Resource Intensification and Resource Depression in the Pacific Northwest of North America: A Zooarchaeological Review

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In the Pacific Northwest of North America, researchers routinely suggest changes in human use of animals explain hunter-gatherer organizational changes and development of cultural complexity. For example, most models developed to explain developing cultural complexity invoke salmon in some fashion. Yet until recently, fish remains were not carefully studied and more generally, zooarchaeological evidence has not been systematically used to test models of culture change. This study reviews the 10,000-year-old faunal record in the Pacific Northwest to test predictions drawn from models of resource intensification, resource depression and hunter-gatherer organizational strategies. The records from two subareas, the South-Central Northwest Coast (Puget Sound/Gulf of Georgia) and the Northern Columbia Plateau, are examined in detail, representing 63 archaeological sites. While minor changes in animal use are evident, the overall record is characterized by stability rather than change.

INTRODUCTION

Faunal data, shown to have tremendous power world-wide for testing models of forager evolution, have been underutilized in the Pacific Northwest of North America. In this paper, we use zooarchaeological

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records that have accumulated in the last 25 years to test assertions about changing animal use over time in a region so well known for its complex foragers.

In the Pacific Northwest, anthropologists and prehistorians routinely have suggested causal linkages between the abundance of animal resources, human subsistence strategies, and the development of complex hunter-gatherer social organizations. Salmon in particular has been emphasized. As Matson notes, "... the harvesting and storage of salmon have long been recognized as the economic underpinning of the NWC [Northwest Coast]" (1992, p. 367). Until dramatic declines in salmon abundance in the twentieth century associated with overfishing and habitat destruction, millions of fish migrated up coastal rivers and streams from California to the Bering Sea as part of spawning cycles. Anthropologists describing Indian groups in the coastal and interior areas of the Pacific Northwest in the nineteenth and early twentieth century suggested that salmon was the main food staple and further, that the semi-sedentary settlement pattern, which included aggregation into villages during the winter months, was made possible by the catching, drying and storing of salmon. Cressman *et al.*'s (1960) recovery of salmon bones in a 10,000-year old component on the Columbia River established a long history of salmon use and archaeologists have since focused on determining the antiquity of intensive exploitation.

The search for the origins of the ethnographic pattern on the Northwest Coast and Columbia-Fraser plateaux generally begins with the Archaic period because the Paleo-Indian occupation is poorly represented. Many researchers suggest an early period of broad spectrum foraging (11,000 to 5000–4000 BP), followed by development of logistically organized collecting strategies with intensified exploitation of some resources, particularly salmon, triggered by various combinations of sea level stabilization, population growth, and the development of storage and mass harvesting technology (Ames, 1994; Ames and Marshall, 1980; Burley, 1979; Chatters, 1995; Fladmark, 1975; Galm, 1985; Hayden, 1995; Matson, 1992, Matson and Coupland, 1995; Moss *et al.*, 1990; Prentiss and Chatters, 2003; Schalk, 1981; Schalk and Cleveland, 1983; Thoms, 1989). Explanations for the development of sociopolitical complexity, including ranking, emphasize the inherent abundance of resources as well as technologically and socially negotiated means of increasing productivity. Increases in foraging productivity, termed by most regional scholars "intensification," are suggested to have occurred through various means: economies of scale through technology from mass capture and processing, resource extension through storage, resolving scheduling conflicts through logistical organization of labor, or expanding the number of habitats from which fish or other resources could be taken (Kew, 1992; Whitlam, 1983). Social ranking is argued to result

from social control of resource access (for example, ownership of weirs or tidelands) and control of storable commodities exchanged through feasting and trade.

It is not our goal to evaluate the sufficiency of models that explain social complexity and its relationship to animal use, however, we argue that the central assumption of most models, that certain resources were more intensively used over time, has not been adequately demonstrated. To test models for intensification deductively at a regional scale requires multiple lines of evidence. Studies of capture technology, processing, and storage technology as well as the animal remains themselves are all relevant but each has inherent limitations. Ames and Maschner (1999) use the presence and configuration of house structures and interior features from multiple sites across the Pacific Northwest as a marker for mass salmon production, based on the reasoning that most food processing and storage would take place within such structures. This is a reasonable argument, yet to use houses alone as evidence of heavy salmon use risks circularity. For example, in discussing the houses of the Paul Mason phase on the Skeena River of British Columbia, Matson (1992, p. 417) notes "It is difficult to see how 'permanent' house structures so far up the Skeena River could exist unless salmon was stored in quantity." Salmon bones were recovered from the site, but their frequency is not used to demonstrate extent of salmon use. Dozens of wood-stake intertidal weirs associated with streams supporting large salmon runs in southeast Alaska dating to 3500 BP and later provide direct evidence for mass fish capture and in turn, logistical organization of labor for procurement and processing for storage (Moss *et al.*, 1990). The ages of known weirs may not accurately represent the antiquity of the practice of mass fish harvesting across the region; due to regional tectonics and the dynamic evolution of coastal environments, the recognition and dating of tidal fish weirs is highly dependent on geologic history (Moss and Erlandson, 1998a). Additionally, this evidence does not show which taxa were being captured. The occurrence and abundance of certain tool types (quartz microliths, slate knives) have been used as markers for certain procurement technologies based on ethnographic descriptions of fishing gear, but they may not have been used the same way in the past. For example, slate points and quartz microblades from the Sequim site yielded artiodactyl blood residues (Edmunds, 1999) contrary to the traditional view that slate points were part of the marine hunting repertoire (Matson, 1992) and suggestion elsewhere that quartz-vein microliths were used for fish (Flenniken, 1980).

We assert that zooarchaeological data should play a larger role in evaluating these models. Prior to the mid-1980s fish assemblages were not routinely analyzed; now it is time to use the fish and other zooarchaeological

data to test models of subsistence change. These records can be used to evaluate central assumptions such as the primacy of salmon and whether its role changed over time. Monks (1987) and Moss (1993) have argued that archaeologists suffer from *salmonopea*, in other words, that salmon has been given too large a role relative to other important resources without justification. Ethnohistoric data, too, have been reevaluated: Hunn (1990) suggests the percentage estimates of salmon in the diet made by earlier anthropologists for the Columbia Plateau are inflated. Cannon (2001) suggests that salmon was consistently important through time, citing the early abundance of salmon bones at Namu, on the British Columbia coast (6000 BP), and arguing that efficient capture and storage methods were not technologically challenging and could have developed very early.

Zooarchaeological evidence provides an independent approach to measuring changing subsistence strategies, separate from feature records. It has been common for archaeologists to use contextual evidence of sedentism and complexity and then assume it rests on increased production without testing predicted expectations about faunal remains. Systematic comparisons of features across sites is difficult due to noncomparable recording and reporting, possibly contributing to the tendency noted by Cannon (2001) for researchers to rely on evidence from a small number of individual sites and assume they are representative of broader regional trends. Faunal data can circumvent this because taxonomically defined categories provide more analytic comparability across multiple assemblages, notwithstanding potential differences in recovery, taphonomy, and reporting (Driver, 1991, 1993).

An important issue related to subsistence change deserves further examination using zooarchaeological data: the impact of human predation on prey populations. A growing body of evidence from various parts of the world shows that human foragers greatly affected the animal populations they were exploiting (Grayson, 2001). Researchers in the Pacific Northwest have tended to ignore this and assume that resource yields could be indefinitely increased through human effort and technology. Matson (1992) expressed the view that resources such as salmon were impervious to exploitation pressure, despite Hewes' early argument for possible resource depression. Hewes (1947, 1973) explained exceptionally large catches in the Euro-American fishery on the Columbia River in the 1860s by suggesting salmon were in a "resting period" (1973, p. 149). He argued that salmon populations were rebounding in response to reduced fishing pressure due to decimation of the Native American population in the early 1800s. In the last 20 years, resource depression has been suggested in other areas of the American west (e.g., Bayham, 1979; Broughton, 1997; M. D. Cannon, 2000; Janetski, 1997) while in the Pacific Northwest, results are mixed. Etnier

(2002) and Lyman (2003a) conclude that human exploitation of northern fur seal and Steller sea lion was sustainable. On the other hand, Croes and Hackenberger (1988) suggest overexploitation of invertebrates, and Butler (2000) sees possible declines in multiple vertebrate taxa, including salmon and sturgeon. Martin and Szuter (1999) suggest that low ungulate abundance in areas of the Plateau in the early nineteenth century was due to Native American hunting, although Lyman and Wolverton (2002) counter that the patterns can be explained by environmental limitations.

In this paper we examine the 10,000-year-old faunal record in selected regions of the Pacific Northwest to test predictions from models postulating changing animal-based subsistence over time, reviewing relative exploitation of different taxa, indications of impact on prey populations, and where possible, correlations with described organizational strategies. Did salmon really play such a pivotal role? Was salmon, or any other resource, used more intensively over time and does overall animal use vary with development of logistical organization? Could animal resources have been used intensively for thousands of years without suffering from decline?

In the following section, we review the environmental variables that structure animal distribution and abundance, then outline the methods and materials used to test the models. The sufficiency of the models is then examined against the subsistence record for the late Pleistocene–early Holocene (11,000–7000 BP) and for two subregions, the South-Central Northwest Coast (Puget Sound/Gulf of Georgia) and the Northern Columbia Plateau, for the time period 7000 BP to European contact. Together, these records represent 63 archaeological sites, 220,000 vertebrate specimens and 130 kg of invertebrate remains. These two subregions were chosen in part because of our long involvement with the research. More importantly, these provide good test cases because a number of specific models for increased social complexity and subsistence change were directly informed by records from each area (Burley, 1979, 1980; Chatters, 1995; Croes and Hackenberger, 1988; Matson, 1992).

ENVIRONMENT, PALEOENVIRONMENT, AND ANIMAL ABUNDANCE

The Pacific Northwest contains two main geographic and climatic provinces, the coastal zone and the arid interior, separated by ranges of north-to-south trending mountains (Chatters, 1998; Suttles, 1990) (Fig. 1). The coastal zone extends from northern California (40°N) to Yakutat, Alaska (60°N) and is characterized by a narrow continental shelf and narrow coastal plains. From northern California to the outer Washington coast,
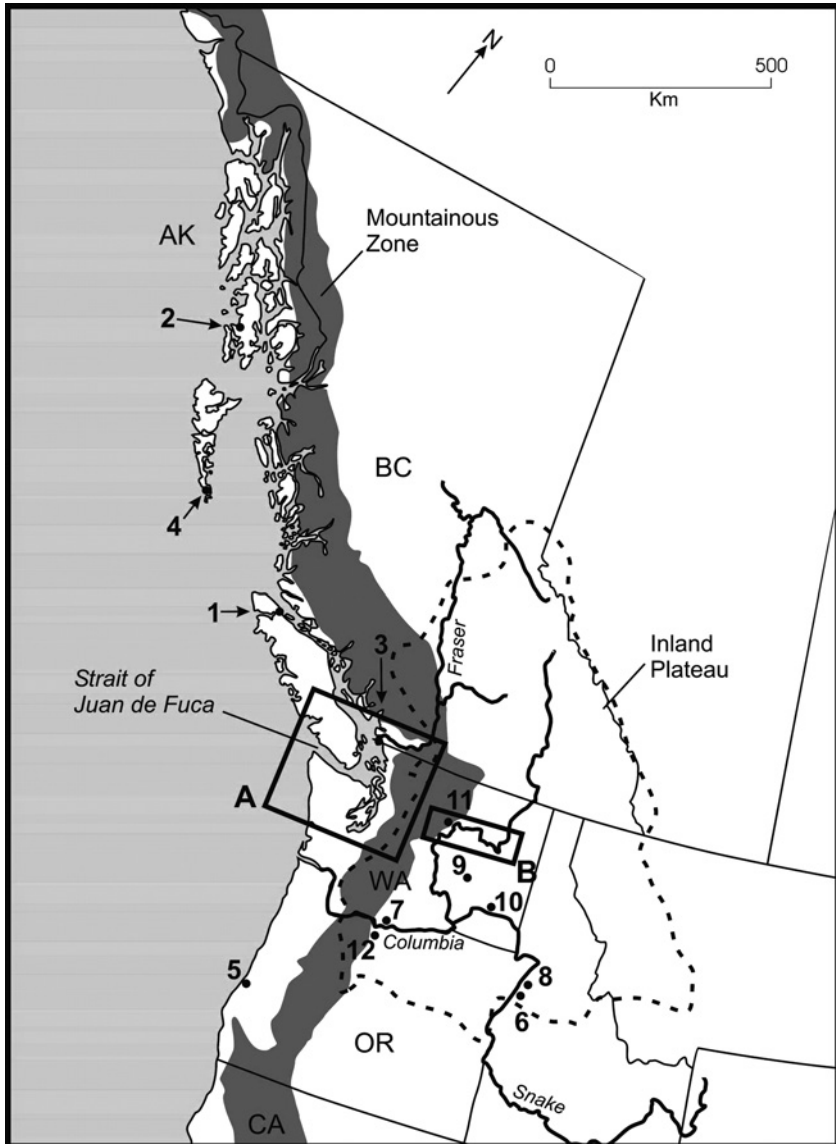
Fig. 1. Pacific Northwest, showing early Holocene sites: *Northwest Coast*: (1) Bear Cove EeSu-8, (2) Chuck Lake Crg-237, (3) Glenrose Cannery DgRr6, (4) Kilgii Gwaay (1325T), (5) Tahkenitch 35DO130; *Plateau*: (6) Bernard Creek Rockshelter 10IH483, (7) Bob's Point 45KL219, (8) Kirkwood Bar 10IH699, (9) Lind Coulee 45GR97, (10) Marmes 45FR50 (includes Rockshelter and Floodplain localities), (11) Plew 45DO387, (12) The Dalles Roadcut 35WS8; and South-Central Northwest Coast (A) and Northern Columbia Plateau (B) subareas.

the coastline is relatively straight, interrupted by a few estuaries. The outer coast receives the full brunt of storms moving east off the Pacific. From the Strait of Juan de Fuca northward, the coastal margin becomes more convoluted and is characterized by relatively quiet, sheltered bays and offshore islands. For the coastal zone in general, upwelling of nutrient-rich waters supports complex food webs and overall high abundance of marine life. The dominant terrestrial vegetation of the coastal zone is coniferous forest. Rivers draining the coastal zone are relatively short (50–100 km), heading in adjacent mountain ranges. The Columbia and Fraser rivers are important exceptions; they cut through coastal mountain ranges, and have headwaters in the Rocky Mountains, draining vast areas of the interior. Climate within the coastal zone is maritime with relatively cool, dry summers and wet, mild winters. As winter storms move east off the ocean and onto land, the air masses release much of their moisture on the west side of mountain ranges.

The arid interior is drained by the Columbia and Fraser River systems; the region encompasses a much narrower latitudinal range than the coast, between about 45°N and 53°N. The interior includes relatively flat, low-lying plains about 100 m asl, and upland plateaux and mountain ranges as high as 3000 m (Chatters, 1998). The climate is continental, with hot summers and cold winters. Terrestrial productivity is determined mainly by available moisture. Precipitation varies with elevation. Lowest areas receive as little as 16 cm of yearly rainfall and support shrub-steppe type vegetation; better watered high elevations support coniferous forests. Most surface water is part of the Columbia and Fraser river systems, which depend largely on winter snow pack. The incised river systems do not have extensive riparian zones, but supported huge spawning salmon populations.

Mountainous areas and foothills of the Cascades and Coast Range are important animal habitat as well, however the archaeological record is less well known. Work since 1990 reveals a record of systematic use by people from both sides of the mountains (Burtchard, 1998; Lewarch and Benson, 1991; Lyman, 1995a; Mack and McClure, 2002; Mierendorf *et al.*, 1998; Reimer, 2003).

The abundance of animal resources in the region has been used to explain the degree of complexity found in Pacific Northwest cultures, especially for coastal groups (Drucker, 1955; Fagan, 2000). Indeed, hundreds of animal species were important to Native peoples, providing food and raw materials for tools, clothing, and other needs. However, since the late 1970s, scholars have examined the notion of "abundance" more critically and highlighted the clumped, or patchy distribution of animal populations (O'Leary, 1992; Schalk, 1977; Suttles, 1974).

Direct measurement of absolute prehistoric animal population levels is difficult, but the factors that structure relative abundance now and in the

past are beginning to be understood. Numerous species are abundant only during seasonal aggregations as part of reproduction cycles. While salmon are the best-known example of cyclic seasonal availability, most marine and freshwater fishes seasonally aggregate during spawning periods, often in shallow water and would have provided high caloric return at such times. Some animals are found only in discrete habitats (for example, shellfish exposed during low tide) or are best caught at certain locations. For example, salmon in rivers cluster in constricted locations such as waterfalls and rapids.

A general factor that structures animal abundance is latitude. Along the coast, terrestrial productivity, including animal biomass, declines south to north because decreasing temperature reduces growing season and increasing precipitation suppresses fires and forest turnover (Schalk, 1981). Declining terrestrial productivity helps explain why the duration of salmon migratory runs shorten with increasing latitude. A migratory "run" can occur over several months in the southern part of the Pacific Northwest or a few days in the north (O'Leary, 1992; Schalk, 1977). Productivity of marine environments is less affected by latitudinal gradients *per se*, but is affected by physiographic variation in shorelines. The reticulate coastline north of the Strait of Juan de Fuca creates extensive habitat for marine mammals, fishes and intertidal invertebrates; the straighter, more exposed coastal zone to the south is less productive (Schalk, 1981). Scholars have suggested that human reliance on terrestrial versus marine resources along the coastline correlates with this strong environmental patterning (Hildebrandt and Levulett, 1997; Schalk, 1981).

Over the last 10,000 years, animal abundance and distribution have varied in response to climate change, sea level change, and geomorphic processes. Multiple climate records for the interior Pacific Northwest suggest warmer, drier conditions between *ca.* 8000–4500 BP followed by neoglacial conditions (cooler, moister) (Chatters, 1998). Archaeofaunal abundances suggest mammal and salmon populations declined and then rebounded in response to these conditions (Chatters *et al.*, 1995; Chatters, 1995; Fryxell and Daugherty, 1963; Lyman, 1992; Sanger, 1967; Schalk, 1983). For the coastal zone, there has been limited study of how Holocene paleoclimate changes (Mann *et al.*, 1998; Moss *et al.*, in press; Whitlock, 1992) would affect animals important to human economies. An exception is Finney *et al.* (2000, 2002) who argue that salmon abundance has fluctuated markedly over the last 2000 years, mainly due to periodic shifts in ocean-atmosphere circulation and ecosystems dynamics.

Sea level changes, both regional and local, are a major type of environmental change in coastal areas. Fladmark (1975) argued that until sea levels stabilized after 6000 years ago, improving conditions in spawning

habitat, salmon productivity would have been low relative to historic times and would not have supported specialized subsistence (see also Cannon, 1991). Scholars also have called on sea level rise and stabilization resulting in increased sedimentation to explain the shift in shellfish representation from taxa requiring rock substrate (mussels, barnacles, whelk) to clams, which burrow in sand and silt, a pattern noted at Glenrose Cannery (Ham, 1976), Namu (Cannon, 1991), West Point (Larson, 1995), Crescent Beach (Matson, 1992), Hidden Falls (Erlandson, 1989), and Decatur Island (Ives, 2003).

