III. Redefining Anthropogenic Environments and Their Uses

9. Fishes *and* Loaves? Explaining Sustainable, Long-Term Animal Harvesting on the Northwest Coast Using the "Plant Paradigm"

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Abstract: Models accounting for social complexity on the Northwest Coast stress intensification of animal resources, especially salmon. Faunal records from the past 6,500 years on the southern Northwest Coast, however, indicate sustainable use, rather than intensification of salmon. Recent research demonstrating a significant role for, and cultivation of, plant resources, likewise challenges existing models. Implications of plant cultivation for understanding sustainable harvesting of animal resources include enhanced animal abundance and opportunities for garden hunting and strategies for management of animal resources based on parallel knowledge and engineering. Further, because horticulture involves delayed returns, it has been widely accepted in the human behavioral ecology literature as evidence of conservation behavior; its occurrence indirectly supports the possible role of conservation behavior in explaining sustainable use of salmon.

The hunter-fisher peoples of the Northwest Coast of North America have long held iconic significance in anthropological understandings of the relationship between subsistence strategies and social organization, inspiring the concept "complex foragers." Their role as a critical testing ground for theoretical concepts and models about the nature and development of foraging societies began in the days of Boas and early anthropological classifications, and continues today. Recent research challenges two of the central assumptions of theoretical models for the development of social complexity in the region. First is the assumption that

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plants played only a minor role in subsistence, while maritime animal resources, particularly salmon (Matson 1983, 1992) were key; second is the belief that it was intensification of maritime resource use that allowed the development of social complexity. The first is challenged by Deur and Turner's edited volume (2005), an extensive compilation of ethnohistorical information that documents the importance of managed plant staples in many areas of the Northwest Coast. Our recent research using faunal records from archaeological sites in two areas of the Pacific Northwest (Butler and Campbell 2004), which shows no evidence of increasing use of resources such as salmon, relative to other resources, challenges the second assumption. Beyond providing new insights into the prehistory of this particular region, these arguments have theoretical implications in the broader arena of understanding resource management and conservation among foragers.

In our previous work, we followed a strategy for examining resource depression of animal prey species that had been applied by other archaeologists to the American West. We used prey choice models derived from optimal foraging theory to construct a test for resource depression in high-ranked prey species, expecting that long-term population growth would have led to declines in favored prey. Our archaeologically derived data from subareas of the Northwest Coast and the Columbia Plateau (Butler and Campbell 2004) indicate that native peoples used salmon and artiodactyls, top-ranked resources, over much of the past 10,000 years, presumably with increasing intensity, yet without causing evident depression of these resources. These data are particularly telling because of the great time depth of our record and because they apply to two environmentally very different areas of North America where foraging persisted as the dominant subsistence strategy throughout prehistoric times. Our faunal results are not only contrary to expectations of intensification but also differ from findings in many other areas, where resource depression has been documented using similar methods.

Our search for explanations of sustainability leads us to challenge the claim in the human behavioral ecology (HBE) literature that conservation behavior would be rare in small-scale foraging societies (Borgerhoff Mulder and Coppolillo 2005; Hames 2007; Smith and Wishnie 2000). If our data had shown that harvests were not sustainable, they would readily have been interpreted as indicating that prehistoric foragers in the area were not conservationists. But the reverse is not true in spite of the fact that equilibria between hunter-fishers and prey species were maintained over thousands of years, through changes in population density, mobility, and technology. We argue that the HBE approach to conservation ignores the full range of factors that are key to understanding human subsistence strategies, their evolution, and their stability.

The growing awareness of intensive plant use and management (e.g., Deur and Turner, eds. 2005) intersects our work on use of animal resources in two ways. It opens up new avenues for understanding sustainability of Northwest Coast foraging strategies, and it strengthens our conceptual challenge to the prediction from HBE that conservation behavior would be rare, by providing cases that appear to meet the HBE criteria.

