Adult	Burke Museum	32070
Sciurus carolinensis	Eastern Gray Squirrel	F	Adult	Pers. Coll.	REK M2
Castor Canadensis	American Beaver	M	Adult	Burke Museum	34594
Microtus oeconomus	Tundra Vole	?	Adult	Pers. Coll.	REK M3
Erethizon dorsatum	N. American Porcupine	F	Adult	Burke Museum	32146

Appendix B: Collection Agreements

December 1, 2001

Robert Kopperl
Department of Anthropology
University of Washington
Box 353100
Seattle, WA 98195-3100

Dear Mr. Kopperl,

As per your request, I give you permission to obtain datable organic material, such as charcoal, from the Rice Ridge (KOD-363) assemblage stored at the Alutiiq Museum and Archaeological Repository in Kodiak, Alaska. You may submit this material to a radiocarbon dating laboratory for destructive analysis in order to give greater chronological control to the site, of which I am the property owner. Please send me the results of this analysis after you receive them.

Sincerely,
Dale L. Rice
Marie Rice
Dale Rice and Marie Rice
10746 Bells Flats Rd.
Kodiak, AK 99615
(907) 487-2589

Permission to Sample and Submit Charcoal from Rice Ridge to Beta Analytic, Inc. for Radiocarbon Dating

DESCRIPTION & INVENTORY OF OBJECTS/COLLECTIONS (attach additional sheets if necessary)

Archaeological faunal materials recovered from the Rice Ridge site (KOD-363)

I agree to allow the object(s) described to be transfer to the Burke Museum at the University of Washington, following the conditions outlined above, and studied by anthropology student Robert Kopperl.

Collection Owner Marie Rice Dale Rice Date May 30, 2000

Anthropology Dept. Miriam Kahn Date 5/18/00
Miriam Kahn, Ph.D., Anthropology Dept., Chair

Researcher Robert Kopperl Date 5/17/00
Robert Kopperl

Permission to Analyze Rice Ridge Faunal Remains

DESCRIPTION & INVENTORY OF OBJECTS/COLLECTIONS (attach additional sheets if necessary)

Archaeological faunal materials recovered from excavations of the Crag Point site (KOD-241).

I agree to allow the object(s) described to be transfer to the Burke Museum at the University of Washington, following the conditions outlined above, and studied by anthropology student Robert Kopperl.

Collection Owner [illegible] Angeli Date 6-30-00

Anthropology Dept. Miriam Kahn Date 5-31-00
Miriam Kahn, Ph.D., Anthropology Dept., Chair

Researcher Robert Kopperl Date 5-31-00
Robert Kopperl

Permission to Analyze Crag Point Faunal Remains

DESCRIPTION & INVENTORY OF OBJECTS/COLLECTIONS (attach additional sheets if necessary)

Archaeological faunal materials recovered from the Uyak Site (AM - 3)

I agree to allow the object(s) described to be transfer to the Burke Museum at the University of Washington, following the conditions outlined above, and studied by anthropology student Robert Kopperl.

Mayor

Collection Owner Allen Panamaroff Sr **Date** 06/02/00

Anthropology Dept. Miriam Kahn **Date** 5/18/00

Miriam Kahn, Ph.D., Anthropology Dept., Chair

Researcher Robert Kopperl **Date** 5/17/00

Robert Kopperl

Permission to Analyze Uyak Faunal Remains

Vita

Robert Elliott Kopperl was born in Grand Rapids, Michigan in 1973. He received a Bachelor of Arts in Anthropology and Philosophy from Grand Valley State University in Allendale, Michigan, in 1995. Later that year, he moved to Seattle, Washington. Here he attended the University of Washington and received a Master of Arts in Anthropology in 1998 and a Doctor of Philosophy in Anthropology in 2003. His research interests include north Pacific maritime adaptations, zooarchaeology, evolutionary ecology, and specifically the prehistory of south-central Alaska and coastal Washington and prehistoric use of fish and sea mammal resources. He has participated and supervised fieldwork in a variety of contexts including university field schools, museum public eduction projects, private contract projects, and United States Forest Service public outreach programs.