Earthquake-related events have caused local sea level changes. Subsidence of up to 2 m, uplift up to 7 m, and tsunami effects up to 30 km inland have been documented for sections of the tectonically active Oregon and Washington coasts in the last 3000 years (Atwater, 1987; Atwater and Moore, 1992; Bucknam *et al.*, 1992; Darienzo *et al.*, 1994). Earthquake events can cause high mortality in human and nonhuman animal populations in the immediate zone of impact, and greatly modify coastal landscapes (Hutchinson and McMillan, 1997; Minor and Grant, 1996; Troost and Stein, 1995; Woodward *et al.*, 1990), but as Losey (2002) has shown, they do not necessarily reduce resource productivity for extended periods as animal populations can re-establish within a few years, or they enhance habitat for some animals while reducing it for others.

Dune building, spit formation, and sedimentation of bays affect animal abundance in coastal zones as well (Cannon, 1991; Connolly, 1995; Minor and Toepel, 1986). Sea level rise extensively altered the lower sections of rivers; lower gradients increased sedimentation, creating deltas and floodplains, and highly productive estuaries and riparian zones (Hutchings and Campbell, 2005; Tveskov and Erlandson, 2003). Changing river hydrology (sedimentation, waterfalls, landslides) affects upriver salmon migration, and in turn human use patterns (Chatters *et al.*, 1995; Hayden and Ryder, 1991, 2003; Kujit, 2001; Sanger, 1967). In addition to affecting animal populations in the past, all of the above geomorphic processes affect archaeological site preservation and visibility and hence our ability to track long-term changes in human subsistence patterns (A. Cannon, 2000; Connolly, 1995; Erlandson *et al.*, 2000; Fedje and Josenhans, 2000; Lyman, 1991; Minor and Grant, 1996; Stein, 1992; Tveskov and Erlandson, 2003).

USING FAUNAL DATA TO MEASURE CHANGE IN SUBSISTENCE SYSTEMS

In using faunal remains to examine intensification, the possibility of human-caused resource depression, and changing organizational strategies,

we need to acknowledge methodological challenges and develop explicit bridging arguments that link faunal measures with theoretical concepts. Variations in methods of recovery, identification, and quantification as well as differences in preservation conditions, site seasonality or assemblage duration affect intersite comparisons. For our study, we selected assemblages with these concerns in mind. We also must define intensification, resource depression, and organizational strategies, collector versus forager, and how they will be measured using faunal data.

The term *intensification* has been variously used in the anthropological literature, with different theoretical implications (Ames, in press). In the Pacific Northwest, most scholars have used intensification to mean *increasing productivity* (yield per unit area) and suggested it was achieved through cultural mechanisms (technology, labor organization) that *increased foraging efficiency* (yield per unit effort). In contrast, others such as Cohen (1981; drawing on Boserup, 1965) for the North Pacific in general and Broughton in California (1994, 1997, 1999) acknowledge the increasing productivity meaning of the term, but take an alternative view on how it was achieved, suggesting that intensification occurred through a process of *declining foraging efficiency*, wherein the total productivity of a unit of land is increased but individuals must work harder (spend more energy, per unit time) in the process. This directly contradictory perspective is consistent with archaeological applications of optimal foraging models (e.g., Broughton, 1994; Janetski, 1997; Nagaoka, 2002). According to the prey choice model, resources are ranked according to costs/benefits; predators will take high ranked resources (those that maximize return rate) until their numbers decline due to exploitation pressure. Predators must then shift to lower-ranked resources, which by definition take more energy to capture/process, thus lowering foraging efficiency. An absolute decline in prey population abundance from harvesting pressure is termed *resource depression*.

This is more than a semantic confusion, it is also a theoretical schism. On one side is the assumption that increased productivity can be achieved by increased efficiency; on the other is the belief that efficiency declines with increasing productivity. It is difficult to resolve this contradiction, avoid confusion with the recent foraging applications, and yet still be consistent with the Pacific Northwest literature. Direct measurement of either productivity or efficiency, which are theoretically clear and distinct, would be ideal but would require extensive chronological control and many assumptions.

It is more expedient to focus on a clear implication of most regional models, which is that intensification involves a narrowing of the subsistence focus, by putting more energy into the exploitation of a few resources that yielded storable surpluses (for contrasting views, see Kew, 1992 and Whitlam, 1983). For example, Matson states "Clearly an important part of

the basic question of the origins of NWC complexity is the development of the salmon-based economy" (1992, p. 367). Ames notes, "Research on intensification on the coast emphasizes the timing of increases in salmon production and the development of a storage-based economy" (1994, p. 216). The implication is that over time more effort is put into salmon production relative to other resources. This is apparent also in interpretations that emphasize the increasing number of features linked to storage or capture as indicative of "intensification." This narrowing of the resource base has been called specialization, or a focal adaptation in other areas (Cleland, 1976), although the term has not seen much use in the Pacific Northwest.

Therefore, in this study we define intensification as increasing specialized resource use and resource depression as a decline in prey abundance due to human exploitation or other factors.

Resource depression studies draw on the prey choice model from foraging theory (e.g., Stephens and Krebs, 1986) to derive expectations about resource selection and subsistence change resulting from increased foraging pressure (e.g., Broughton, 1999; M. D. Cannon, 2000b; Kopperl, 2003; Nagaoka, 2002). According to the model, a predator's most efficient strategy is to take the highest ranked prey when encountered and shift to lower ranked resources only when the density of high ranked prey is reduced. If the predator population increases or becomes less mobile, resource depression of high ranked prey should occur. A variety of ethnographic and zoologic data sets suggest that body size is a good proxy measure for rank: generally the larger the animal, the higher the return rate. In testing the model, faunal frequencies are tallied as a ratio of large to small-bodied + large-bodied prey; the decline in the proportion of large prey would be taken as evidence for resource depression, in other words, the decline in absolute abundance in prey population.

The prey choice model relies on the fine-grained search assumption, which requires that predators seek all prey types simultaneously and that prey are randomly encountered in a relatively homogeneous environment. To best meet requirements of this assumption, Broughton (1999; see also Smith, 1991) recommends distinguishing prey types that occupy different habitats and that would have been captured using different technologies, as these can be estimated. For this study, we examine resource use in two main patches, the terrestrial patch and the aquatic patch, and rank prey types within each patch according to the body size criterion.

A variety of other factors need to be considered, however, to demonstrate that a decline in proportion of large-bodied prey results from resource depression. Environmental change can reduce prey abundance independent of human predation (e.g., Byers and Broughton, 2004; Wolverton, 2005). Another potential problem with the model as it has been

used is the assumption that small-bodied prey supply lower return rates than larger prey (Madsen and Schmitt, 1998; Ugan, 2005). If small-bodied prey were taken en masse using nets, rather than individually, the overall return rate for the aggregate could be higher than individually caught, larger prey types. Thus a relative increase in small-bodied prey would not result from large fish becoming scarce (due to foraging pressure) but would occur because aggregate small fish capture provided higher energetic returns. We address ways environmental change or procurement technology could introduce interpretive problems in particular contexts below.

Besides these factors, a declining ratio of large prey could reflect an absolute increase in the frequency of small-bodied prey, rather than a decline in the large-bodied prey, given the closed array method of calculation. Finally, they could also reflect a larger human population, and thus a *per capita* decline in density of the large prey, but not an absolute decline (Broughton, 1994). These issues cannot be resolved with faunal frequency data alone; they highlight the need to use additional lines of information, such as changes in prey demographic structure (decline in body size and age) to support a claim for resource depression (Broughton, 1994).

We use two kinds of measures to track faunal changes, a diversity index and several abundance indices (AIs). Shannon's evenness index (H), $H = -\Sigma_{i=1}^{k} p_i \ln p_i$, was calculated for assemblages to measure resource specialization, or intensification as we are using the term. Here, k is the number of categories and p_i is the proportion of the observations found in category i (Zar, 1974). A high evenness value indicates that all taxa were used in relatively equal proportions. A low value indicates that some taxa were used in relatively higher proportions than others, but it is not sensitive to which taxa increase. We emphasize that the evenness index is used to estimate degree of specialization as it exists along a continuum and not as a dichotomous variable (specialized vs. generalized).

Abundance indices (AIs) were constructed to study change in animal use by measuring proportion of one taxon to another, or to groups of taxa. For resource depression questions, AIs take the form "frequency of large-bodied taxa/frequency of large bodied + small bodied taxa," based on the logic that body size correlates well with rank. The resulting index ranges from 0 to 1 with higher values indicating greater proportion of high ranked prey in the assemblage. We constructed similar indices to measure whether certain taxa became increasingly used over time, not specifically based on body size.

We also use the faunal record to examine organizational change in hunter-gatherer land-use strategies (Binford, 1980). As noted above, a common view is that early people in the region were highly mobile broad spectrum foragers; the entire social group moved from place to place, procuring

resources as they became seasonally available. Eventually, this land-use strategy gave way to a collector-based system, which involved reduced mobility focused around a residential base; from there, logistical task groups went out and selectively targeted specific resources that were processed and brought back for storage. Most studies have used contextual information such as generalized versus specialized tool kits or the presence of formal house construction to examine organizational changes. For the Plateau records where we have some control over site functional context, we develop more specific expectations about the faunal remains themselves to track organizational change (see also Chatters, 1995). Expectations cannot be expressed as absolute values but rather on relative comparisons across functional site types (for example, permanent residence versus hunting camp), and over time.

DATA SELECTION

In presenting Pacific Northwest faunal records, we first summarize records from throughout the region dating to the Late Pleistocene-Early Holocene time period. We review all assemblages because of the small number (13 sites), and because similarity in tool forms across the region suggests a consistent adaptation. For the period after 7000 BP, the scale of land use adaptations is smaller and more published data exist than we can consider in detail. Therefore we examine trends in two subregions, the South-Central Northwest Coast and the Northern Columbia Plateau, located at roughly the same latitude (Fig. 1).

We focus on assemblages that have been systematically studied and include fine screen samples (1/8 in. [3.2 mm] or smaller), thus most assemblages are from sites excavated since the early 1980s. We made exceptions regarding field recovery for several early Holocene sites (given the scarcity of sites dating to this period) and three later Holocene sites on or near the outer coast (the Hoko River sites and Ozette) because they figure prominently in regional overviews. Vertebrate data were tabulated mainly using number of identified specimens (NISP, Grayson, 1984) and invertebrates using weight (kg), as these were the most commonly published measures.

We included faunal records only if at least family level identifications were provided and our data analyses treat taxa at the family level as well. Using family level identifications imposes certain limitations on the comparisons, particularly in testing foraging models, which require distinguishing prey by body size. Some families such as flatfish (Pleuronectidae) include species of widely varying sizes; halibut can reach lengths

over 2.5 m while some flatfish species are one-tenth that size. However, summarizing the records at the family level provided a consistent way to compare project faunal records, given that most reports list taxa at variable levels of identification (family, genus, species). As well, Driver (1991), Gobalet (2001), and Lyman (2002) have recently pointed out various factors such as level of experience, depth of reference collections and assumptions concerning available taxa that affect faunal identifications. We suggest that treating animal taxa at the family level increases the comparability.

Site assemblages were broken down into the finest possible time units or components allowed by published data. Ages used are the midpoints of the cultural phases assigned in the sources, or when radiocarbon dates were reported, the mean of the dates (uncalibrated). Remains of small, burrowing rodents and moles probably are intrusive and were excluded. We only calculated AIs or evenness values when the number of specimens included in the comparison was ≥30 NISP and assessed whether assemblage sample size affected the measures, using Spearman Rank Order correlation (Zar, 1974), following Grayson (1984).

LATE PLEISTOCENE−EARLY HOLOCENE SUBSISTENCE (11,000−7000 BP)

Ideas about the "origins" of Pacific Northwest culture and subsistence strategies have been linked to larger debates on the peopling of the New World. Until the 1990s, the dominant view was that the first inhabitants of the New World were big-game hunters who entered areas south of continental ice through the so-called ice-free corridor, about 11,500 BP. According to this model, the big game hunting tradition gave way to a more generalized adaptation, which included use of riverine and marine resources. Pacific Northwest culture histories dating from the first half of the twentieth century claimed that earliest cultures were riverine, then coastal, then sea-going (Lyman, 1991; Matson and Coupland, 1995). In 1979, Fladmark introduced the alternative idea that people entered the New World by sea, "island hopping" down the coastline from Alaska in boats, as areas became deglaciated and biologically productive (now thought to be as early as 17,000 years cal BP [Hoffecker and Elias, 2003]). In this model, further developed by R.L. Carlson ([1983, 1998]; see C. C. Carlson, 2003), the earliest people of the Pacific Northwest focused on marine, not terrestrial resources.

Pacific Northwest faunal and other site records are insufficient to rigorously test ideas about peopling and Paleo-Indian adaptations. Pre-Clovis sites are unknown in the region. Surface finds of fluted points typical of

Paleo-Indian occupations occur throughout the region, but there are only two buried Clovis-era deposits. The Manis Mastodon site (45CA218) is insufficiently published to be evaluated (Grayson and Meltzer, 2002). The Richey-Roberts Clovis site (45DO482) contains bone tools but there is no published faunal analysis. The earliest record of coastal settlement, from the Kilgii Gwaay, Ground Hog Bay 2, On-Your-Knees-Cave, Namu, and Hidden Falls sites, dates between 9000 and 10,000 BP. Use of marine resources is assumed from their location (Moss and Erlandson, 1995) and further confirmed by the marine-dominated faunal assemblage from Kilgii Gwaay (Fedje, 2003) and carbon isotope study of the 9500-year-old human remains from one of the sites (On-Your-Knees Cave, 49-PET-408: Dixon, 1999; Dixon *et al.*, 1997). Although consistent with a maritime migration, because these records postdate Clovis by more than 1000 years, they do not directly address how or when people came to the New World.

Researchers consider the Archaic adaptations after 10,000 BP to be broadly similar across the entire region, at least initially. Although in diverse environments, assemblages that have been assigned variously to the Windust, Old Cordilleran, Cascade, North Coast Microblade and Nesikep traditions share an immediate consumption economy based on a broad spectrum of resources, generalized portable tool kits, and only ephemeral house construction, indicating frequent residential mobility (Prentiss and Chatters, 2003).

We summarize the earliest direct evidence for animal use from 13 sites (Tables I and II; Fig. 1) with radiocarbon ages at least as old as 7000 BP. Even after being selective, there are a number of data gaps (for example, the fish remains from Lind Coulee have not been studied; mammal remains from Chuck Lake or Bernard Creek are not quantified). These 13 sites, widely dispersed in time and space, are incomplete representatives of multiple cultural systems. Without being able to make quantitative comparisons among different seasonal assemblages of a single cultural system, which would be the most definitive approach to identifying broad spectrum foraging, we are restricted to more general observations. For example, the wide range of animals–fishes, birds, mammals, and invertebrates–present in both Northwest Coast and Plateau sites between 10,000 and 7000 BP, is consistent with, but not definitive of, broad spectrum foraging. The marine sites tend to have higher richness than interior sites, with as many as nine families of fish, and six to eight families of birds at Bear Cove, Kilgii Gwaay, and Tahkenitch. Marine mammals (mainly seals but also dolphins at Bear Cove) were found at all coastal sites as well as at The Dalles Roadcut site, about 300 km up the Columbia River. Sea otters are found at two coastal sites, Kilgii Gwaay and Bear Cove, where they occur with river otter,

Table I. Background Information on Early Holocene Faunal Assemblages, Northwest Coast and Plateau (Site Abbreviations Used in Table II and Figs. 4 and 12)

Site name (abbreviation)	Site number	Culture area	Reference	Analytic unit	Age (BP)
Bear Cove (BearCv)	EeSu-8	NWC	Carlson, 2003	Component 1	5690
Chuck Lake (ChkLk)	Crg-237	NWC	Ackerman *et al.*, 1985; Ackerman *et al.*, 1989; Ackerman, 1989	Locality 1	7920
Glenrose Cannery (GlnCn)	DgRr6	NWC	Casteel, 1976; Ham, 1976; Imamoto, 1976; Matson, 1976	Old Cordilleran	6360
Kilgii Gwaay (KlgGw)	1325T	NWC	Fedje, 2003	Single component	9440
Tahkenitch Landing (Tahkch)	35DO130	NWC	Greenspan, 1986; Barner, 1986; Minor and Toepel, 1986	4A	6650
Bernard Creek Rockshelter (BrnCrk)	10IH483	Plateau	Casteel, 1977; Randolph and Dahlstrom, 1977	Deepest 1.75 m, Block 1	7200
Bob's Point (BobsPt)	45KL219	Plateau	Minor *et al.*, 1999	Below Mazama tephra	7600
Kirkwood Bar (KrkBr)	10IH699	Plateau	Chatters, 1997; Reid and Chatters, 1997	Single component	6800
Lind Coulee (LindCl)	45GR97	Plateau	Irwin and Moody, 1978; Lyman, 2000	Single component	8810
Marmes Rockshelter (MarmRk)	45FR50	Plateau	Butler, 2004; Ford, 2004; Gustafson, 1972; Gustafson and Wegener, 2004; Sheppard *et al.*, 1987	Component 1 & 2	9500
Marmes Floodplain (MarmFl)	45FR50	Plateau	Butler, 2004; Ford, 2004; Gustafson and Wegener, 2004; Sheppard *et al.*, 1987	Single component	9900
Plew (Plew)	45DO387	Plateau	Draper, 1986	Occupation 1	7700
The Dalles Roadcut (RdCt)	35WS8	Plateau	Butler, 1990a; Cressman *et.al.*, 1960; Hansel-Kuehn, 2003; Butler and O'Connor, 2004	Unit 1 & 2	7820

Table II. Frequency of Animal Family (NISP) by Habitat, Site (abbreviation) and Time Unit (BP), Early Holocene, Pacific Northwest

		Northwest Coast					Pluvial Lake	Columbia River			Plateau			
		Marine inlet			Estuary						Columbia-Snake Tributary			
		ChkLk	KlgGw	BearCv	GlnCn	Tahkch	LindCl	BobsPt	RdCt	Plew	MarmRk	MarmFl	BrnCrk	KrkBr
		7920	9440	5690	6360	6650	8810	7600	7820	7700	9500	9900	7200	6800
Fish														
Riverine	Cyprinid/catostomid (minnow/sucker)				1			3	347		24	1746	264	8674
Riverine/ marine	Acipenseridae (sturgeon)				3	1			45					
	Gasterosteidae (stickleback)				28									
	Osmeridae (smelt)				10									
	Salmonidae (salmon, trout, whitefish)	6	1	6	167	6		140	13464	14	3	16	108	349
Marine	Chimaeridae (ratfish)			11										
	Clupeidae (herring)	6	18	18		21								
	Cottidae (sculpin)	55	1	2		155								
	Embiotocidae (surfperch)					56								
	Gadidae (cod)	356	40	49		143								
	Hexagrammidae (greenling)	148		2		6								
	Pleuronectidae (right-eye flounder)	6	3	2	1	27								
	Rajidae (skates)		5											
	Scorpaenidae (rockfish)	37	473	266										
	Squalidae (dogfish)		27	7										
Birds														
Riverine	Cinclidae (dipper)												x	
Cosmopolitan	Accipitridae (eagle, kite, hawk)		1	1					1097				x	
	Cathartidae (vulture)								270			x		
	Corvidae (jay, crow)			1					41				x	
	Phasianidae (grouse)												x	6
	Passeriformes (perching birds)													17