The body of work that represents what we suggest is a new "plant paradigm" for the Northwest Coast (Deur and Turner, eds. 2005; Lepofsky 2004; Peacock and

Turner 2000; Turner 1996, 1998; Turner et al. 2000) shows that plant foods were an important dietary staple and that these resources were managed and enhanced in systematic ways—indeed cultivated. Because of the entrenched stereotype of Northwest Coast peoples as maritime foragers, relying primarily on animal resources, this new perspective represents a significant paradigm shift, not simply additional knowledge. Further, Deur and Turner (2005) expose a theoretical blind spot, arguing that consistent downplaying of the management of plant resources dates back to the colonial agenda for land appropriation, and that within anthropology it can be traced specifically to Boas's agenda of disproving evolutionary models. Several contributors to their volume (e.g., Ames, Atleo, Smith) challenge the traditional dichotomous approach to agriculture and foraging as overly polarized and suggest the adaptive strategies stand in no necessary evolutionary relationship. Blukis Onat (2002) similarly argues that the subsistence classifications dominating the literature, which are Eurocentric, hierarchical, and based on the concept of exploitation, impede our understanding of relationships that obtained between Northwest Coast native peoples, animals, and plants. She also argues that the way agriculture and even cultivation have been defined and identified privileges a certain suite of domesticated terrestrial animals and cereal grains as key components, excluding fishery-based economies.

Reconsidering evolutionary models of the relationship between foraging and agriculture ties directly to the debate over the level of conservation practiced in small-scale human societies. Alvard (2002), who claims that foragers are unlikely to practice conservation behavior, argues that the appearance of plant and animal husbandry in many places in the world within a relatively narrow time frame (in other words, the “origins” of agriculture) represents one of the few widespread instances of conservationist behavior. As the evidence for management and enhancement of resources among foragers mounts, assumptions that they are unlikely to forgo short-term gains for long-term ones are challenged in direct proportion.

The goal of this chapter is to consider the empirical and theoretical implications of the new “plant paradigm” for the Northwest Coast for understanding sustainable animal resource use. The following section reviews our faunal data in the context of resource depression studies and the conservation debate. We define concepts of management and sustainability, which we suggest can be usefully applied to archaeological records. A summary of the expanded view of plant use on the Northwest Coast is followed by a discussion of the implications for sustainable animal use. The concluding section outlines directions for archaeological research that will be needed to understand the evolution of cultural practices that contribute to long-term resource sustainability.

Resource Depression Studies and the Conservation Debate

Over the past 20 years, the pendulum has swung from viewing foraging societies as “living in harmony” with their environments to demonstrating their multiple impacts on landscapes and ecological communities (Grayson

2001; Hames 2007; Kay and Simmons 2002; Krech 1999). Historic and archaeological records, as well as studies of contemporary foragers, have documented cases of resource depression apparently resulting from the impact of human predation on particular animal taxa. Such findings have been used in support of the argument that conservation behavior in foraging and small-scale societies is rare.

Most of this research is situated within foraging theory; archaeological research in particular focuses on examining long-term records of animal bones representing harvested prey for evidence of resource depression. 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; Cannon 2000; Kopperl 2003; Nagaoka 2002). Changes in proportion of high- and low-ranking prey represented in faunal assemblages are assumed to reflect changes in their abundance, given optimal foraging assumptions. 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. Reduction in prey density is termed *resource depression* and is predicted to occur if the predator population increases or becomes less mobile, although persistence of preferred prey species is also a possible outcome of optimal foraging models. Winterhalder and Lu (1997), using simulation models, concluded that foraging-prey systems can stabilize without intentional conservation behavior and that prey "switching," use of fallback foods, in certain circumstances, contributes to prey species persistence.

In the HBE paradigm, foragers are not expected to exercise restraint in harvesting because of the unknown future and the possibility of "cheaters" taking the harvest. Selection should favor those who choose immediate returns over long-term benefits, and conservation behavior (forgoing immediate return) would be rare. Countering the claims of many anthropologists that traditional belief systems and practices are conservationist, HBE has developed stringent criteria to be applied to proposed cases of conservation behavior. Belief systems alone are insufficient evidence of conservationist behavior; the proposed behavior or practice must have a demonstrated effect in preserving resources, and it must also be shown that the behavior/practice was *designed* (consciously or unconsciously, by intent or by selection) to conserve (Smith and Wishnie 2000). Another criterion, that the practice involves a short-term cost, is favored by Alvard (1995). Intentional conservation is thought to occur only under certain conditions including when resource access can be controlled, or when resources are resilient and temporospatially bounded, where the sustained yield rates exceed the immediate, and where social parameters are in place to counter free-riding (Smith and Wishnie 2000). Social organizations that meet these conditions are widely recognized in small-scale societies, but according to Smith and Wishnie, collective action concerning common pool resources is rarely persistent because of factors such as ineffective regulating of free-riders or external factors such as environmental change or competition with other economic systems.

Resource Use on the Northwest Coast

Northwest Coast researchers have tended to assume that abundant animal resources, especially the marine resources and anadromous fish traditionally cited by anthropologists as the foundation for the degree of complexity in Pacific Northwest cultures (Drucker 1955; Fagan 2000), could be sustainably harvested. Moreover, researchers often have thought that resource yields could be indefinitely increased through human effort and technology (Matson 1992), which has been termed *intensification* in the regional literature. (Note: the term *intensification* more often refers to increased effort and decline in efficiency [e.g., Broughton 1994; Cohen 1981]; the meaning used in most optimal foraging models predicts resource depression as an outcome of optimal foraging strategies under conditions of rising population levels.)

A few studies in the Pacific Northwest have applied archaeological and other empirical data to test whether resource use was indeed sustainable, with mixed results. Etnier (2002, 2007), working with northern fur seal (*Callorhinus ursinus*) on the outer coast of Washington state, and Lyman (2003), studying Steller sea lion (*Eumetopias jubatus*) on the Oregon coast, conclude that human exploitation of these species was sustainable. Wessen (1994) rejects localized overexploitation of preferred bivalve species at the Ozette site based on mean valve size. On the other hand, Croes and Hackenberger (1988) suggest overexploitation of invertebrates on the coast of Washington, and Butler (2000) sees possible declines in multiple vertebrate taxa, including salmon (*Oncorhynchus* spp.) and sturgeon (*Acipenser* sp.) on the lower Columbia River, based on archaeological remains. Analyzing wapiti (*Cervus elaphus*) remains in archaeological sites throughout the American West, Kay (1994) suggests this taxon was overhunted in the Columbia Plateau but not in coastal areas of the Pacific Northwest (but see Kay 2007; Lyman and Wolverton 2002; Martin and Szuter 1999, concerning the Plateau). Lacourse and colleagues (Chapter 4 of this volume) present an argument for overexploitation of western red cedar in the late Holocene on Haida Gwaii.

Methods and Results

Our study focused on faunal remains dating between 6400 B.P. (uncalibrated) and European contact in the south-central Northwest Coast. The sites are located along the Puget Sound, Gulf of Georgia, Strait of Juan de Fuca, and outer coast of Washington (Figure 9-1). These records represent 19 archaeological sites and 220,000 vertebrate specimens (Butler and Campbell 2004). We chose assemblages that had been excavated using at least 1/8-in (3.2 mm) mesh to reduce recovery bias against smaller-bodied fauna; records were summarized at the family level, using number of identified specimens (NISP) as the counting unit. Site assemblages were broken down into the finest possible time units or components allowed by published data. For the age of the component, we used either the mean of reported radiocarbon dates (uncalibrated) or the midpoint of the cultural phase assigned in the source, if no radiocarbon dates were reported. Remains of small, burrowing rodents and moles probably are intrusive and were