Table II. Continued

	Northwest Coast					Pluvial Lake	Columbia River			Plateau			
	Marine inlet			Estuary						Columbia-Snake Tributary			
	ChkLk	KlgGw	BearCv	GlnCn	Tahkch	LindCl	BobsPt	RdCt	Plew	MarmRk	MarmFl	BrnCrk	KrkBr
	7920	9440	5690	6360	6650	8810	7600	7820	7700	9500	9900	7200	6800
Laridae (jaeger, gull, term)			4		4			4072					
Anatidae (ducks, geese, swan)		6	11		35	9		39			x	x	
Ardeidae (herons)			1			2							
Rallidae (rail)					1								
Podicipedidae (grebes)		3											
Diomedeidae (albatross)		16											
Coastal													
Gavidae (loons)			9		1								
Phalacrocoracidae (cormorant)	x	2	1		11			955					
Alcidae (auk)		50	1										
Procellariidae (shearwater)				3	3								
Land mammals													
Ungulates													
Cervidae (wapiti, deer)	x		35	23	1	28		11	2	27	7	x	5
Bovidae (bison, sheep, goat)						136			2				6
Antilocapridae (antelope)										14	2		
Carnivores													
Felidae (cat)								1			3	x	
Canidae (dog, wolf, coyote, fox)				2				11	4	2	68	x	3
Ursidae (bear)		54										x	
Procyonidae (racoon)													
Mustelidae (mink, fisher, skunk, river otter, badger)		3	2	2		30		9			7	x	22

Table II. Continued

	Northwest Coast						Plateau						
	Marine inlet			Estuary		Pluvial Lake	Columbia River			Columbia-Snake Tributary			
	ChkLk	KlgGw	BearCv	GlnCn	Tahkch	LindCl	BobsPt	RdCt	Plew	MarmRk	MarmFl	BrnCrk	KrkBr
	7920	9440	5690	6360	6650	8810	7600	7820	7700	9500	9900	7200	6800
Rodents, Leporids													
Leporidae (rabbit, hare)						13			23	5	51		27
Sciuridae (marmot)	x					7		14		3	20		
Castoridae (beaver)			2	4		3		6		2	1		
Muridae (muskrat)						6		4			1		
Erethizontidae (porcupine)												x	
Marine mammals													
Delphinidae (dolphin, porpoise)			49										
Phocidae (true seals)	x	36		3	1								
Otariidae (eared seals)		2	20					6					
Mustelidae (sea otter)		10	5										
Total verteb. NISP[a]	688	752	505	244	475	234	143	20396	45	80	1922	372	9109
Invertebrates													
Riverine													
Gastropoda (landsnails)						x				x	x	x	x
Pelecypoda (bivalves)								x	x				
Marine													
Pelecypoda	x	x		x									
Gastropoda (snail, slug)	x	x		x									
Arthropod	x	x											

Note. "x" indicates present but not quantified.
[a]Mammal bone from RdCt (35WS8) was quantified using minimum number of individuals (MNI).

which is found in over half of the site assemblages, including interior sites. Birds are reported as present at eight of the 13 assemblages, but only quantified at six. Use of marine invertebrates is documented at three of the five coastal sites; Kilgii Gwaay has the oldest recorded shell deposit in the area. Freshwater mussels are known for five interior sites and land snails possibly were a food resource at Bernard Creek (Randolph and Dahlstrom, 1977).

The pattern of shifting taxa dominance observed among the assemblages is also consistent with expectations for broad spectrum foraging in which residentially mobile populations move from place-to-place consuming locally/seasonally abundant resources. Salmon dominate the vertebrate assemblage at four riverine sites, one near the coast (Glenrose Cannery) and three inland on the Columbia River (Roadcut, Bob's Point, and Plew). Rockfish are the dominant vertebrate at Bear Cove and Kilgii Gwaay, while cod and sculpin dominate at Tahkenitch. Cod are the dominant fish at Chuck Lake. In all Snake River system assemblages, minnow (Cyprinidae) and sucker (Catostomidae) dominate the fish assemblages and dominate the entire vertebrate assemblage at Kirkwood Bar; remains are from taxa that range between 10 and 40 cm in length. Artiodactyls dominate at only two sites, bison (Bovidae) at Lind Coulee, and cervids (mainly deer with some wapiti [*Cervus elaphus*]) at Marmes Rockshelter. People probably were taking advantage of local abundance, in some cases supported by a broad "food web" as Monks (1987) has suggested for later coastal occupations. The Dalles Roadcut site, located next to a major series of rapids known historically as the premier fishing site on the Columbia River, is an example. Here, at about 7800 BP, humans, seals, and birds converged to procure salmon, and humans may have taken advantage of their competitors as well, although this convergence also makes the taphonomic issues more complicated (Butler and O'Connor, 2004; Cressman *et al.*, 1960; Hansel-Kuehn, 2003). A similar food web may be represented at Kilgii Gwaay, where the five mammal families present are carnivores known to eat fish, but given the low frequency of salmon, it is not this fish that is bringing them together.

To track long-term temporal trends, we include assemblages from this group in later Holocene regional comparisons, when data are sufficient to derive quantitative measures.

SOUTH-CENTRAL NORTHWEST COAST (7000−150 BP)

Faunal assemblages examined are from 42 components at 19 sites located along the Puget Sound, Gulf of Georgia, Strait of Juan de Fuca, and outer coast of Washington (Tables III–VII; Fig. 2). The total NISP includes

Table III. Background Information on Faunal Assemblages, South-Central Northwest Coast, 7000–150 BP (Site Abbreviations Used in Table III–VII and Figs. 4–11)

Site name (abbreviation)	Site number	Habitat	Reference	Analytic unit	Age (BP)
Allentown (Alltn)	45KI431	Riverine	Butler and Corcoran, 1996; Ford, 1996; Lewarch et al., 1996	Single component	350
Bay Street (BaySt)	45KP115	Coastal	Butler and Baker, 2002; Ford, 2002; Lewarch et al., 2002	Component 1	675
				Component 2	475
				Component 3	300
Burton Acres (BrtAc)[a]	45KI437	Coastal	Kopperl and Butler, 2002; Bovy, 2002a; Phillips, 2002; Stein and Phillips, 2002	Precontact	600
				Postcontact	100
Crescent Beach (CresBc)	DgRr1	Coastal	Matson, 1992; Rankin, 1991 (no mammal fauna)	St. Mungo	4000
				Locarno Beach	3000
				Marpole	2000
Decatur Island (Dec-165) (Dec-169)	45SJ165 45SJ169	Coastal Coastal	Lyman, 2003b; Wigen, 2003; Ives, 2003; Ives and Walker, 2003 Lyman, 2003b; Wigen, 2003; Ives, 2003; Walker, 2003	Single component	1950
				Analytic unit 2	2330
				Analytic unit 3	2280
				Analytic unit 5	2510
Duwamish (Duwam)[b]	45KI23	Riverine	Butler, 1987; Campbell, 1981; Livingston, 1987; Lyman, 1981; Lewarch, 1987	III	1180
				II	950
				I	500
Glenrose Cannery (GlnCn)	DgRr6	Riverine	Casteel, 1976; Ham, 1976; Imamoto, 1976; Matson, 1976	St. Mungo	4000
				Marpole	2000
Hoko R. Rockshelter (HokRk)	45CA21	Riverine	Wigen and Stucki, 1988	Single component	450
Hoko River Wet Site (HokWt)	45CA313	Riverine	Croes, 1995; Croes and Blinman, 1980	Single component	2540
Ozette (Ozet)[c]	45CA24	Coastal	Huelsbeck, 1994a, 1994b; Wessen, 1994; DePuydt, 1994	Unit V	440
Pender Canal (PenCn)	DeRt1	Coastal	Hanson, 1995	Single component	850
Sbabadid (Sbabd)	45KI51	Riverine	Butler, 1990b; Chatters, 1981	Single component	140
Sequim (Seqm)	45CA426	Upland	Lyman, 1999; Gough and Morgan, 1999 (no fish or invertebrates)	Analytic Unit A	2550
				Analytic Unit B	1950
				Analytic Unit C	500
				Analytic Unit D	450

Table III. Continued

Site name (abbreviation)	Site number	Habitat	Reference	Analytic unit	Age (BP)
Tsawwassen (Tsaww)	DgRs2	Coastal	Kusmer, 1994	Marpole	1950
				Transition	1300
				Gulf of Georgia	850
Tualdad Altu (TualAl)	45KI59	Riverine	Butler, 1990b; Chatters *et al.*, 1990; Chatters, 1988	Single component	1610
West Point (Wst-428)[d]	45KI428	Coastal	Wigen, 1995; Lyman, 1995b; Ford, 1995; Lewarch and Bangs, 1995	Component 1	3900
				Component 2	3090
				Component 3	2525
				Component 4	1075
				Component 5	450
(Wst-429)[d]	45KI429	Coastal	Wigen, 1995; Lyman, 1995a,b; Ford, 1995; Lewarch and Bangs, 1995	Component 1	3900
				Component 2	3090
				Component 3	525
				Component 4	1075
				Component 5	450
White Lake (WhtLk)	45KI438 & KI438A	Riverine	Butler and Corcoran, 1996; Ford, 1996; Lewarch *et al.*, 1996	Single component	350

[a]Fish records separated into two components; other fauna aggregated into single analytic unit.
[b]Fish and bird records separated into three components; mammal & invertebrate remains aggregated into single analytic unit.
[c]Invertebrate records aggregated from entire site; rest of fauna from Unit V.
[d]Invertebrate records aggregated from both sites, summed for each component.

Table IV. Frequency of Fish Family (NISP) by Site and Time Unit, South-Central Northwest Coast, 7000–150 BP

	Allhtn 350 (BP)	BaySt 675 (BP)	BaySt 475 (BP)	BayAc 300 (BP)	BrtAc 600 (BP)	BrtAc 100 (BP)	CresBc 4000 (BP)	CresBc 3000 (BP)	CresBc 2000 (BP)	Dec-165 1950 (BP)	Dec-169 2330 (BP)	Dec-169 2280 (BP)	Dec-169 2510 (BP)
Riverine/freshwater													
Acipenseridae (sturgeon)							34	29	130				
Cyprinid/Catostomid (minnow/sucker)	35						357	54	21				
Gasterosteidae (stickleback)							1		1		3		
Osmeridae (smelt)	1						7	13			18		29
Salmonidae (salmon and trout)	19461	49	12	61	180	388	6341	7443	1405	11	117	7	218
Marine													
Agonidae (poacher)													
Ammodytidae (sandlance)											83		3
Anoplopomatidae (sablefish)													
Batrachoididae (toadfish)		1		9	2	4	37	29	171				
Clupeidae (herring)	1	178	172	61	2902	1378	862	547	53		1564	24	82
Cottidae (sculpin)	88	10	6	3	53	6	526	354	43	9	43	2	69
Chimaeridae (ratfish)		8	7	2	14	3				12	2		
Embiotocidae (surfperch)	2	10	1	33	86	6	17	21		1	89	25	58
Engraulidae (anchovy)								25			196	3	6
Gadidae (cod)											3	1	
Hexagrammidae (greenling)		31		22	2	6			2	3	10	7	6
Pholidae (gunnel)											3		
Pleuronectidae (right-eye flounder)	11	218	53	128	171	47	4864	1857	607	6	27	15	72
Rajiidae (skates)					29	1	5	11		4	10		
Scorpaenidae (rockfish)					22	6				1	3	1	
Squalidae (dogfish)	5	42	9	8	9	6	209	220	32	5	16	1	19
Stichaeidae (prickleback)											309	1	20
Thunnidae (tuna)													
NISP fish	19604	547	261	327	3470	1851	13260	10603	2465	52	2496	87	595
N of families	8	9	8	9	11	11	12	12	10	9	17	11	12

Table IV. Continued

	Duwam 1180 (BP)	Duwam 950 (BP)	Duwam 500 (BP)	GlnCn 4000 (BP)	GlnCn 2000 (BP)	HokRk 450 (BP)	HokWt 2540 (BP)	Ozet 440 (BP)	PenCn 850 (BP)	Sbabd 140 (BP)	Tsaww 1950 (BP)	Tsaww 1300 (BP)	Tsaww 850 (BP)
Riverine/freshwater													
Acipenseridae (sturgeon)				81	1	5							2
Cyprinid/Catostomid (minnow/sucker)		1	1	47							7		
Gasterosteidae (stickleback)				5									
Osmeridae (smelt)			1	48									
Salmonidae (salmon and trout)	494	1971	964	7009	575	9794	584	3059	194	248	184	34	76
Marine													
Agonidae (poacher)													
Ammodytidae (sandlance)													
Anoplopomatidae (sablefish)						71							
Batrachoididae (toadfish)											12		
Clupeidae (herring)	21	3			2	372	4	78	945		138	26	12
Cottidae (sculpin)		229	99			5596	121	3357	130		21	2	6
Chimaeridae (ratfish)	6	12	8			209			20				
Embiotocidae (surfperch)	8	16	16			1161	3	1709	1841		8	6	
Engraulidae (anchovy)		3	2			45							
Gadidae (cod)	46	211	131			617	586	43	256		3		
Hexagrammidae (greenling)						18029	171	9201	127				
Pholidae (gunnel)													
Pleuronectidae (flatfish)	58	250	89	68		2195	1745	1010	12		380	50	8
Rajiidae (ray)	6	2	6			60	8	43	8				
Scorpaenidae (rockfish)		6	1			5092	347	3360	406		3		2
Squalidae (dogfish)	52	194	78	4	1	976	243	201	148		33	42	4
Stichaeidae (prickleback)						312	10	9	1				
Thumnidae (tuna)								1					
NISP fish	691	2899	1396	7262	579	44543	3822	22071	4088	248	789	160	110
N of families	8	13	12	7	4	16	11	12	12	1	10	6	7

Table IV. Continued

	TualAl 1610 (BP)	Wst-428 3900 (BP)	Wst-428 3090 (BP)	Wst-428 2525 (BP)	Wst-428 1075 (BP)	Wst-428 450 (BP)	Wst-429 3900 (BP)	Wst-429 3090 (BP)	Wst-429 2525 (BP)	Wst-429 1075 (BP)	Wst-429 450 (BP)	WhtLk 350 (BP)
Riverine/freshwater												
Acipenseridae (sturgeon)												
Cyprinid/Catostomid (minnow/sucker)	29	150	130	7			6	3			3	4
Gasterosteidae (stickleback)												
Osmeridae (smelt)												
Salmonidae (salmon and trout)	7892	324	1608	110	69	61	101	19	4	187	552	2410
Marine												
Agonidae (poacher)			1									
Ammodytidae (sandlance)							1					
Anoplopomatidae (sablefish)												
Batrachoididae (toadfish)		38	18			1	4					
Clupeidae (herring)	41	71	23	1	1		26	1	1		7	
Cottidae (sculpin)		588	171	4	2	1	209	36	10	15	4	
Chimaeridae (ratfish)	8	77	42	4			91	11	4	4	111	
Embiotocidae (surfperch)	8	284	126	9	1	1	34	7	4	15	63	
Engraulidae (anchovy)		5									49	
Gadidae (cod)		53	15				36	10	1		2	
Hexagrammidae (greenling)		14	1				12				31	
Pholidae (gunnel)											14	
Pleuronectidae (flatfish)	350	1196	336	9		1	187	40	8	12	292	
Rajidae (ray)		1	7				3					
Scorpaenidae (rockfish)	2	1	1				5					
Squalidae (dogfish)	750	175	62		2		50	6		4	4	
Stichaeidae (prickleback)												
Thunnidae (tuna)												
NISP fish	9080	2977	2541	144	75	65	765	133	32	237	1132	2414
N of families	8	14	14	7	5	5	14	9	7	6	12	2

Table V. Frequency of Mammal Family (NISP) by Site and Time Unit, South-Central Northwest Coast, 7000–150 BP

	Allntn 350 (BP)	BaySt 675 (BP)	BaySt 475 (BP)	BaySt 300 (BP)	BrtAc 525 (BP)	Dec-165 1950 (BP)	Dec-169 2330 (BP)	Dec-169 2280 (BP)	Dec-169 2510 (BP)	Duwam 725 (BP)	GlnCn 4000 (BP)	GlnCn 2000 (BP)
Terrestrial/freshwater												
Aplodontidae (mountain beaver)												
Bovidae (bison, sheep, goat, cow)	3	1		2						81		
Canidae (dog, coyote, wolf, fox)		1	2			1		6		41	36	19
Castoridae (beaver)					2	1				10	44	6
Cervidae (deer, wapiti)	18	157	43	42	30	69	42	73		338	101	39
Equidae (horse)									1			
Felidae (cats, lynxes & allies)										4		
Leporidae (rabbit, hare)												
Muridae (muskrat)												
Mustelidae (river otter, mink, weasel, marten)					1	4	32			5		1
Procyonidae (racoon)					2	2		1		1	4	1
Sciuridae (marmot)												
Suidae (pig)	1											
Ursidae (bear)										15	5	4
Marine												
Phocidae (true seal)						10	11	10	3	30	23	6
Otariidae (eared seal)												
Delphinidae (dolphin)												
Mustelidae (sea otter)							1					
Cetacea (whale, dolphin, porpoise)												
Eschrichtiidae (gray whale)												
Balaenopteridae (humpback, finback whale)												
Balaenidae (right whale)												
NISP mammal	22	159	45	44	35	87	86	90	4	525	213	76
N of Families	3	3	2	2	4	6	4	4	2	9	6	7

Table V. Continued

	HokRk 450 (BP)	HokWt 2540 (BP)	Ozet 440 (BP)	PenCn 850 (BP)	Sbabd 140 (BP)	Seqm 2550 (BP)	Seqm 1950 (BP)	Seqm 500 (BP)	Seqm 450 (BP)	Tsaww 1950 (BP)	Tsaww 1300 (BP)	Tsaww 850 (BP)
Terrestrial/freshwater												
Aplodontidae (mountain beaver)												
Bovidae (bison, sheep, goat, cow)												
Canidae (dog, coyote, wolf, fox)	92		1546	75		1				1	2	62
Castoridae (beaver)	25	1	16	6	39	2						3
Cervidae (deer, wapiti)	307	8	485	240	43	380	275	64	92	3		5
Equidae (horse)					1							
Felidae (cats, lynxes & allies)							1					
Leporidae (rabbit, hare)	21		2	3		18	1					
Muridae (muskrat)												
Mustelidae (river otter, mink, weasel, marten)	46		47		1					1	1	
Procyonidae (racoon)	26		29	1		1						
Sciuridae (marmot)						1						
Suidae (pig)	1											
Ursidae (bear)		1	16		1	2	6	1	3			
Marine												
Phocidae (true seals)	2372	7	321	66	3					1		4
Otariidae (eared seals)	226	4	45422	2								
Delphinidae (dolphin)	37		826	43								
Mustelidae (sea otter)			471									
Cetacea (whale, dolphin, porpoise)	86	2										
Eschrichtiidae (gray whale)			244									
Balaenopteridae (humpback, finback whale)			265									
Balaenidae (right whale)			12									
NISP mammal	3239	23	49702	436	88	405	283	65	95	6	3	74
N of Families	11	6	14	8	6	7	4	2	2	4	2	4