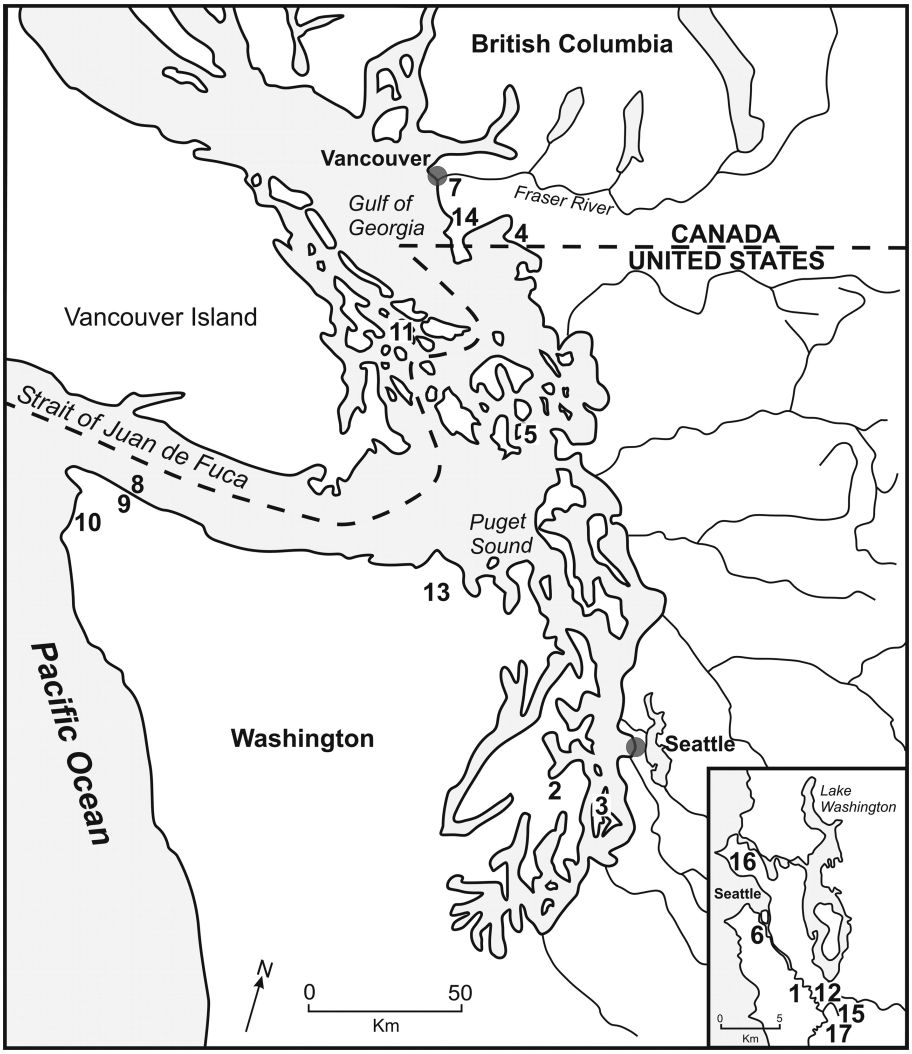

Figure 9-1. *Map of the south-central Northwest Coast showing site locations: (1) Allentown, 45KI431; (2) Bay Street, 45KP115; (3) Burton Acres, 45KI437; (4) Crescent Beach, DgRr1; (5) Decatur Island, 45SJ165, 45SJ169; (6) Duwamish, 45KI23; (7) Glenrose Cannery, DgRr6; (8) Hoko River Rockshelter, 45CA21; (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. Reprinted here with kind permission from Springer Science Business Media: Journal of World Prehistory, "Resource Intensification and Resource Depression in the Pacific Northwest of North America," Vol. 18, 2004, p. 359, Virginia L. Butler and Sarah K. Campbell, Figure 2, © 2004 Springer Science + Business Media, Inc.*

excluded. For this study, we examined resource use in two main patches (sensu Smith 1991), the terrestrial patch and the aquatic patch, and ranked prey types within each patch according to the body size criterion. 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 plus large-bodied prey. A decline in the proportion of large prey is the predicted expression of resource depression (i.e., activities of the predator lead to reduced capture rates of the prey). Our study examined resource depression of salmonids and artiodactyls, the top-ranked taxa in the aquatic and terrestrial patches, respectively. Because of variation in recovery method, we could not directly compare relative use of fish and mammals.

We constructed an Abundance Index (AI) for salmonids (NISP Salmonidae/NISP Salmonidae + NISP Other fish). Salmonids are the highest ranked fish family because species in the family tend to reach much larger size than species in other families. We controlled for large-scale habitat differences and access (dispersed in marine waters, concentrated seasonally in rivers) by distinguishing sites by major habitat location (coastal, riverine) in analysis.

If predation was sufficiently heavy on salmonids, we would expect the index to decline over time. In the south-central Northwest Coast data, the AI for salmon (Figure 9-2) shows no temporal trend in either coastal ($r = .017$, $p > .5$) or riverine assemblages ($r = .007$, $p > .5$). For the coast sites, there are a range of values for every time period, suggesting salmon was the focus of the fishery in some locations and only a minor or moderate constituent in others. Riverine sites generally have high ratios for all time periods.

We developed predictions using 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 (for a discussion of patches and ranking, see Butler and Campbell 2004). Artiodactyls are far and away the largest mammals in the terrestrial patch (with body size ranging from 45 to over 400 kg (Chapman and Feldhamer 1982; Maser 1998) and would thus have been the highest ranked. We constructed the AI for artiodactyls (NISP Artiodactyls/NISP Artiodactyls + NISP Small mammals) to evaluate the potential for resource depression of the higher ranked artiodactyls. If human activities depressed the populations of artiodactyls, we would expect to see declines in the artiodactyl AI. Contrary to this expectation, the AI actually *increases* over time in coastal sites ($r = .643$, $p = .018$; Figure 9-3). Riverine sites show no trend in the index ($r = .029$, $p > .5$).

Discussion

Our data show none of the patterning in relative abundance that would be expected if resource depression of these important prey species occurred (we did not look at other measures such as age and size composition [see Etnier 2007]). People occupying the sites we included were able to use salmon in the same proportions relative to other fish over more than 6,000 years despite

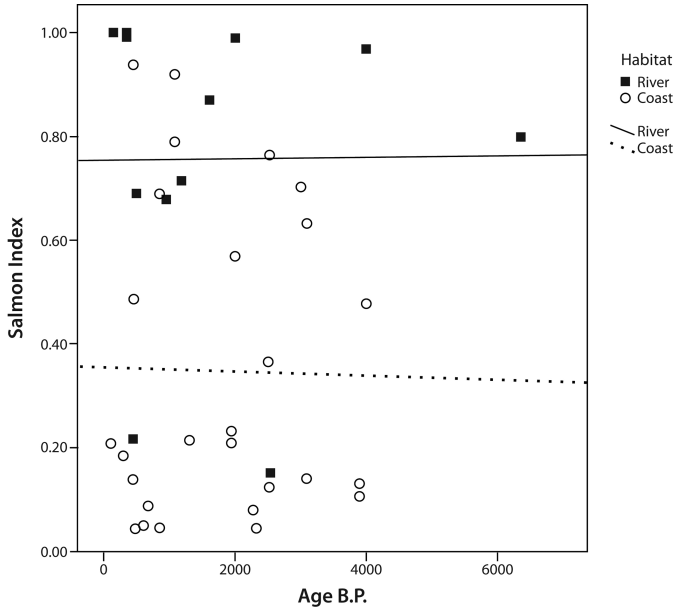

Figure 9-2. *Abundance Index for salmon (NISP Salmonidae/NISP Salmonidae + NISP Other fish) vs. age for south-central Northwest Coast assemblages by habitat.*

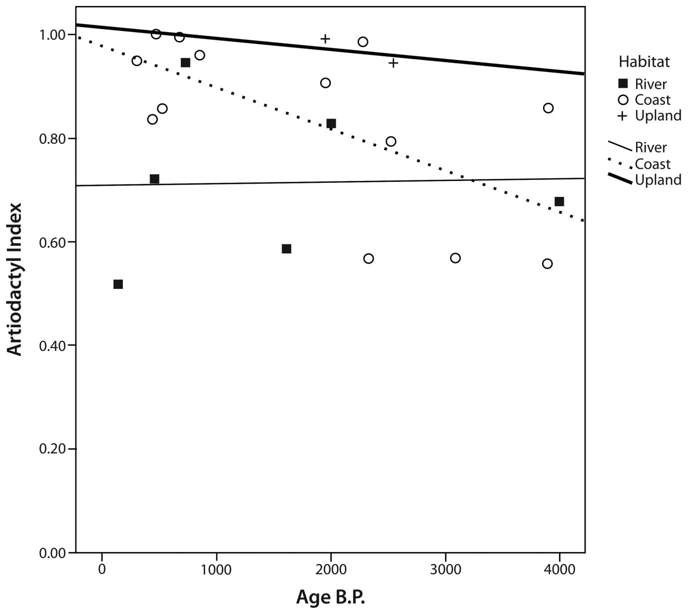

Figure 9-3. *Abundance Index for artiodactyls (NISP Artiodactyls/NISP Artiodactyls + NISP Small mammals) vs. age for south-central Northwest Coast assemblages by habitat.*

apparent population growth and widely accepted evidence for increasing sedentism and circumscription (Ames and Maschner 1999). Likewise, people were able to use high-ranked artiodactyls without a decrease in relative abundance, even in increasing proportions.