Table V. Continued

	TualAl 1610 (BP)	Wst-428 3900 (BP)	Wst-428 3090 (BP)	Wst-428 2525 (BP)	Wst-429 3900 (BP)	Wst-429 3090 (BP)	Wst-429 1075 (BP)	Wst-429 450 (BP)
Terrestrial/freshwater								
Aplodontidae (mountain beaver)	6	10	59	1	14	2		1
Bovidae (bison, sheep, goat, cow)								
Canidae (dog, coyote, wolf, fox)	11	4	1					
Castoridae (beaver)	23	6	13	5	1		1	2
Cervidae (deer, wapiti)	102	134	121	27	24	24	3	7
Equidae (horse)								
Felidae (cats, lynxes & allies)	1		1		3			
Leporidae (rabbit, hare)	2	1	15	1		1		
Muridae (muskrat)	23	1	1					
Mustelidae (river otter, mink, weasel, marten)	2	2	3		1			
Procyonidae (racoon)	15	2						
Sciuridae (marmot)								
Suidae (pig)								
Ursidae (bear)	5	1						1
Marine								
Phocidae (true seals)		25	13	2	28	5	1	1
Otariidae (eared seals)								
Delphinidae (dolphin)		2	11					
Mustelidae (sea otter)								4
Cetacea (whale, dolphin, porpoise)		6						
Eschrichtiidae (gray whale)								
Balaenopteridae (humpback, finback whale)								
Balaenidae (right whale)								
NISP mammal	190	194	238	36	71	32	5	16
N of Families	10	12	10	5	6	4	3	6

Table VI. Frequency of Bird Family (NISP) by Site and Time Unit, South-Central Northwest Coast, 7000–150 BP

	Dec-165 1950 (BP)	Dec-169 2330 (BP)	Dec-169 2280 (BP)	Dec-169 2510 (BP)	Duwam 1180 (BP)	Duwam 950 (BP)	Duwam 500 (BP)	GlnCn 2000 (BP)	GlnCn 4000 (BP)	HokRk 450 (BP)
Accipitridae (eagle, kite, hawk)		1		1	1	1	3		x	121
Alcidae (auk)	1	21	3							414
Anatidae (ducks, swans, geese)	17	19	11	4	6	14	1	18	28	902
Ardeidae (herons)		2	2							8
Cathartidae (vulture)										
Cinclidae (dipper)										
Corvidae (jay, crow)		1		1	1					4
Diomedeidae (albatross)										73
Emberizidae (towhee, sparrow)										
Falconidae (falcon)										1
Gavidae (loon)	1	2	5			1	3		1	119
Gruidae (crane)										2
Haematopodidae (oystercatcher)										
Hydrobatidae (petrel)										
Icteridae (blackbird, oriole)										
Laridae (jaeger, gull, tern)	2	8		1	1	1				289
Pandionidae (osprey)		18								
Pelecanidae (pelican)										
Phalacrocoracidae (cormorant)		1				2				133
Phasianidae (grouse)										
Picidae (woodpecker)							1			
Podicipedidae (grebe)	5	3	3		6	28	9		1	152
Procellariidae (shearwater)										224
Rallidae (rail)										
Scolopacidae (sandpiper)	1									3
Order passeriformes (perching birds)		1								59
NISP bird	27	77	24	7	15	47	17	18	30	2504
N of Families	6	11	5	4	5	6	5	1	4	15

Table VI. Continued

	HokWt 2540 (BP)	Ozet 440 (BP)	PenCn 850 (BP)	Tsaww 1950 (BP)	Tsaww 1300 (BP)	Tsaww 850 (BP)	TualAl 1610 (BP)
Accipitridae (eagle, kite, hawk)		9	3			11	
Alcidae (auk)	251	179					
Anatidae (ducks, swans, geese)	185	169	29	110	9	25	72
Ardeidae (herons)		4	1				
Cathartidae (vulture)			1				
Cinclidae (dipper)							
Corvidae (jay, crow)		16				1	
Diomedeidae (albatross)	2	80		1			
Emberizidae (towhee, sparrow)							
Falconidae (falcon)		1					
Gaviidae (loon)	40	14	6	9			
Gruidae (crane)							
Haematopodidae (oystercatcher)		1					
Hydrobatidae (petrel)		2					
Icteridae (blackbird, oriole)							
Laridae (jaeger, gull, tern)	14	219	1	2		3	1
Pandionidae(osprey)							
Pelecanidae (pelican)		74					
Phalacrocoracidae (cormorant)	6	104					
Phasianidae (grouse)			1				2
Picidae (woodpecker)			1				
Podicipedidae (grebe)	5	6	1				2
Procellariidae (shearwater)	24	178		1			
Rallidae (rail)					1	2	2
Scolopacidae (sandpiper)		9					
Order Passeriformes (perching birds)		1					
NISP bird	527	1066	44	123	10	42	79
N of Families	8	17	9	5	2	5	5

Note. "x" denotes taxon is present.

Table VII. Frequency of Invertebrates (Weight, g) by Site and Time Unit, South-Central Northwest Coast, 7000–150 BP

	Allntn 350 (BP)	BaySt 675 (BP)	BaySt 475 (BP)	BaySt 300 (BP)	BrtAc 525 (BP)	CrsBc 4000 (BP)	CrsBc 3000 (BP)	CrsBc 2000 (BP)	Dec-169 2330 (BP)	Dec-169 2280 (BP)	Dec-169 2510 (BP)	Duwam 725 (BP)
Hard rock												
Anomiidae (jingle shell oyster)	2											
Cirripedia, Subclass (barnacles)	1270	3504	2717	1591	368	38	199	231	565	4	3	3754
Littorinidae (periwinkle)		32	10	14	2							10
Lottidae (limpet)		11	14	6					6			4
Mytilidae (mussels)	2198	2035	1194	1191	113	185	249	261	2544	36	97	4665
Nassariidae (dogwhelks)	1				1					3		
Neoloricata, Order (chiton)									10			
Ostreidae (native oyster)	2	128	487	153	2							54
Pectinidae (rock scallop)												
Thaidiidae (dogwinkles)	4	437	217		13	3	39	86	12	1		1083
Soft Sediment												
Cardiidae (cockle)	16	121	209	326	541	11	166	642	2428	2	28	1359
Mactridae (horse clam)	23	32	86	154	357	2	411	219	329		14	1442
Naticidae (moonsnail)		134	205	168	98							206
Saxicavidae (geoduck)												36
Tellinidae (sand, benthose clam)	5	12	20	17	2				13	4		595
Veneridae (venus clam)	10	7197	7816	3657	5685	21	1112	575	12954	115	352	5712
Other												
Crab			1		1							
Dentaliidae (dentalium)												1
Echinoids (urchin, sand dollar)	5		4.6						380	2	1	34
Margaritiferidae (freshwater mussel)												
Pectinidae (free-swimming scallop)					6							
Total weight	3534	13643	12981	7277	7188	260	2176	2014	19241	167	495	18955
N of Families	11	11	13	10	13	6	6	6	10	8	6	14

Table VII. Continued

	GlnCn[a] 4000 (BP)	GlnCn[a] 2000 (BP)	Ozet[a] 525 (BP)	PenCn 850 (BP)	Sbabd[a] 140 (BP)	Tsaww 1950 (BP)	Tsaww 1300 (BP)	Tsaww 850 (BP)	WstPT 3900 (BP)	WstPT 3090 (BP)	WstPT 2525 (BP)	WstPT 1075 (BP)	WstPT 450 (BP)	WhtLk 350 (BP)
Hard rock														
Anomiidae (jingle shell oyster)														
Cirripedia, subclass (barnacles)			12258	622	6	281	40	209	2	190		59	63	40
Littorinidae (periwinkle)	8	2	55162	3		x	x	x	19	14		3	1	
Lottidae (limpet)		1	6129	82	1	x	x	x	5	7		1	1	1
Mytilidae (mussels)	3		131776	2490		292	40	586	2517	1429	6	508	412	1234
Nassariidae (dogwhelks)														
Neoloricata, Order (chiton)			18387			x				1			4	
Ostreidae (native oyster)				25			x					1	15	
Pectinidae (rock scallop)		1												
Thaididae (dogwinkles)	22	17	3064	649		x	x	x	660	1434	52	84	159	
Soft Sediment														
Cardiidae (cockle)	6	5	3064	803	1	3135	1048	98	132	963	1	155	1725	
Mactridae (horse clam)	15	8		89	83				65	474	2	77	122	
Naticidae (moonsnail)				x	17				42	56		3	217	
Saxicavidae (geoduck)	3													
Tellinidae (sand, benttnose clam)		2		7					51	76	1	17	14	
Veneridae (venus clam)	28	20	61292	4722	27	1392	850	502	1479	4459	20	928	2511	16
Other														
Crab	1		3064	6		x	x	x	2				7	
Dentaliidae (dentalium)														
Echinoids (urchin, sand dollar)				116		x		x	9	6	0.4	1.5	18	
Margaritiferidae (freshwater mussel)					34									
Pectinidae (free-swimming scallop)	1													
Total weight	9	8	9	9613	7	5100	1978	1395	4983	9109	81	1837	5269	1291
N of Families	9	8	9	13	7	10	9	9	12	12	7	12	14	4

Note. "x" denotes taxon present.

[a] Quantity is number of specimens, not weight, and thus total weight is not provided for these sites.
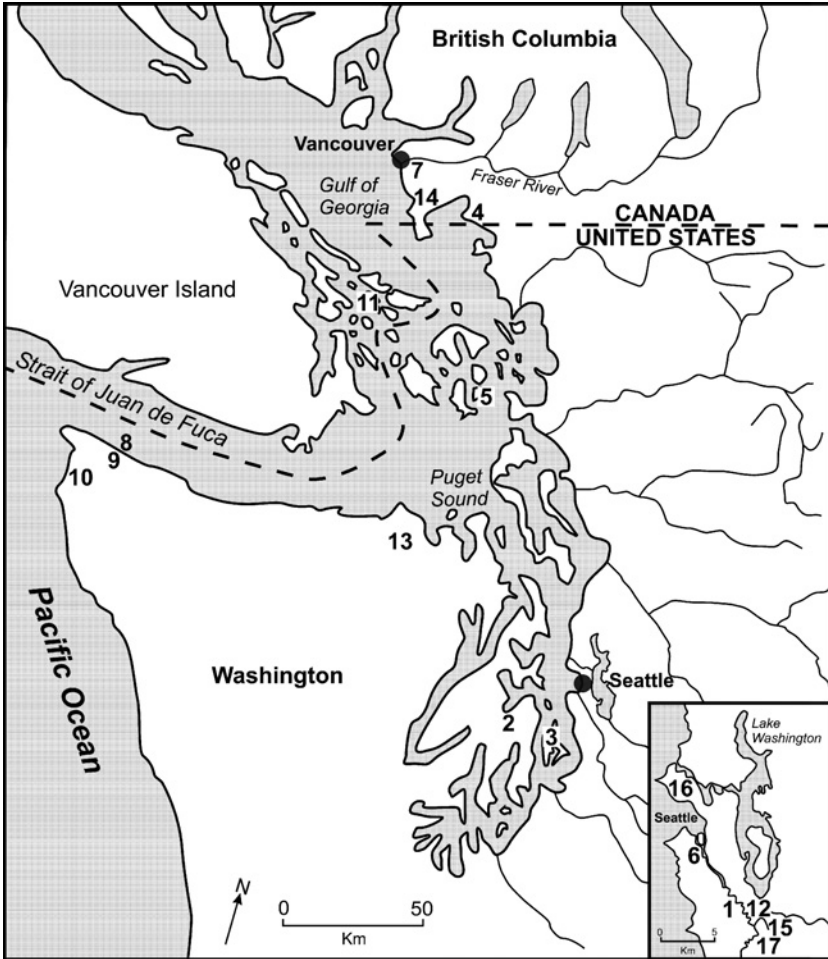
Fig. 2. Map of South-Central Northwest Coast showing site locations: (1) Allentown 45KI431, (2) Bay Street 45KP115, (3) Burton Acres 45KI437, (4) Crescent Beach DgRr1, (5) Decatur Island 45SJ165, 45SJ169, (6) Duwamish 45KI23, (7) Glenrose Cannery DgRr6, (8) Hoko River Rockshelter 45CA21, (9) Hoko River Wet Site 45CA313, (10) Ozette 45CA24, (11) Pender Canal DeRt1, (12) Sbabadid 45KI51, (13) Sequim 45CA426, (14) Tsawwassen DgRs2, (15) Tualdad Altu 45KI59, (16) West Point 45KI428, 45KI429, (17) White Lake 45KI438, 45KI438A.

163,871 fish, 56,587 mammal, 4657 bird, and 129 kg of invertebrates. Fish outnumber both mammals and birds by an order of magnitude, yet this is still an underestimate of their abundance, given differences in recovery methods. Mammal and bird remains commonly are derived from much

larger volumes of matrix than fish remains. For example, in Zone A of the Tsawwassen site (DgRs2), mammal and bird remains were recovered from about 4500 L of sediment (screened with 6.3 mm mesh) whereas quantification of fish and invertebrates is based on recovery from 24 liters (screened with 4 and 2 mm mesh) (Arcas Consulting Archeologists, 1994, p. 27). At face value, the large number of mammal remains present at Ozette (of the 56,587 of the mammal remains reported here, 49,702 are from this site) depart from the fish-dominated pattern, however, recovery did not include mesh finer than 1/4″ (6.4 mm), thus fish bones are underrepresented. Of greater concern, major differences in excavation volumes used in sampling different animal classes preclude direct comparison of animal taxa from different classes (for example, salmonid to cervid), thus each class is considered separately below. To assess the importance of local resource availability, we assigned sites to broad habitat categories (coastal, riverine, upland) based on location.

Fish

Twenty-four families of fish are represented (Table IV), most of which are listed by ethnographers as resources used by inhabitants of the Northwest. Three ethnographically important species, eulachon (*Thaleichthys pacificus*), sturgeon (*Acipenser* spp.), and lamprey (*Lampetra* spp.), are rare or absent in these assemblages. This is probably because they are associated with large river systems, habitats minimally sampled here, and for lamprey, because of preservation bias. The importance of salmon throughout time is supported by its ubiquity (present in 38 out of 38 components) and relative abundance (ranked first in over half, second in seven, and third in eight) (Table VIII). The dominance of other fish—flatfish, sculpin, surfperch, herring, ratfish, and greenling—in 18 components, indicates other important fisheries.

Pacific Northwest resource intensification models suggest that focal fisheries would be expected to increase through time (through storage and mass harvesting). Evenness of taxonomic representation is expected to decline, and in addition, the AIs for taxa linked to intensification (salmonid, herring, and flatfish) should increase.

To examine the possibility of resource depression, we defined an aquatic patch, combining marine and riverine habitats. These patches were not distinguished given that salmonids, one of the primary resources, migrate between habitats; however, we control for variation in resource distribution to some degree by comparing faunal changes according to site location (coastal, riverine). To test for salmonid resource depression, we constructed the Salmonid Index (NISP Salmonidae/NISP

Table VIII. Ubiquity and Relative Abundance of Fish Families in 38 Assemblages, South-Central Northwest Coast (Includes Assemblages With ≥30 NISP; the 10 Most Abundant Families are Included)

Taxon	Ubiquity (frequency of occurrence in assemblages)	Abundance (frequency of assemblages in which taxon is ranked first)
Salmonidae (salmon and trout)	38	20
Pleuronectidae (right-eye flounder)	34	7
Cottidae (sculpin)	34	2
Squalidae (dogfish)	33	0
Embiotocidae (surfperch)	32	1
Clupeidae (herring)	28	5
Gadidae (cod)	22	0
Chimaeridae (ratfish)	21	1
Scorpaenidae (rockfish)	18	0
Hexagrammidae (greenling)	12	2

Salmonidae + NISP Other fish), using the logic described earlier. We argue that salmonids are the highest ranked fish family because species in the family tend to reach much larger size than species in other families. Nonsalmonid species that can attain larger sizes (halibut [*Hippoglossus stenolepis*] in Pleuronectidae; lingcod [*Ophiodon elongatus*] in Hexagrammidae; cabezon [*Scorpaenichthys marmoratus*] in Cottidae), are very scarce or absent in all but two sites, Ozette and the Hoko River Rockshelter, so the logic of the relationship (large prey/large prey + small prey) should hold when examining regional trends. A potential problem with the equation of large size and high rank relates to technological changes that would elevate energetic returns of small fish (taken en masse through mass capture) relative to large fish caught individually. We suggest this factor does not undermine our test, given salmonid life history, which entails seasonal aggregation of large runs that migrate to spawning grounds. It seems probable that whenever mass capture methods began to be utilized, salmonids would have been preferentially taken this way. Overall then, if predation was sufficiently heavy on salmonids, we would expect the index to decline over time.

Contrary to expectations from regional intensification models, there is no distinct linear trend in evenness for either riverine or coastal site assemblages (Fig. 3). As discussed below, habitat and access to resources probably explains the overall lower evenness values for the riverine sites, where salmonids tend to dominate. Regarding the resource depression question, the AI for salmon actually increases slightly over time for coastal assemblages ($r = 0.333$, $p = 0.068$), although the result is not significant at the 0.05 level (Fig. 4). Riverine sites have generally high ratios for all time periods and show no temporal trend. We note as well that the ratios are not
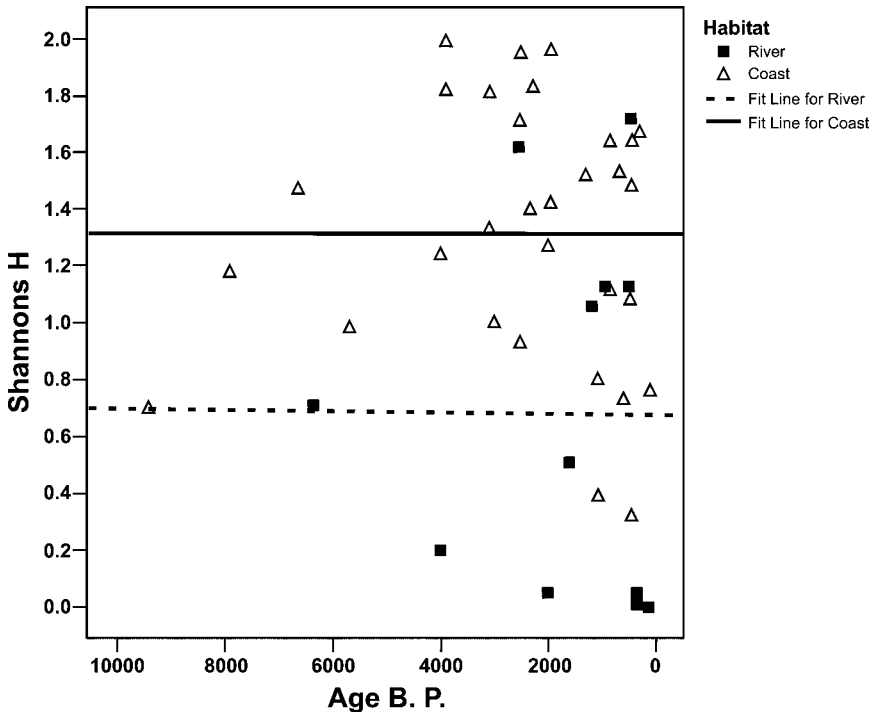
Fig. 3. Scatterplot of evenness values (Shannons H) based on fish family, South-Central North-west Coast and early Holocene assemblages (coastal: $r = 0.004$, $p = 0.98$; riverine: $r = 0.007$, $p = 0.98$). Best-fit regression line drawn for each habitat type.

correlated with assemblage sample size ($r_s = 0.038$, $p > 0.05$). Salmon ratios are low in four of the five earliest components, while the highest ratios are after 4000 BP. Yet for every time period, there are a range of values, suggesting salmon was the focus of the fishery in some locations, and only a minor or moderate constituent in others. Site location, especially proximity to salmon streams, is the simplest explanation. The four early low ratios occur at Bear Cove, Chuck Lake, Tahkenitch, and Kilgii Gwaay, all of which are in coastal habitats. The important role that rivers play in providing access to migrating salmon is indicated by the striking contrast to the high ratios at Glenrose Cannery, at the mouth of the Fraser River. Similar low ratios are seen in later coastal sites as well, while sites located on rivers or at the mouths of rivers historically known to support salmon tend to have ratios greater than 0.7, including specialized fishing camps (Allentown, White Lake) and villages (Duwamish, Sbabadid, Tualdad Altu). The only exceptions are the Hoko River wet site and rockshelter site with low
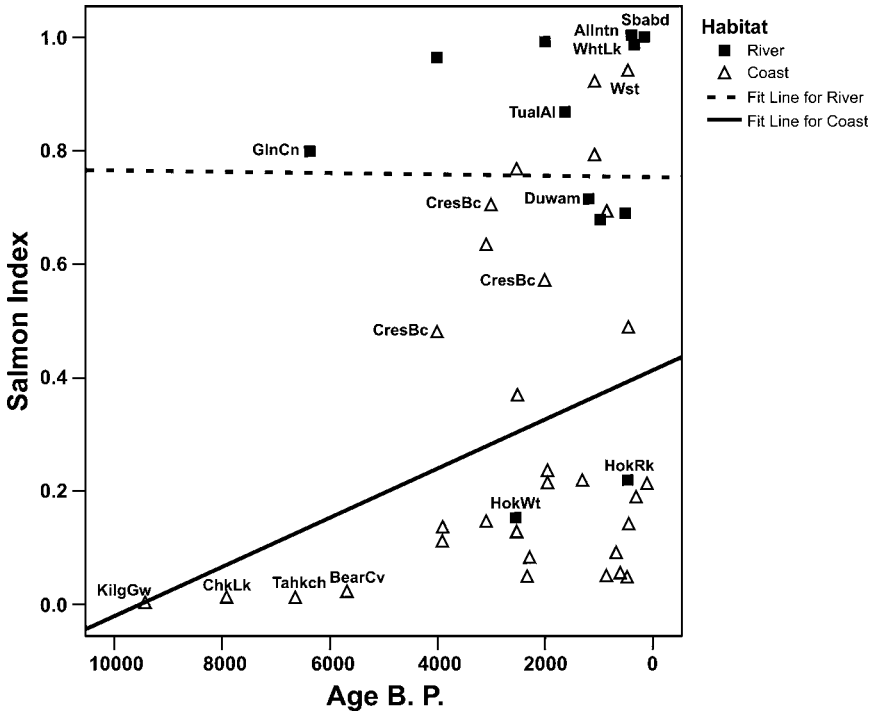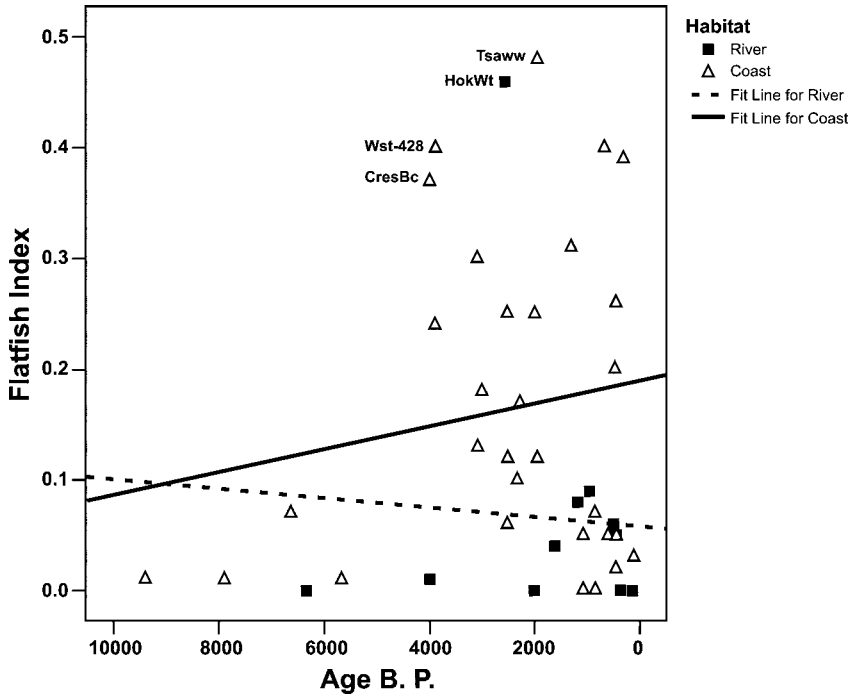
Fig. 4. Abundance Index for salmon (NISP Salmonid/NISP All Fish) South-Central Northwest Coast and early Holocene assemblages (coastal: $r = 0.333$, $p = 0.068$; riverine: $r = 0.007$, $p = 0.98$). Best-fit regression line drawn for each habitat type. Sites noted in text are indicated with abbreviations; see Tables I and III for key.

ratios. Coastal locations, on the other hand are more variable. Most have ratios less than 0.25, while moderate to high ratios at Crescent Beach and the later West Point components are not readily explained by proximity to salmon streams. Further study of paleoenvironments and shoreline changes is needed to understand these patterns.

We can control for local environmental factors by examining change at individual sites. If widespread regional processes such as sea level stabilization or introduction of storage account for patterning, we would expect parallel changes in separate sites, but this does not occur (Fig. 5). While two sites spanning over 4000 years show a long-term increase in salmon (Glenrose Cannery and West Point-45KI28) that appears to support the regional model of salmon intensification, other sites show fluctuations or declines (Crescent Beach, Decatur Island). Even the Glenrose Cannery record only weakly supports the model. With ratios over 0.8 as long ago as
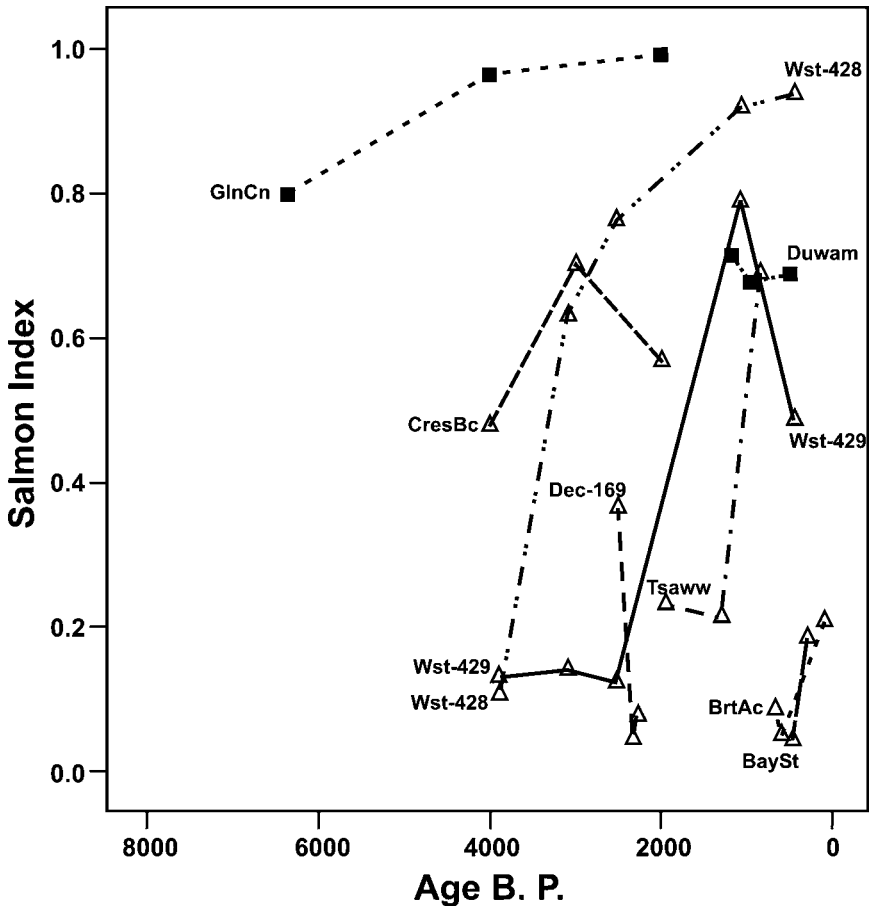
Fig. 5. Abundance Index for salmon (NISP Salmonid/NISP All Fish) South-Central Northwest Coast and early Holocene assemblages, tracking changing ratios within sites (single component sites excluded). Key to site abbreviations, see Table III.

6300 BP, a shift to indices closer to 1.0 by 4000 BP may not represent a significant change in adaptation. Clearly, complex factors contribute to these patterns, but changes in season of use or local environmental change seem more plausible than region-wide changes in subsistence strategies. Overall, these records do not support general models for increasing specialized use of salmon *or* decline in salmon use due to resource depression.

Sites in the coastal habitat show a slight trend in increased herring use ($r = 0.369, p = 0.04$). Herring is present in all the early Holocene coastal assemblages but only in low ratios (Fig. 6), until after 2500 BP when it occurs
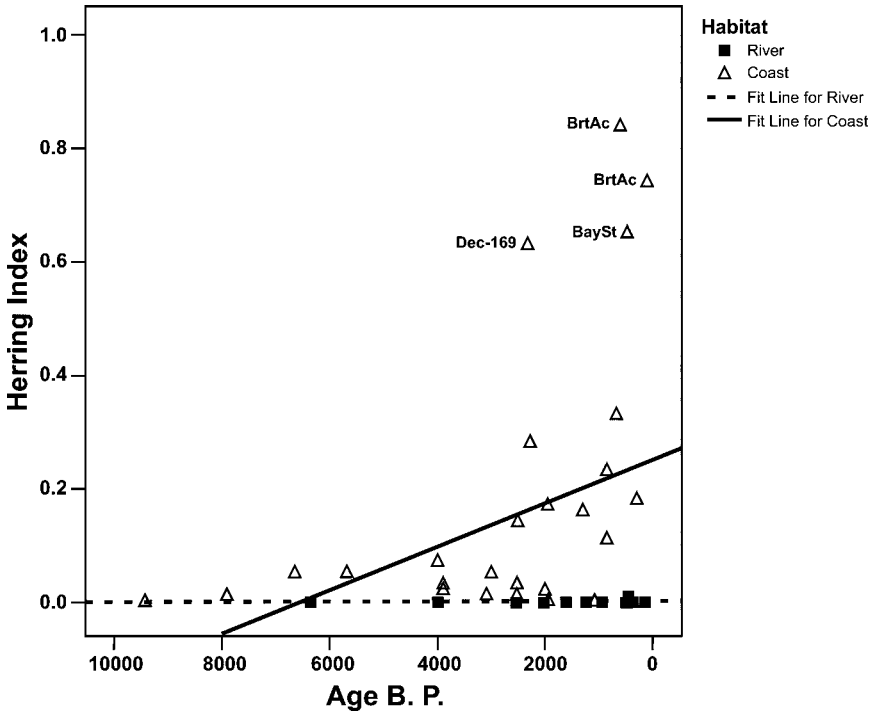
Fig. 6. Abundance Index for herring (NISP Herring/NISP All Fish) South-Central Northwest Coast and early Holocene assemblages (coastal: $r = 0.369$, $p = 0.04$; riverine: $r = 0.213$, $p = 0.51$). Best-fit regression line drawn for each habitat type. Sites noted in text are indicated with abbreviations; see Table III for key.

in moderate amounts in several components, and in a high ratio (0.6) at Decatur Island (SJ169/AU2). The herring index is not correlated with assemblage sample size ($r_s = 0.216$, $p > 0.10$). The highest ratios are late, at about 650 BP, at Burton Acres and Bay Street midden. Because herring are so small bodied, the development of specialized herring fishery sites indicated here (see also Arcas Consulting Archeologists, 1999; Kopperl, 2001), may be best interpreted in light of mass capture methods. Herring rakes are the method most frequently cited in ethnohistoric sources.

Based on the abundance of flatfish at the Hoko River wet site, Croes and Hackenberger (1988) suggest that flatfish are a storable resource that could be subject to intensification. Flatfish are part of Native fisheries from the early Holocene on (Table II) but occur in low ratios (Fig. 7). After 4000 BP, flatfish make a moderate contribution at a number of sites throughout time, but nowhere in such high ratios as herring or salmon. The two highest

Fig. 7. Abundance Index for flatfish (NISP Flatfish/NISP All Fish) South-Central Northwest Coast and early Holocene assemblages (coast: $r = 0.166$, $p = 0.373$; riverine: $r = 0.061$, $p = 0.85$). Best-fit regression line drawn for each habitat type. Sites noted in text are indicated with abbreviations; see Table III for key.

ratios (about 0.5) are found at the Hoko River wet site, and the Tsawwassen Marpole component; ratios are almost as high one thousand years earlier at Crescent Beach (St. Mungo) and West Point (KI428-Component 1). Overall, there is no regional scale pattern of increased use (coastal sites: $r = 0.166$, $p = 0.373$; the flatfish index is not correlated with assemblage sample size: $r_s = 0.048$, $p > .50$).

Mammals

Cervids, the most ubiquitous mammal family, occur in all components with at least 30 identified mammal remains (Tables V, IX) and are most abundant in all but four. Most sites have both deer and wapiti, which Lyman (1995b) has shown alternate in dominance in Puget Sound faunas. The second most widely distributed taxon, harbor seal, ranks first only at West Point (45KI429-Component 1). Canids (mainly domestic dogs) are

Table IX. Ubiquity and Relative Abundance of Mammal Families in 25 Assemblages, South-Central Northwest Coast (Includes Assemblages With ≥30 NISP; the 12 Most Ubiquitous Families are Shown Below)

Taxon	Ubiquity (frequency of occurrence in assemblages)	Abundance (frequency of assemblages in which taxon is ranked first)
Cervidae (deer, wapiti)	25	21
Phocidae (true seal)	15	1
Canidae (dog, coyote, wolf, fox)	15	1
Castoridae (beaver)	16	0
Procyonidae (racoon)	13	0
Mustelidae (river otter, mink, weasel, marten)	12	0
Ursidae (bear)	11	0
Leporidae (rabbit, hare)	9	0
Aplodontidae (mountain beaver)	8	0
Delphinidae (dolphin)	5	0
Felidae (cats, lynxes & allies)	5	0
Otariidae (eared seal)	3	2

also extremely widespread and the dominant mammal in one Tsawwassen site component where at least some are from deliberate interments and ceremonial contexts (Arcas Consulting Archeologists, 1999). Canids are second in abundance in seven other assemblages. Beavers are the fourth most ubiquitous taxon. Other families, including carnivores (mustelids, procyonids, ursids and felids), as well as rabbit/hare and mountain beaver, are found in less than half the assemblages.

Among marine mammals, dolphins and fur seals have a restricted distribution, but the latter dominate at Hoko River Rockshelter and Ozette, which reflect specialized marine mammal hunting (Carlson, 2003; Huelsbeck, 1994a). Sea otter are fifth in abundance at Ozette, and sixth at Hoko River Rockshelter; only a single bone has been identified in Puget Sound (Decatur Island SJ169 AU2; Table V), supporting a previous observation that sea otter are scarce in the inland waters of the southern northwest coast (Hanson and Kusmer, 2001). In our samples, whale is positively identified only at Ozette on the outer coast.

Most previous synthetic studies of Pacific Northwest coastal subsistence have not considered the role of terrestrial mammals or developed expectations about changes in mammal use (Hodgetts and Rahemtulla, 2001). It is reasonable to expect that increasing logistical land-use with specialized procurement sites for example, should result in less even assemblages over time and regional intensification models in general would suggest increasing specialization and declining evenness. We developed predictions from the prey choice model for changing animal use in the "terrestrial patch," in which we include freshwater wetlands on the basis that at this regional

scale, wetland areas do not represent a clearly distinct patch choice for hunters. There are obligate wetland species, such as beaver, and very extensive areas of wetlands that may have been targeted on separate forays. Yet on the other hand, some species, such as wapiti, move in and out of wetlands, and there are small wetland patches throughout the region that are imbedded in larger forest and prairie areas and would not require separate forays. Hunters targeting terrestrial game may have also been attracted to local wetlands as part of hunting strategies; human hunters have long used wetland areas to mire large game. Cervids are far and away the largest mammal in the terrestrial patch (with body size ranging from 45 to 500 kg [Maser, 1998]) and would thus have been the highest ranked. Small mammals represented in regional sites by the families Aplodontidae, Procyonidae, Mustelidae, Castoridae, Leporidae, Muridae [muskrat], Sciuridae [marmot], and Felidae, are much smaller, and, according to the model, would have entered the diet in greater frequency with declining encounters with high ranked cervids. [Canid remains were excluded from the comparison, since most of the remains identified to species were from dog rather than a hunted resource]. We constructed the Cervid Index (NISP Cervidae/NISP Cervidae + NISP small mammals) to evaluate potential for resource depression of the higher ranked cervids.

As shown in Fig. 8, coastal sites show a significant trend of decreasing evenness over time ($r = 0.615$, $p = 0.009$), indicating more focused use of certain mammal taxa over time or shift in land-use towards greater logistical organization or perhaps both factors at work. Temporal trends are not evident for riverine sites, which generally show higher evenness than coastal sites for all time periods. The four upland components from the Sequim site have low evenness values; other site records indicate this site was a specialized deer and wapiti hunting camp for the duration of occupation (Morgan, 1999). There is no correlation between evenness and assemblage sample size ($r_s = 0.223$, $p > 0.20$).

Contrary to the prediction from the resource depression model, the Cervid Index actually *increases* over time in coastal sites (Fig. 9): the correlation is only moderate (and not significant) when all the sites are included ($r = 0.423$, $p = 0.132$), but increases when the Bear Cove site (located hundreds of kilometers north of the other sites) is excluded ($r = 0.643$, $p = 0.018$). Riverine sites show no trend in the Cervid Index. This index is not related to sample size ($r_s = -0.028$, $p > 0.5$).