Because our results contrasted with those of other studies, we revisited the HBE literature that supported predictions of resource depression given optimal foraging and rising human population levels. We found that our results had no clear significance in the broader debate about the extent to which small-scale societies practiced behaviors designed to conserve resources and found troubling logical biases that make it almost impossible to demonstrate conservation behavior. Because both emic (intention) and etic (long-term efficacy) measures are involved, and both short- and long-term data sets are theoretically necessary, arguments over whether a particular practice is effective, costly, and consciously or otherwise designed rarely can be resolved with empirical evidence. In other words, cases are likely to be rejected for failure to meet one criterion or another, not because the absence of the criterion can be demonstrated, but because it cannot be shown one way or the other. We suggest that this asymmetry goes beyond a normal "burden of proof" and guarantees a frequency of Type II error that renders the concept nonuseful.

In fact, Type I errors are likely to be frequent as well. As Ruttan and Borgerhoff Mulder (1999) have pointed out, concordance of findings with optimal foraging predictions is taken as adequate demonstration of causality without necessarily testing other explanations. While declining ratios of top-ranked prey are argued to reflect the impact of human populations on prey populations, and have been taken to indicate that foragers did not practice conservation, the absence of impacts can be dismissed as an epiphenomenon unless intentional design can be demonstrated. When impacts are attributed to overuse there is not the same requirement to prove that it is not an epiphenomenon of other factors. These are issues ultimately of causality. It is not clear that we sufficiently understand the causal relationships among factors such as mobility, ecosystem structure, population growth rates, and harvesting practices to determine which are dependent and which are independent variables.

We see it as useful to deconstruct the term *conservation,* particularly to separate intent from effect, and create analytic variables that can be applied to different kinds of records, including archaeology. Two other concepts, *management* and *sustainability,* might be useful, and more readily operationalized. Management can be defined as practices that enhance or protect resources at some costs. The costs can be in terms of capital investment, for example, the costs involved in building walls to extend intertidal clam habitat or tilling a garden plot apart from harvesting. Costs are also incurred in forgoing immediate harvests, as in burning a plant patch that will not return to full productivity for several years or not killing a pregnant doe. Other examples are social restrictions on when or where to take resources or how resources are to be shared; these are often related to ownership of resources and are discussed separately from other management practices below. Determining whether management practices actually result in enhancement of resources needs to be considered separately, through the concept of sustainability.

Sustainability, the ability of something, such as a yield, a predator-prey relationship, or an ecosystem, to persist for an extended period, is robust and useful in terms of measuring and understanding the stability of forager adaptations. As Costanza and Patten (1995) point out, sustainability is a concept, like fitness in biology, that can only be determined after the fact. They also point out the importance of specifying the temporal and spatial scale of what is being sustained, because the concept is applicable to a wide range of scales. These specifications address some of the concerns raised by Borgerhoff Mulder and Coppolillo (2005). Its presence is not an indicator of conservation behavior, nor should its absence be treated as an indication that people are wasteful. Many other factors influence sustainability, and these need to be examined in either case. Use of this concept encourages exploration of a broad set of issues, including ecosystem structure, climate change, and technological change, and because it meets the criterion of demonstrated effect, the possibility of deliberate conservation as well.

We argue that our test for resource depression shows sustainable harvesting of key resources over a long period of time in spite of apparent human population increase (for a discussion of empirical sufficiency of the test, see Butler and Campbell 2004). We further believe that this is an indicator of sustainability in a broader sense, implying resilience and sustainability of habitats and food webs, a case strengthened by finding a similar record for salmon and artiodactyls in the adjacent Plateau (Butler and Campbell 2004), where people used many of the same resources and even the same populations of migratory and transhumant fish and mammals. Elsewhere (Butler and Campbell 2004; Campbell and Butler 2009), we considered factors that might promote equilibrium in predator-prey relationships over long time periods in the Pacific Northwest: low population size and limited harvesting pressure (see also Byers et al. 2005; Hunn 1982), predator suppression, resource flexibility including prey switching (Kay 1994, 2007; Winterhalder and Lu 1997), environmental change (Broughton and Bayham 2003; Byers et al. 2005), biological factors inherent to the faunal resources, such as life history and reproductive biology of salmon (Waples et al. 2008), and finally social institutions and beliefs (Haggan et al. 2006; Hunn 1982; Johnsen 2001; Trosper 2002). While many of these may contribute, we concluded that resource flexibility and social institutions were especially important to sustainability (Campbell and Butler 2009). Our previous work has mainly considered questions of sustainable animal use independent from plant use, however. We suggest the "plant paradigm" has varied and important implications to our understanding of human-animal relationships and, moreover, allows for consideration of sustainability at the ecosystem scale, which is much more powerful than studying human-animal or human-plant interactions alone.