Birds

The role of birds in Northwest Coast subsistence has received much less attention than mammals and fish. Bovy's recent overview (2002b) of
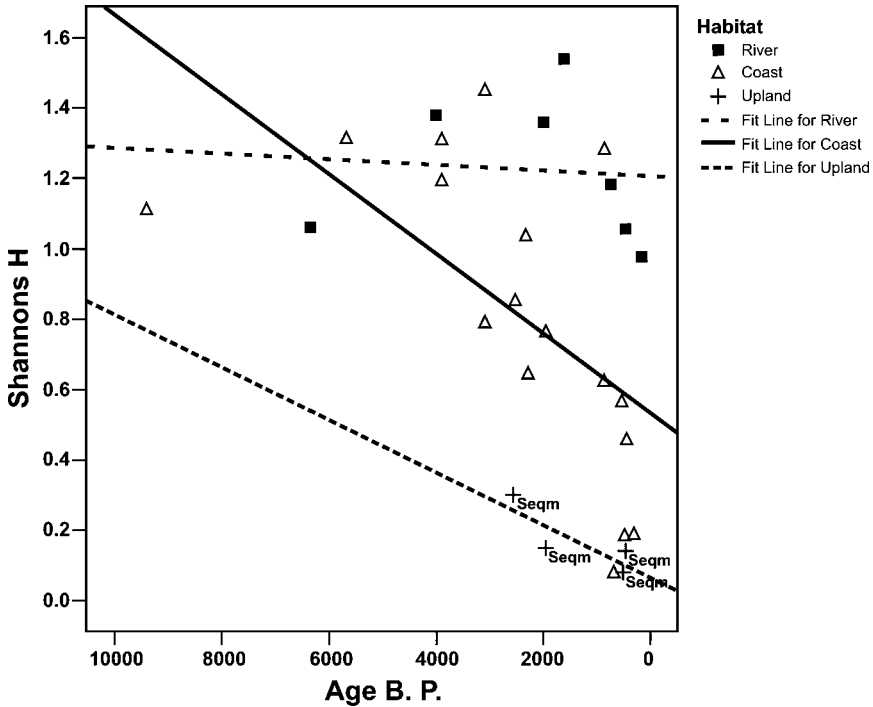
Fig. 8. Scatterplot of evenness values (Shannons H) based on mammal family, South-Central Northwest Coast and early Holocene assemblages (coastal: $r = 0.615$, $p = 0.009$; riverine: $r = 0.082$, $p = 0.86$; upland: $r = 0.834$, $p = 0.16$). Best-fit regression line drawn for each habitat type. Sites noted in text are indicated with abbreviations; see Table III for key.

taphonomic factors responsible for overrepresentation of wing elements in multiple Northwest Coast sites illustrates the variety of insights provided by avifaunal records. Ethnographic accounts show that birds had a wide variety of uses and that highly sophisticated capture methods were used (DePuydt, 1994). This suggests the possibility of specialized bird procurement locations and gear, but these topics have been little researched.

Table VI shows the 17 south-central Northwest Coast assemblages with remains that were identified to at least family. The small number of assemblages with identified specimens partly is because bird remains were not systematically analyzed at over half of the sites. Analytic bias though, does not alter the conclusion that bird bone frequency is much lower than fish and mammals. Only 10 assemblages contain 30 NISP or more. Despite low bone counts, each assemblage has at least four families (Table VI). Overall, aquatic birds comprise 94% of the total NISP. As shown in Table X,
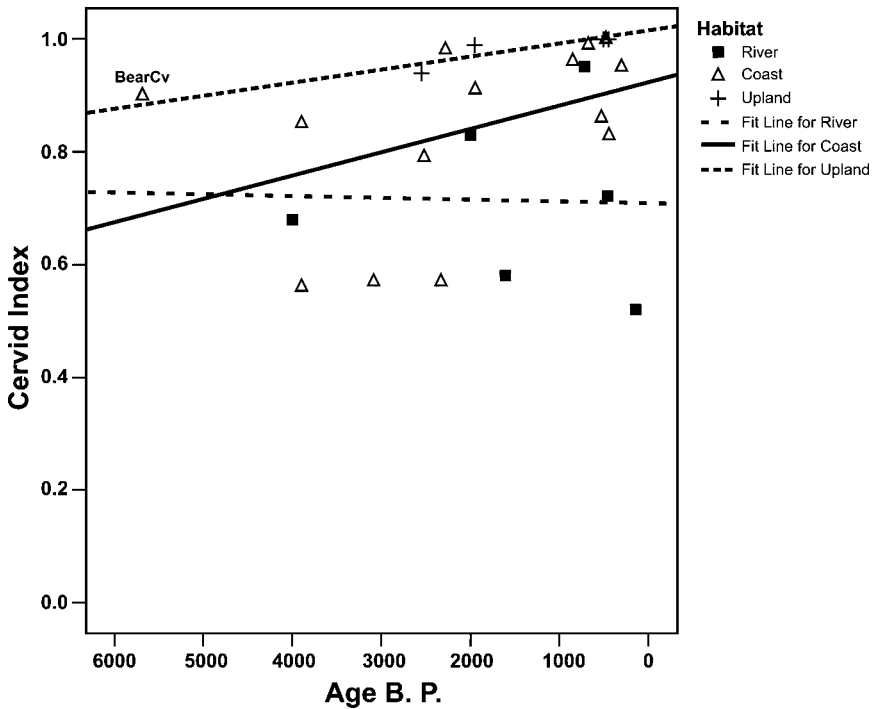
Fig. 9. Abundance Index for cervids (NISP Cervidae/NISP Cervidae + NISP small mammals) South-Central Northwest Coast assemblages (coastal: $r = 0.423$, $p = 0.132$; riverine: $r = 0.029$, $p = 0.956$; upland: $r = 0.849$; $p = 0.151$). Best-fit regression line drawn for each habitat type.

Anatidae (ducks, swans, and geese) is both the most ubiquitous and highest ranking family, being first or second in abundance in all assemblages except one. Grebes and gulls each rank first in one assemblage (Duwamish-II and Ozette, respectively). At both the Hoko River wet site and Decatur Island (SJ169-AU 2), alcids (auklets, murrelets, and murres) are most frequent.

Marine Invertebrates

As indicated by our early Holocene coastal assemblages (Table II) and others (Indian Sands—Moss and Erlandson, 1998b; Hidden Falls—Erlandson, 1989), the earliest documented occupants along the coast harvested invertebrates. In the Puget Sound-region, the earliest known shell assemblage is the Dupont Southwest Site (ca. 5500-years-old; Wessen, 1989). Invertebrate remains were present in virtually all of our later

Table X. Ubiquity and Relative Abundance of Bird familIes in 10 Assemblages, South-Central Northwest Coast (Includes Assemblages With ≥30 NISP; the Eight Most Abundant Families are Shown)

Taxon	Ubiquity (frequency of occurrence in assemblages)	Abundance (frequency of assemblages in which taxon is ranked first)
Anatidae (ducks, swans, geese)	10	6
Podicipedidae (grebe)	9	1
Gavidae (loon)	8	0
Laridae (jaeger, gull, tern)	7	1
Accipitridae (eagle, kite, hawk)	6	0
Alcidae (auk)	5	2
Phalacrocoracidae (cormorant)	5	0
Corvidae (jay, crow)	5	0

Holocene assemblages, although not necessarily indicated in Table VII because of limited analysis or quantification. Four families occur in most of the assemblages (Table XI): venerids (little neck and butter clams), mussels, barnacles, and cockles. Venerids are highest ranked in 13 of the 23 components, mussels in six. Cockles (Cardidae) rank highest in three assemblages, and dogwinkles (Thaidae) in one. Although barnacles never rank first, they rank second in five assemblages.

Researchers around the world have debated the food value of shellfish—are they low-ranking starvation food, or did their ease of collection and availability during seasons of low resource productivity make them an important constituent of a broad marine adaptation (see reviews in Erlandson, 2001; Moss, 1993)? On one hand, their antiquity and widespread occurrence in the Pacific Northwest suggest they were a consistent staple. On the other hand, scholars have cited the relatively late appearance of

Table XI. Ubiquity and Relative Abundance of Marine Invertebrate Taxa in 22 Assemblages, South-Central Northwest Coast (Includes Assemblages Quantified Using Weight; the 10 Most Abundant Taxa are Shown)

Taxon	Ubiquity (frequency of occurrence in assemblages)	Abundance (frequency of assemblages in which taxon is ranked first)
Veneridae (venus clam)	22	13
Mytilidae (mussels)	22	5
Cirripedia, subclass (barnacles)	21	0
Cardiidae (cockle)	21	3
Thaididae (dogwinkles)	18	1
Mactridae (horse clam)	17	0
Lottidae (limpet)	15	0
Tellinidae (sand, bentnose clam)	15	0
Ostreidae (native oyster)	10	0
Naticidae (moonsnail)	10	0

large shell middens (after 4500 BP) as evidence that shellfish are low ranked foods. Using the widespread occurrence of shell middens to argue shellfish were an important food staple is questionable because of discovery and preservation biases. Shell middens are highly visible, increasing chance of discovery over nonshell bearing sites and shell also promotes bone preservation. Therefore, the remains of animal procurement activities spatially distinct from shellfish use are undoubtedly underrepresented in the record. The broader question of shellfish use relative to other resources cannot be addressed with most Pacific Northwest assemblages because of noncomparable recovery and quantification of invertebrates relative to other animals.

We *can* evaluate changes in the types of marine invertebrates used and implications for paleoenvironmental change and subsistence. A number of researchers have noted an apparent shift from taxa that utilize rocky substrates to soft-sediment burrowing species over time. Cannon (1991) has explained the pattern as a broad regional paleoenvironmental trend related to sediment build-up along the coastline with sea level stabilization. According to this view, sedimentation of coastal environments associated with higher, stable sea levels reduced rocky intertidal habitat and enhanced productivity of soft bottom habitats. Stilson (1972) predicted a similar trend related to delta progradation. The "mussel-to-clam" shift is also predicted by Botkin (1980) in southern California from optimal foraging models. He argues that foragers would initially target mussel beds (given ease of access and clustering habit, thus lower procurement costs) and shift to burrowing clams when mussel beds were depleted from overharvesting.

To evaluate empirically whether this suggested shift occurred across the subregion, regardless of cause, an AI comparing abundance of hard substrate taxa relative to soft-bottom taxa was calculated. Figure 10 suggests a slight but not significant trend towards increasing use of soft-sediment taxa at coastal sites ($r = 0.256$, $p = 0.276$). The two sites with the highest ratios of hard-substrate taxa, Allentown and White Lake, are among the latest assemblages. Interestingly enough, these are riverine sites, mainly salmon fishing camps, located several miles from saltwater during the time of occupation. Native inhabitants probably transported shellfish to the site by canoe to consume while they fished (Lewarch *et al.*, 1996).

A confounding factor may be local environmental variation, which we can control for by examining change at individual sites. If a regional explanation such as increased sedimentation associated with sea level change accounts for patterning, we would expect relatively synchronous changes across separate sites, but this does not occur (Fig. 11). Of the multicomponent sites, Crescent Beach and West Point show the expected trend, while the opposite trend occurs at Tsawwassen, which overlaps with West Point
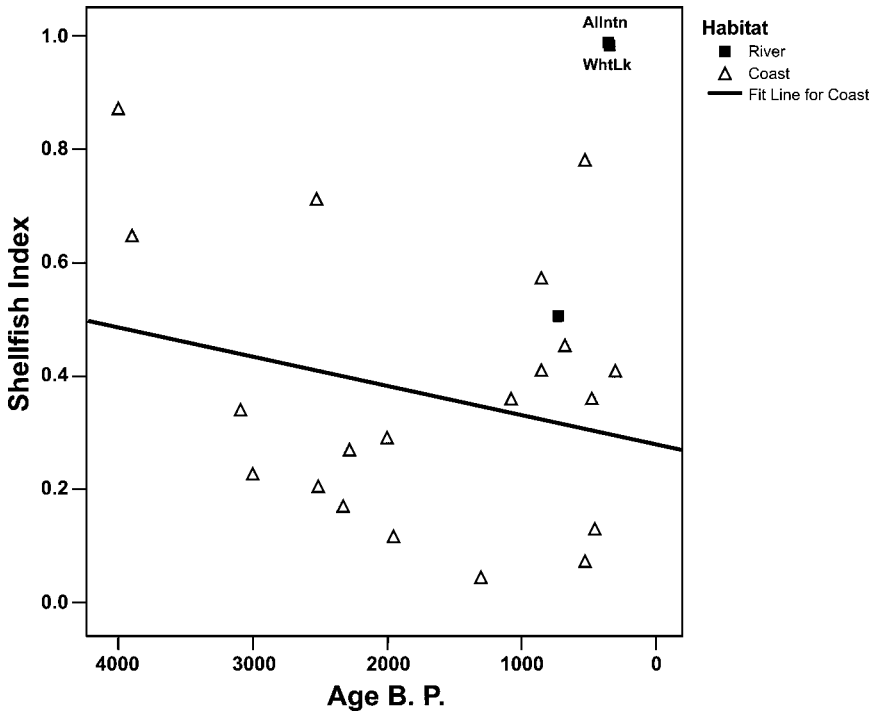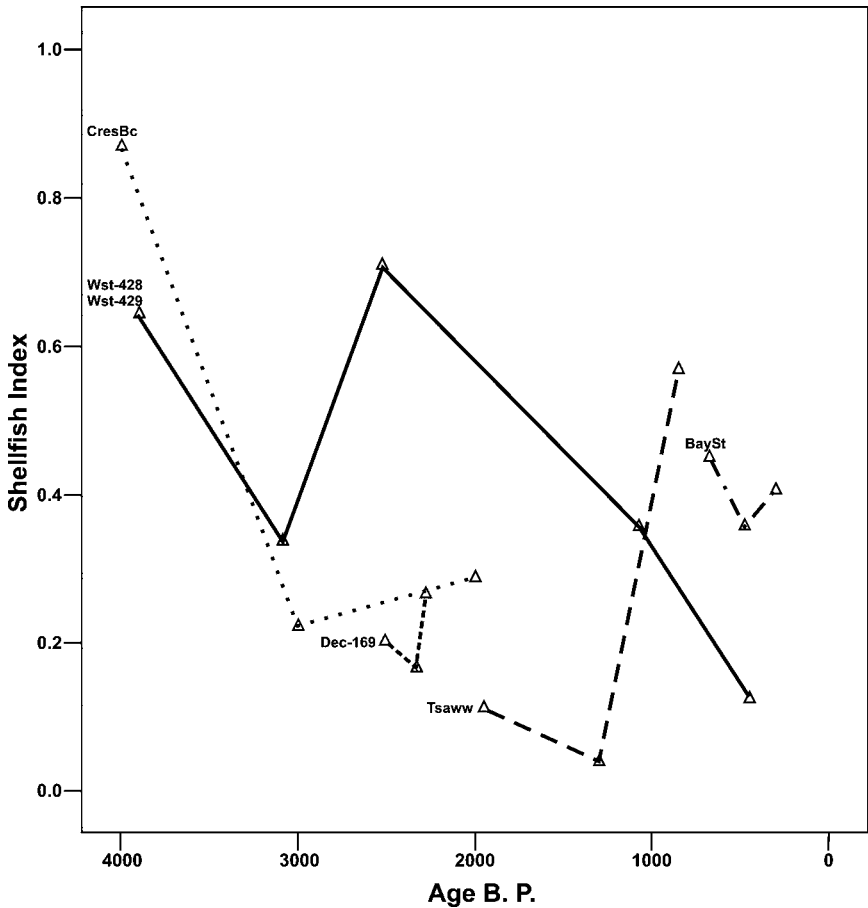
Fig. 10. Abundance Index for shellfish (Wt. Hard Substrate Taxa/Wt. Hard Substrate Taxa + Wt. Soft Substrate Taxa) South-Central Northwest Coast assemblages (coastal: $r = 0.256, p = 0.276$). Best-fit regression line drawn for coastal assemblages. Sites noted in text are indicated with abbreviations; see Table III for key.

temporally. Finer chronological resolution at Bay Street midden and Decatur Island reveals minor fluctuations in ratios, but no strong trend.

Summary

Abundance measures for salmon, cervids, and rocky substrate shellfish calculated for the South-Central Northwest Coast assemblages show no strong declines as would be predicted if resource depression occurred. Neither do the AIs or the evenness index provide strong evidence for development of a focal economy at the regional scale. Salmon are the most widespread and abundant fish, but their use does not increase over time relative to other fish, contrary to the implications of many Pacific Northwest resource intensification models. There is a distinct segregation of specialized fishery sites by habitat, with specialized salmon fisheries in riverine

Fig. 11. Abundance Index for shellfish (Wt. Hard Substrate Taxa/Wt. Hard Substrate Taxa + Wt. Soft Substrate Taxa), South-Central Northwest Coast assemblages, tracking changing ratios across components within sites (single component sites excluded); see Table III for key to abbreviations.

locations throughout the time span. The only fish taxon that shows temporal patterning is herring: its increased abundance in coastal sites after 2500 BP and its dominance in some assemblages after 700 BP are evidence for development of specialized fishing strategies, and suggest logistical organization of settlement and land use.

This overview calls attention to the importance of large terrestrial game (wapiti, deer), which has been little considered in syntheses of Northwest Coast subsistence. There is evidence that cervid use increases through

time (relative to small mammals) and the decline in mammal evenness values over time suggests increasing specialization on certain mammal taxa. Both patterns may relate in part to development of logistical organization and specialized upland hunting camps, as at Sequim, but could also reflect changes in habitat extent due to anthropogenic or other environmental changes. There is a consistent contrast between animals exploited at Ozette and Hoko River Rockshelter on the outer coast (where marine mammals comprise 96 and 84% of the mammal fauna, respectively) versus the sites along the inland waterways of Puget Sound and the Gulf of Georgia. A marine mammal focus is indicated at the former, but with only two components and limited time depth, change through time cannot be examined.

NORTHERN COLUMBIA PLATEAU (7000−150 BP)

Faunal records are presented from 82 components at 33 sites analyzed as part of two large hydroelectric projects on the upper Columbia River in the Northern Plateau (Fig. 1; Table XII). This data set differs in several ways from the Northwest Coast one. The assemblages are from a more limited geographic area, thus there is a greater likelihood that contemporaneous sites represent the same cultural system, although that system is not represented in its entirety because of the riverine bias in site sampling. Site components were classified by function (residential base, camp, and station), allowing us to consider how settlement organization and site function affect faunal representation. Preservation of bone is not as good as in the coastal shell middens, but it is more consistent between different types of sites. In these assemblages, fish was collected from the same volumes as the other vertebrates, so evenness values were calculated across all vertebrates.

The vertebrate remains total 22,559 NISP, including 14,828 mammal, 4980 fish, 2746 reptile/amphibian, and five bird specimens; 72,919 freshwater mussel specimens were tallied from the Wells Project (Table XII). Cervidae is the most abundant and most ubiquitous vertebrate taxon; Salmonidae is a close second (Table XIII). Marmots are more widespread and abundant than either bovids or antilocaprids. Remains of reptiles and amphibians are widespread. Turtle (*Chrysemys* sp.) remains comprise over half the specimens in this joint category. Specimens were identified mainly by carapace and plastron fragments, which may explain their abundance (reptile and amphibian ranks first in eight components). Only five bird specimens were identified to family level (Table XII). Since bird remains were not analyzed in one of the projects, the low frequency is somewhat misleading, but even if specimens had been systematically documented, their numbers would probably be much lower than other vertebrates.

Table XII. Frequency of Animal Family (NISP), by Site, Site Type, and Time Unit, Northern Columbia Plateau

Site No.	DO204	DO204	DO204	DO204	DO211	DO211	DO211	DO211	DO214	DO214	DO214	DO214	DO242	DO242
Site Type	2	3	3	3	3	3	1	1	2	2	2	3	2	2
Age (BP)	700	2800	4400	5000	2900	2900	2900	4200	1000	1200	1100	3000	300	700
Fish														
Salmonidae (salmon & trout)					33	126	858	11	7	40	189	5	4	
Cyprinid/catostomid (minnow/sucker)							8		3	26	8			
Reptilia/amphibia birds			5	6	5	21	30	13	50	163	12	9	1	
Strigidae (owl)														
Phasianidae (grouse)														
Accipitridae(eagle, etc.)														
Mammals														
Antilocapridae (pronghorn)									1	12	22			1
Bovidae (bison, sheep, goat)					1				4	15	17	3	3	2
Canidae (dog, etc.)					1		1			2				3
Castoridae (beaver)												5		1
Cervidae (deer, wapiti)	2	2	1		6	22	12	2	8	72	90	13	9	15
Equidae (horse)														
Erethizontidae (porcupine)														
Felidae (cats, etc.)														
Leporidae (rabbit, hare)		1				1	1	2	2		3		3	
Muridae (muskrat)								1	1					
Mustelidae (river otter, etc)		1			1	1		3			1		1	
Procyonidae (racoon)														
Sciuridae (marmot)		3	1		5	15	10	8	1	14	20	84		
Ursidae (bear)														3
NISP all vertebrates	2	7	8	6	52	186	920	40	77	344	362	119	21	25
Invertebrates														
Margaritiferidae														
Unionidae														

Table XII. Continued

	DO242	DO242	DO243	DO243	DO243	DO243	DO243	DO273	DO273	DO273	DO282	DO282	DO282	DO282
Site No.	1	3	3	2	2	3	3	3	3	3	3	3	3	3
Site Type / Age (BP)	3500 (BP)	5000 (BP)	1500 (BP)	3000 (BP)	3000 (BP)	5000 (BP)	1200 (BP)	1000 (BP)	5000 (BP)	1000 (BP)	5000 (BP)	5000 (BP)	5000 (BP)	5000 (BP)
Fish														
Salmonidae (salmon & trout)	42	8	2	9	21	4					1	2	8	3
Cyprinid/catostomid (minnow/sucker)														
Reptilia/amphibia birds	52	2	2		5						1	2	18	1
Strigidae (owl)														
Phasianidae (grouse)														
Accipitridae (eagle, etc.)														
Mammals														
Antilocapridae (pronghorn)	2			1		1								
Bovidae (bison, sheep, goat)	190	2		4										
Canidae (dog, etc.)	22		1			2	6							
Castoridae (beaver)	3													
Cervidae (deer, wapiti)	345	4	8	11	12	2	5	2			2	1		
Equidae (horse)														
Erethizontidae (porcupine)														
Felidae (cats, etc.)														
Leporidae (rabbit, hare)											2	1		
Muridae (muskrat)														
Mustelidae (river otter, etc)														
Procyonidae (racoon)														
Sciuridae (marmot)	21	1	1	2	6	10			2	1		2	2	
Ursidae (bear)														
NISP all vertebrates	677	17	14	27	44	19	11	2	2	1	6	8	28	4
Invertebrates														
Margaritiferidae														
Unionidae														

Table XII. Continued

	DO285	DO285	DO285	DO285	DO326	DO326	DO326	DO326	OK2	OK2	OK2	OK2	OK2A	OK2A	OK2A
Site No. / Site Type	3	3	3	3	2	3	2	3	1	1	1	2	2	1	3
Age (BP)	300	1000	1700	3000	200	1060	3000	3100	300	1300	3200	4000	1000	3000	5000
Fish															
Salmonidae (salmon & trout)	62	11	9	5	6	2	10	67	73	104	90	104	4	133	79
Cyprinid/catostomid (minnow/sucker)	3				2	1			12	6	1	12	1		
Reptilia/amphibia birds	14	6	120	50	4	6	25	134	15	129	24	17		12	27
Strigidae (owl)															
Phasianidae (grouse)															
Accipitridae (eagle, etc.)															
Mammals															
Antilocapridae (pronghorn)	3	1	15	8	2	28	1	14	3	10	2	1		5	
Bovidae (bison, sheep, goat)		1	1	2	15	37	6	4	2	18		31		187	
Canidae (dog, etc.)						1				5	5	1			
Castoridae (beaver)										4	2				
Cervidae (deer, wapiti)	8	9	22	13	64	27	5	31	582	689	281	476	20	63	4
Equidae (horse)									8						
Erethizontidae (porcupine)													3		
Felidae (cats, etc.)										1		1			
Leporidae (rabbit, hare)					5	5		1			2	4	1		
Muridae (muskrat)															
Mustelidae (river otter, etc)			1		2	2		53	7						
Procyonidae (racoon)															
Sciuridae (marmot)	7	2	16	31	19	43	51	108	13	12		2	1		1
Ursidae (bear)											1				
NISP all vertebrates	97	30	185	109	119	152	98	412	715	978	408	649	30	400	111
Invertebrates															
Margaritiferidae															
Unionidae															

Table XII. Continued

Site No.	OK2A	OK4	OK4	OK4	OK11	OK11	OK18	OK18	OK18	OK250	OK250	OK250	OK258
Site Type	3	2	1	3	2	1	3	2	3	2	1	2	1
Age (BP)	5000 (BP)	700 (BP)	2400 (BP)	3600 (BP)	3400 (BP)	4800 (BP)	2000 (BP)	3300 (BP)	3800 (BP)	2000 (BP)	3200 (BP)	4400 (BP)	600 (BP)
Fish													
Salmonidae (salmon & trout)	9	21	532	27	63	276			2	7	159	10	20
Cyprinid/catostomid (minnow/sucker)		3	21	3	138	522					10		7
Reptilia/amphibia birds	6	9	146	3	254	482		37	1	93	191	66	63
Strigidae (owl)													
Phasianidae (grouse)													
Accipitridae (eagle, etc.)													
Mammals													
Antilocapridae (pronghorn)			3		10	56							28
Bovidae (bison, sheep, goat)		10	54	13	17	345				11	4	32	344
Canidae (dog, etc.)			4	1	19	30				3	32	2	25
Castoridae (beaver)			1		5	9							1
Cervidae (deer, wapiti)		81	687	59	256	1456				147	488	104	1500
Equidae (horse)													19
Erethizontidae (porcupine)					6	68							
Felidae (cats, etc.)						5					1		
Leporidae (rabbit, hare)					2	14							
Muridae (muskrat)					2	1							
Mustelidae (river otter, etc)						11							
Procyonidae (racoon)	1						1	1	1	1			
Sciuridae (marmot)		3	9	1	62	261					6	5	10
Ursidae (bear)					1	4							2
Total Vertebrate NISP	16	127	1457	107	835	3540	1	38	4	262	891	219	2020
Invertebrates													
Margaritiferidae													
Unionidae													

Table XII. Continued

Site No. Site Type Age (BP)	OK258 1 2800 (BP)	OK287/8 3 700 (BP)	OK287/8 2 900 (BP)	OK287/8 1 1000 (BP)	OK287/8 2 1500 (BP)	OK287/8 2 4600 (BP)	OK287/8 2 5000 (BP)	DO189 1 3000 (BP)	DO372 1 630 (BP)	DO372 1 2300 (BP)	DO387 2 6400 (BP)	DO387 2 6700 (BP)	DO387 2 7700 (BP)
Fish													
Salmonidae (salmon & trout)	65		2	5	4		4	609			64		14
Cyprinid/catostomid (minnow/sucker)	33									1			
Reptilia/amphibia	210			1		17		60					1
Birds													
Strigidae (owl)													
Phasianidae (grouse)													
Accipitridae (eagle, etc.)													
Mammals													
Antilocapridae (pronghorn)	11		11	37	7	35	2	7		25		1	
Bovidae (bison, sheep, goat)	165		4	16	359	4	8	16		31			
Canidae (dog, etc.)	148				2	5		3	4	9			4
Castoridae (beaver)	3				1	1		1	2	12			
Cervidae (deer, wapiti)	1854	1	13	114	60	64	26	264	2	24	2	2	2
Equidae (horse)													
Erethizontidae (porcupine)													
Felidae (cats, etc.)	2							1					
Leporidae (rabbit, hare)								1	6	14	6		23
Muridae (muskrat)					4	15	1						
Mustelidae (river otter, etc)										9			
Procyonidae (racoon)													
Sciuridae (marmot)	9				4	1		7		1			
Ursidae (bear)	2								2	10			
NISP all vertebrates	2502	1	30	173	441	142	41	968	16	136	72	3	44
Invertebrates													
Margaritiferidae								609			2099	81	7285
Unionidae								2			407	53	414

Table XII. Continued

Site No.	OK69	OK69	OK74	OK74	OK382	OK383	OK383	OK422	OK422	OK424	OK424	
Site Type	1	3	2	1	1	1	3	3	3	3	2	Total
Age (BP)	4000 (BP)	4300 (BP)	2900 (BP)	4100 (BP)	4000 (BP)	4400 (BP)	4300 (BP)	6000 (BP)	6500 (BP)	6700 (BP)	7300 (BP)	
Fish												
Salmonidae (salmon & trout)	6	4		6		29	8	1		2	3	4084
Cyprinid/catostomid (minnow/sucker)	2	6		59		11	1			1		896
Reptilia/amphibia Birds			7	1		20	2			81	14	2746
Strigidae (owl)						3						3
Phasianidae (grouse)						1						1
Accipitridae (eagle, etc.)						1						1
Mammals												
Antilocapridae (pronghorn)	41	8				29	1					403
Bovidae (bison, sheep, goat)	4		1			8	1				29	2026
Canidae (dog, etc.)				1	14	1		1		11		407
Castoridae (beaver)				1	8				1			61
Cervidae (deer, wapiti)	55	9	2	1		59	1	1		14	3	10291
Equidae (horse)												27
Erethizontidae (porcupine)					1							79
Felidae (cats, etc.)												9
Leporidae (rabbit, hare)	31	15		3	48			2	7	32	190	433
Muridae (muskrat)				1					2			25
Mustelidae (river otter, etc)							1	1				94
Procyonidae (racoon)												1
Sciuridae (marmot)	1		1		9	16		1		4		955
Ursidae (bear)					7						1	17
NISP all vertebrates	140	42	11	82	87	179	14	7	10	145	240	22559
Invertebrates												
Margaritiferidae	66	56	2171	2202		381	124	13639	18082	5096	71	51962
Uniomidae		162		6316		14	13	4337	8431	808		20957

Note. Chief Joseph Project (Livingston, 1985—fauna; Salo, 1985—context and age); Sites in italics, Wells Project (Chatters, 1986; Lyman 1988; Galm and Lyman, 1988). Site types— 1 = residence, 2 = camp, 3 = station.

Table XIII. Ubiquity and Relative Abundance of Vertebrate Taxa in Northern Plateau Assemblages in 51 Site Components (Includes Assemblages With ≥30 NISP; the 11 Most Ubiquitous are Shown)

Taxon	Ubiquity (frequency of occurrence in assemblages)	Abundance (frequency of assemblages in which taxon is ranked first)
Cervidae (deer, wapiti)	51	23
Salmonidae (salmon and trout)	49	10
Class reptilia/amphibia[a]	43	8
Leporidae (rabbit, hare)	26	4
Sciuridae[b] (marmot)	44	3
Bovidae (sheep, goat and bison)	37	3
Canidae (dog, coyote, wolf, fox)	32	0
Antilocapridae (pronghorn antelope)	27	0
Cyprinidae/Catostomidae	27	1
Castoridae (beaver)	15	0
Mustelidae		
(River otter, mink, weasel, marten)	11	0

[a]Includes two vertebrate classes, thus is not comparable in taxonomic level, but is included for comparison to highlight the presence of these classes.
[b]Includes marmot only as these are likely to result from human use.

Expected Trends in Faunal Assemblages

Climate has been given a larger role in reconstructions of human subsistence in the interior than on the coast, because of the assumption that animal populations in this arid sagebrush steppe environment would be limited by the relatively low productivity and thus sensitive to changes in terrestrial productivity. Multiple climate records for the interior Pacific Northwest suggest warmer, drier conditions between ca. 8000–4500 BP followed by cooler and moister conditions (Chatters, 1998; Lyman, 1992). It is suggested that large game abundance was low in the early-mid Holocene and then increased with climatic amelioration in the later Holocene (see references in Lyman, 1992), predictions that we test against our faunal records.

Regarding more general issues of subsistence and settlement organization, researchers have been most interested in understanding the transition from early Holocene broad spectrum foraging to the less mobile, more organizationally complex collector strategy. A shift towards reduced mobility and use of central bases, generally defined by pithouse construction, began sometime between 5000 and 4000 BP Chatters (1995) suggests that this earliest phase of more settled life (Pithouse I, dating between 4400 and 3700 BP) continued to be based on broad spectrum foraging. People settled for extended periods in locations with close access to a range of resources and made little use of storage. He suggests this adaptive shift

to more settled life was triggered by increases in available moisture and primary productivity after 4500 BP According to Chatters, this life way ceased abruptly between ca. 3700 and 3600 BP because of rapid climatic cooling. A second phase of pithouse building (Pithouse II) associated with a collector strategy and logistical organization including reliance on storage, emerged at *ca.* 3400 BP when environmental conditions improved. This adaptation continued to the recent period. Parallel to the interpretation of increased logistical organization is the concept that resource use intensified, with a greater focus on salmon and deer over time.

If this model holds, we expect Pithouse I site assemblages to have the highest evenness values of the Holocene. We would expect relatively lower values in the early Holocene, with mobile foraging and people moving to resources as they become seasonally available and lower values in the later Holocene, in Pithouse II, if people are becoming more specialized and intensifying use of particular resources for storage. Site components had previously been assigned to one of three functional classes by Salo (1985) and Chatters (1984), residential base, camp, and station, based on presence or absence of house and other features, and artifact density and diversity. Components assigned to "residential base" contained a housepit or housefloor and at least one other kind of feature, other than midden. "Camps" were defined based on the presence of a living floor and one other feature. "Stations" had one or no features and were characterized by low artifact density and diversity. Stations tend to reflect specialized activities described as "quarries," "lithic scatters," "root camps," or "kill sites." Faunal representation was examined across site types and through time to examine organizational changes in subsistence strategies.

Resource depression models suggest that high ranked prey such as artiodactyls and salmon should decline relative to lower ranked prey (small mammals and nonsalmonid fish), particularly in the late Holocene as human populations become less mobile and increase in size. To test for salmon depression, we used the same index as defined for the coast, but in this case, the smaller, lower ranked fish are resident freshwater minnows and suckers. Salmonid remains recovered from project sites that can be identified to species are predominantly *Oncorhynchus tshawytscha* (chinook salmon), which range in weight between 4.5 and 11.3 kg (Behnke 2002), much larger than the resident fish. We calculated the Artiodactyl Index (NISP Artiodactyl/NISP Artiodactyl + NISP Small mammals) to track change in abundance of large terrestrial mammals. The Artiodactyl Index differs from the Cervid Index on the coast because for the Plateau, we group cervids with bovids and antilocaprids; also, in this case, the small mammal category includes remains from canids, given that site assemblages include examples of coyote, fox, as well as dog.

Fish

Three families were reported from the sites used here: salmonids, catostomids, and cyprinids, but the last two were not always distinguished in analysis so data are presented for the order Cypriniformes. These taxa tend to dominate other fish faunas on the Plateau, though burbot (freshwater cod, *Lota lota*) and sturgeon (*Acipenser* sp.) have been reported (Butler, 1999; Butler, 2004; Heitzmann, 1999).

Salmonid ubiquity (occurrence in 48 out of 51 assemblages) establishes their widespread use (Table XIII). Most assemblages are dominated by salmonids relative to other fish (Fig. 12); all but six site assemblages have ratios of 0.6 or higher. There is no evidence of a decrease indicating resource depression, if anything, salmon increases through time, possibly supporting specialization ($r = 0.443$, $p = 0.015$; the correlation between salmon index and assemblage sample size, $r_s = -0.322$, is not significant at the 0.05 level).
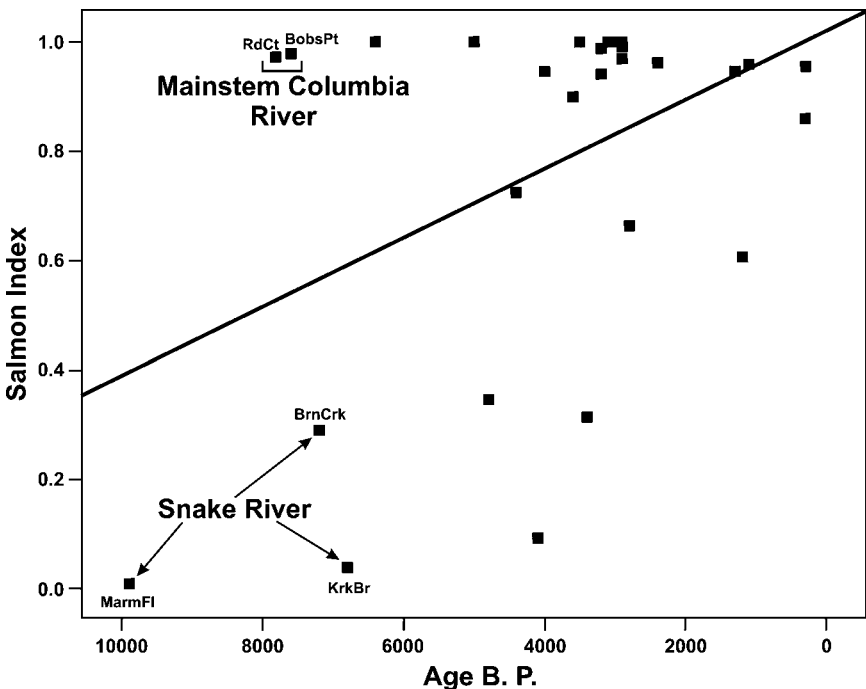
Fig. 12. Abundance Index for salmon (NISP Salmonid/NISP All Fish) Plateau assemblages ($r = 0.443$, $p = 0.015$). Best-fit regression line drawn through entire scatter of points. Key to abbreviations, see Table I.

However, the three early low values (Marmes Floodplain, Kirkwood, and Bernard Creek sites) in the Snake River system are balanced by high values for sites on the mainstem Columbia, possibly reflecting different availability in each system. On the upper Columbia, the low ratios occurring in the period from about 5000 to 3800 BP correlate with a period of lower stream flow and warmer water that may have reduced salmon spawning habitat (Chatters *et al.*, 1995).

Mammals

A subsistence focus on artiodactyls is clear: cervids (primarily deer with some wapiti) are the most widespread and abundant taxon. Although bovids (mostly sheep with some bison) and antilocaprids (pronghorn antelope) are far lower in the overall abundance, they are present in over half of the assemblages, and bovids are ranked first in three (Table XIII). The only other large mammals are bear and horse, which are extremely scarce (Table XII). Horse is thought to have spread into the study area in the early eighteenth century from southern Idaho (see references in Livingston, 1985). Small mammals were clearly an important subsistence item. Sciurids (exclusively marmot in this analysis) are ranked first in three assemblages and occur in 86% of the assemblages. Livingston (1985) suggests this reflects opportunistic use of these creatures that are known to live in habitats close to the sites. Leporids occur in half of the assemblages and are ranked highest in four. The next most common small mammals are canids, which include positively identified domestic dogs, wolf, coyote, and fox specimens. Most of the dog remains in this study came from a dog burial at 45OK258 that had fish remains in its abdominal cavity. The role of dogs in human subsistence is complex and merits considerable investigation as a distinct topic. Osteological and paleopathological analysis of at least 15 individuals at Keatley Creek on the Canadian Plateau indicates dogs served as pack animals (supporting the transportation of goods in a mobile pattern); evidence also showed possibly deliberate breakage of canine teeth and ritual dismemberment (Crellin and Heffner, 2000). Other small mammals (beavers, mustelids, muskrats, porcupines, and raccoons) are uncommon in project sites.

Preliminary analysis of all the records identified significant correlations between assemblage sample size and Artiodactyl Index, which could only be eliminated when assemblages with less than 150 specimens were removed ($r_s = 0.161$, $p > 0.20$). Removing these relatively small assemblages also removed four of the assemblages with ages older than 6700 BP making it difficult to interpret long-term trends. There is no evidence for artiodactyl resource depression in the late Holocene (Fig. 13); in fact, there is a
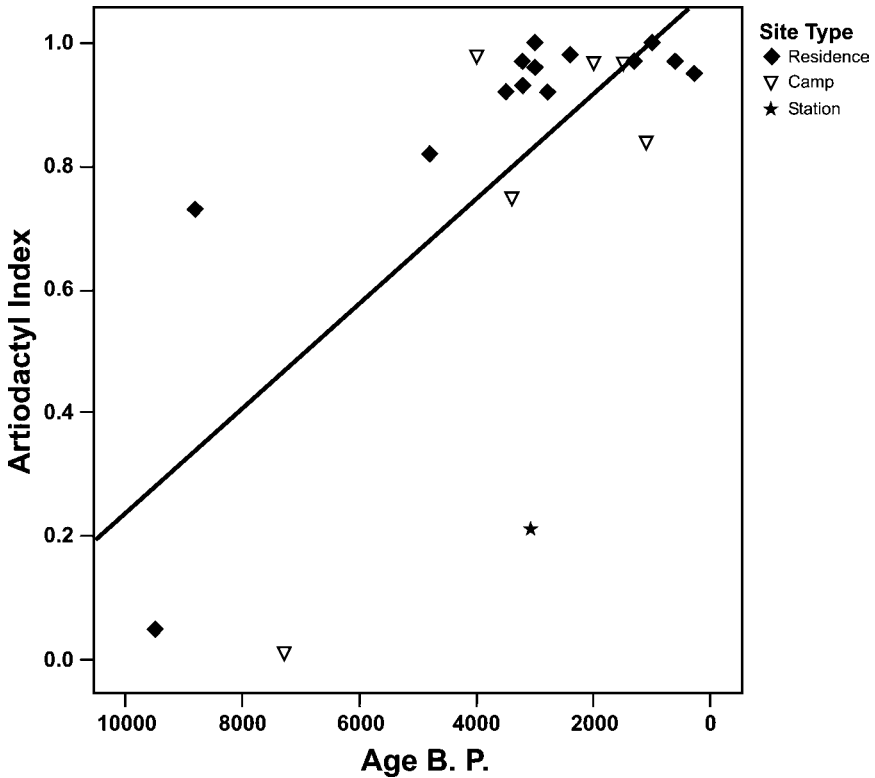
Fig. 13. Abundance Index for artiodactyls (NISP Artiodactyl/NISP Artiodactyl + small mammals) Plateau assemblages ($r = 0.685, p = 0.001$). Best-fit regression line drawn through entire scatter of points.

significant trend for increased artiodactyl abundance ($r = 0.685, p = 0.001$) for the 21 assemblages considered. The data provide some support for our prediction that terrestrial herbivore populations were limited during the mid-Holocene and then increased later in time, due to climatic change. The actual gap in samples between 6700 and 5200 BP (which existed even before removing relatively small sample assemblages) may in fact reflect lowered resource productivity, which resulted in reduced population or occupation of the area.

Invertebrates

Although the two largest species of freshwater mussel, *Margaritifera falcata* and *Gonidea angulata*, were exploited on a regular basis throughout

the Plateau (Lyman, 1980, 1984), archaeological data pertaining to use of mollusks is scanty and inconsistent because they have not been treated systematically with other fauna. In the Wells Reservoir assemblages they are widespread and occur in high density clusters in area sites (Table XII), yet they were not even quantified in the Chief Joseph Project. Varying frequencies of the two taxa have been considered a paleoenvironmental indicator (Chatters, 1995; Lyman, 1980) because of their different habitat preferences, but their overall contribution to subsistence has not been examined in detail. Delacorte (1999) demonstrates in Owens Valley, California, in the western Great Basin that freshwater mussels enter the diet relatively late, which is not unexpected given their low caloric value (Parmalee and Klippel, 1974). The fact that shellfish are common in sites in the Wells Reservoir between 8000 and 4000 BP (Table XII) and are known for even earlier Plateau sites (Table II) is an interesting contrast. Accounting for Plateau patterns using optimal foraging theory will require information on patch structure, resource density and other factors to estimate prey rank.

Overall Changes in Animal Use

Evenness values and Abundance Indices allow us to examine degree of specialization and organization of subsistence across site types. Because of the near absence of structural features in sites dating before 4400 BP, there is no obvious distinction between "residences" and other site types. For analytic purposes, we treat all sites of this age as residences.

Tests for the relationship between sample size and evenness showed a significant correlation, which did not disappear until collections with fewer than 150 identified specimens were removed ($r_s = -0.29$, $p > 0.10$). Unfortunately this resulted in the rejection of about half of the assemblages and all the residences dating to Pithouse I, making it difficult to assess Chatters' predictions. We have plotted best fit regression lines for residences dating before 3600 BP and those dating to the Pithouse II period, between 3600 BP and the contact period (Fig. 14). Early Holocene sites show an upward, although not significant, trend in evenness, while evenness for Pithouse II residences shows no trend. Granting the small number of assemblages, camps and residences during Pithouse II show distinct patterns; the mean evenness values for camps (mean = 1.08, $n = 6$) is higher than residences (*mean* = 0.80, $n = 12$, $t = -1.667$, $p = 0.11$) and the camps show greater variation in values as well.

Overall, after 3600 BP the faunal records give some support for logistical organization. Stations and camps are present and different patterns of faunal remains are seen among the site types. At 3150 BP, one station has a
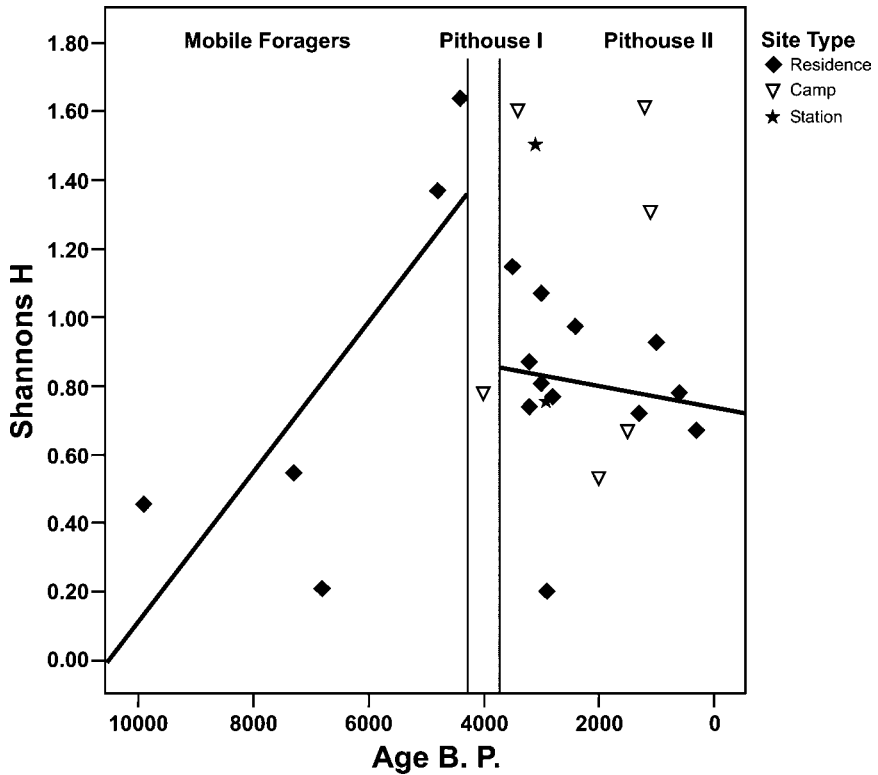
Fig. 14. Scatterplot of evenness values (Shannons *H*), mammals and fish family, Plateau. Best-fit regression line drawn through assemblages from residences for two time periods (10,000–3600 BP: $r = 0.784$, $p = 0.116$; 3600–150 BP: $r = 0.157$, $p = 0.624$).

relatively low Artiodactyl Index in striking contrast to the high ratios at residences at this time (Fig. 13). Such a pattern suggests logistical organization, with forays targeting small mammals.

As measured by the Artiodactyl Index, the use of artiodactyls increased over time, relative to small mammals. This trend could reflect changing cultural preferences and practices, intensification for example, but it is at least equally well explained by environmental change. Recent study of faunal and independent climate records in the Wyoming Basin (Byers *et al.*, 2005), the Great Basin (Byers and Broughton, 2004), California (Broughton and Bayham, 2003) and the mid-western United States (Wolverton, 2005) identify similar trends in artiodactyl abundance that strongly correlates with climate-induced environmental change, which probably affected forage quality and habitat extent. For the Plateau, it is

reasonable to suggest that absolute increases in herbivore abundance due to climatic amelioration in the later Holocene could result in higher harvest rates, regardless of how habitat changes affected the abundance of the small mammals. More work linking local climate records with trends in artiodactyl abundance is needed on the Plateau to substantiate this claim.

Salmon are so abundant and widespread in sites that we see no strong temporal trends and no evidence for increasing specialization.

CONCLUSIONS

Our study contributes to two main questions related to human use of animals in the Pacific Northwest. First, in spite of thousands of years of hunting, fishing, and gathering the same animals, our data show no evidence for resource depression in either the Northwest Coast or Plateau study areas. People were able to use high-ranked artiodactyls in increasing proportions over time; and use of high-ranked salmon was stable relative to other fish. This is an intriguing result, especially derived from two environmentally different areas with different cultural adaptations. Secondly, the implication derived from regional literature, that intensification occurred through specialization in use of certain key resources, is not supported, which suggests a wide range of further research questions. Our test is most definitive in terms of salmon intensification; we found no evidence for an increased use of salmon relative to other resources in either area. On the other hand, the trend for increased use of cervids in coastal sites and artiodactyls on the Plateau could be seen as support for this kind of intensification. At least for the Plateau and possibly coastal sites, however, an increase in absolute abundance of terrestrial herbivores due to environmental change could be the underlying reason why human foragers were able to harvest artiodactyls in increasingly higher relative proportions. The fact that the trend also has been noted for large areas well outside the Pacific Northwest supports the argument that large-scale environmental factors are responsible for the pattern, rather than local cultural mechanisms.

The specific patterns noted here may not obtain in other portions of the Pacific Northwest, indeed we would anticipate variable patterns at different latitudes, given the gradients of both marine and terrestrial resource productivity. Nelson (1990) argued that the Puget Sound basin, from which a portion of our coastal data set derives, is sufficiently distinctive environmentally in its lack of open ocean marine mammal and deepwater fishing habitat to see a different trajectory of cultural development. On the other hand, Nelson argued for the applicability of models of salmon intensification such as that developed by Matson (1983) for the Gulf of Georgia area,

also covered in our corpus of data. Therefore our finding that salmon did not increase relative to other fish in this particular subregion challenges long-held assumptions about changes in animal use through time, and provides incentive for examining the same issues elsewhere.

Resource Depression

Given population increase through time, optimal foraging theory predicts that, all other things being equal, there should be a shift in prey species to lower ranked species as increased predation impacts the highest ranked species. Nonetheless, our study suggests that thousands of years of exploitation of the same species did not deplete animal populations, as measured by the relative mix of high and low-ranked taxa in the faunal assemblages examined.

Salmon, confirmed in its importance as the most abundant and widespread prey fish in both areas, was the target of focal fisheries for 10,000 years, yet there is no evidence of an impact leading to a shift in prey taxa. The fact that salmon were not depressed in either area supports a biological explanation, that salmon populations are highly resilient due to their reproductive strategy and life cycle. Presumably, historic crashes in salmon population prior to major habitat destruction in the twentieth century result from a much higher exploitation rate; comparison of the nineteenth century harvest estimates (Chapman, 1986) to more ancient fisheries may provide better understanding of the limits of that resilience and the comparative recovery time for individual populations.

The results also show that ungulate populations—mainly cervids—were not depressed by thousands of years of Native American hunting. Environmental change may have played a significant role in making this possible, yet other explanations for the nondepression of cervid populations should be considered as well, and may be different for the Northwest Coast than for the Plateau. Kay (1994) has suggested that Pacific coast area wapiti populations were not as vulnerable to overharvesting as Intermountain West animals for several reasons. Coastal wapiti populations could find refuge in dense forest growth, little affected by fire given the damp climate. In the drier Intermountain West, hunters could use fire to open up landscapes and make hunting easier. Also, the limited snowfall in coastal areas meant winter hunting strategies involving chasing animals into deep snow were not possible as they would have been in some regions of the Intermountain West. We suggest two additional hypotheses. First, contrary to Kay, coastal forests experience periodic burns and we suggest that anthropogenic burning served to maintain and expand cervid habitat, even as

predation pressure increased. Second, the gradual elimination of competing predators, may also have allowed humans to expand the total take without causing resource depression.

It is also possible that human populations, limited by other factors, never grew large enough to permanently depress prey populations. This explanation fits best for the Plateau, with its historically lower population densities, but should be considered for the Northwest Coast as well. In the American West, the best evidence for human-caused resource depression is from California (Broughton, 1994, 1999; Grayson, 2001) and Fremont era sites in Utah (Janetski, 1997). In these areas, carbohydrates from maize or acorns and other wild plants helped support relatively large populations that could then exert pressure on animal populations (Byers and Broughton, 2004). Roots were an important plant food on the Plateau (Ames and Marshall, 1980; Lepofsky and Peacock, 2004; Thoms, 1989), but may not have been sufficiently widespread or abundant to support the human population densities required to impact animal populations. Lepofsky's (2004) review of the role of plant remains in coastal areas shows considerable evidence for plant processing but there are insufficient data to interpret temporal trends.

Finally, it is possible that the lack of evidence for resource depression is due to the scale of our analysis; short-term, local resource depression may have occurred, time and again, and not be reflected in our data, especially if it led to rapid site abandonment. Our regional scale data suggest, however, that it did not have a cumulative effect across the region. Future work at a local scale may find the concept useful for explaining shifts in site settlement or changes in resource use that are beyond simple seasonal shifts.

Mechanisms of Intensification

Growth of populations in the Plateau and the Northwest Coast over the last 10,000 years implies that, after initial expansion across the area, productivity per hectare had to increase in order to support larger populations. The approach we have taken here, examining temporal trends in relative proportions of certain animal taxa, allows us to directly address two possible mechanisms for intensification, specialization and logistical organization.

Our data indicate that specialization was not as great a pathway of intensification as expected. The assumption that increased productivity resulted largely from technology for mass harvesting, processing, and storage of salmon may be correct, and is not directly tested here, but the concomitant assumption that this would also result in increased use of salmon

relative to other fish resources is clearly not supported. The suggested evidence for increased use of artiodactyls could mainly be due to overall increases in productivity of forage for supporting larger artiodactyl populations as noted earlier.

On the Northwest Coast, we note little change in overall proportions of different resources used, in spite of increasing specialization in certain habitats. The occurrence of specialized herring fisheries at some locations and a slight overall increase in use of herring is significant. If herring are efficiently caught en masse, and there is little scheduling conflict with other resources, then there may have been sufficient return on herring procurement to warrant specialized camps and gear. This development could result in an overall increase in productivity, by what Whitlam (1983) has called extensification rather than intensification. If such efforts were spread across several species, such as salmon, herring, and flatfish equally, then the overall regional measures of evenness and the salmon index could remain unchanged.

On the Plateau, the records of animal representation across site types support the idea of the development of logistic organization, another mechanism by which productivity could be increased. Unfortunately, the small number of samples does not allow us to test predictions about the earlier Pithouse I phase of broad spectrum foraging, but the later decline in evenness is consistent with development of a more focal economy, a change at least partly dependent on a shift to logistical organization as indicated by the evident partitioning of resource use at different site types.

Increases in productivity per hectare supporting population growth could have resulted from one or more of the following: increased use of plant resources, exploitation of more microenvironments, development of efficient capture methods for many taxa, or increased use of fish relative to mammals. Social allocation of resources may have played an important role as well. Together these factors could have operated to maintain, in spite of population growth, a relative balance of animal resources that we suspect largely reflects absolute environmental abundances.

Future Work

Our conclusions related to subsistence change on the Northwest Coast are somewhat limited because current approaches to sampling and analysis of archaeofaunas preclude direct comparison of proportional representation of taxa from different classes (mammals vs. fish vs. shellfish vs. birds). Thus, we cannot determine whether fish use increased relative to mammals, or shellfish use changed relative to fish or mammals, which limits the test for

intensification used here. This brings up obvious areas of inquiry that can be pursued to confirm or refine the empirical patterns presented and to explore alternative explanations for them. We strongly recommend future projects develop sampling approaches that allow for integration of faunal records across higher level taxonomic divisions and at both site and regional scales to allow for more robust testing of models.

A systematic review of anatomical body part representation and other aspects of carcass use would also be useful. Changes in the ways that animals would be butchered, processed, and transported across a landscape are suggested by regional models regarding development of logistical land use and increasing reliance on stored resources (Binford, 1978). Scholars working elsewhere (Broughton, 1999; Cannon 2003; Kopperl, 2003; Nagaoka, 2002) have explicitly linked butchery and transport patterns to foraging theory models; both body part used and intensity of use is predicted to change as encounter rates with high ranked taxa varies. In the Pacific Northwest, most study of animal butchering and carcass use has focused on salmon and evidence for salmon storage (Coupland *et al.*, 2003; Croes, 1995; Grier, 2003; Matson, 1992). In most cases these efforts have been overly reliant on ethnographic analogy and have not considered important taphonomic and other factors that affect body part representation (Butler and Chatters, 1994; Hoffman *et al.*, 2000; Moss, 1989; Wigen and Stucki, 1988).

We looked solely at animals, therefore cannot address the possible role of plants in structuring human organizational strategies or supporting increased productivity. Until recently, archaeobotanical studies in the Pacific Northwest have lagged behind faunal analysis, and thus it has been difficult to assess plant contribution to ancient human diet. Recent syntheses of Pacific Northwest plant records by Lepofsky (2004) and Lepofsky and Peacock (2004), suggest we are closer to being able to track the varying roles of plants and animals and changes over time.

To examine aspects of intensification using measures besides specialization on prey types will require other types of data that have not been systematically compiled for any region of the Pacific Northwest. These would include measures of relative human population densities, control over biases in habitat sampling, and information about technological developments and facility frequencies. Further discussion will need to consider which geographic and temporal scales are most appropriate for measuring these theoretically defined processes. For example, the dynamism of settlement patterns needs to be recognized in order to define units for comparison. As land-use becomes increasingly logistically organized, it is increasingly difficult to get a representative sample of the overall resource use.

One of our main goals was to demonstrate ways zooarchaeology could contribute to current debates in the Pacific Northwest related to culture

change and process, given the importance ascribed to animals in regional models. We have accomplished this, presenting the first systematic comparison of multiple taxa for large subareas of the Pacific Northwest. In the end, our project may have identified more questions than answers. Future work along some of the lines suggested will allow for greater control over variables to isolate causes for local and regional patterns identified.

ACKNOWLEDGMENTS

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