The New Plant Paradigm

The chapters in Deur and Turner's (eds. 2005) volume present a strong collective case for the intensive use, management, and enhancement of plant resources in various areas of the Northwest Coast. The role of plants was not limited to immediate consumption and nutritional supplementation; some plants were storable, caloric mainstays. In some cases, substantial surpluses were produced that were traded or exchanged in economic and ceremonial contexts, often in standardized amounts. The stereotypic view that Northwest Coast peoples relied little on plants is even more remarkable given their social importance; the ethnohistoric literature reveals that specific plants were referred to in origin myths, allocated by status, and celebrated in "first-fruit" ceremonies (see Deur 2005:300–304 for examples).

The strength of the case comes from compiling hundreds of independent examples drawn from different native peoples, involving multiple practices and taxa. Even so, the information is uneven, because records of these activities come from anecdotal data in historic writings and oral traditions of practices that were largely disrupted by modern land use, and because the coverage is heavily weighted to the British Columbia portion of the Northwest Coast. As Turner and Peacock (2005) comment, many activities that are documented in just a few places can be assumed to be more widespread. On the other hand, we should not assume uniformity across the area, especially given known latitudinal environmental gradients and resource/habitat distributions (Schalk 1981; Suttles 1990). For example, oaks, which do not occur north of the Gulf of Georgia area but occur in increasing densities to the south, where they were an important food staple, are not discussed because of the northern bias in coverage. Addressing the Coast Salish area, Suttles (2005) states that 11 species of plants were grown in individually owned plots somewhere within the area and describes a great deal of overlap between the practices of different groups. However, he also notes exceptions; for example, the Squamish, Chehalis, and Scowlitz apparently denied ownership of plant resources.

Plant and Habitat Management

Descriptions of plant use by many Northwest Coast groups in Deur and Turner (eds. 2005) establish the detailed knowledge of plant growth requirements held by native peoples and how this was translated into strategies for manipulating plants directly as well as landscapes to enhance productivity or abundance. In constructing Table 9-1, we highlighted management practices with examples representing different vegetation and habitat types such as root crops, wetlands, and shrubs; these are not exhaustive. Activities included pruning, replanting, fertilizing, and tilling, demonstrating detailed knowledge of individual plant growth habits and requirements. Most of the plants are perennials, either shrubs or plants with starchy tubers or rhizomes. Root vegetables include about 25 species in habitats ranging from freshwater aquatic (wapato, *Sagittaria latifolia*) to upper tidal marsh (Pacific silverweed, *Potentilla anserina* ssp. *pacifica*), seasonally wet prairie (camas, *Camassia* spp.), and lithosols (onions, *Allium* spp.). About 50 species of berries from more than eight genera, including currants and gooseberries (*Ribes*), blackberries and allies (*Rubus*), and huckleberries and blueberries (*Vaccinium*), were important. Berry bushes are known to have been fertilized, transplanted, and pruned. Root crops also were enhanced by replanting, weeding, fertilizing, aerating, and soil amendment. When these techniques involve costs beyond harvesting costs, they are considered management by our definition.

Table 9-1. *Plant Management Activities and Implications for Animal Resources*

Activity Type	*Plant Example*	*Impacts on Animal Resources*	*Parallels for Animal Resource*
Enhance productivity of plants and habitats			
Remove plant and animal competitors	Weeding (and transplanting) created contiguous monocultural plots of favored rhizomes, Kwakwaka'wakw, Nuu-chah-nulth, southern British Columbia (Deur 2005:306–309) Pruning to reduce shade and competition around estuarine root grounds, group not specified (Turner and Peacock 2005:125) Muskrat, major predator of wapato and valued for meat and fur, documented in archaeological sites, lower Columbia River (Darby 2005:212)	Enhance garden hunting	Eliminate carnivore competitors
Replant	Replanting bulblets of rice-root lily, Kwakwaka'wakw (Turner and Peacock 2005:117)	As above	
Prune	Removing branches of heavily fruited crabapples, northern British Columbia (Turner and Peacock 2005:121)	As above	Selective harvest using weirs/traps (Haggan et al. 2006:15)
Fertilize	Application of fish remains, ashes, clam shells to berry bushes among Heiltsuk, northern British Columbia (Turner and Peacock 2005:118)	As above	
Aerate/till	Removal of rocks; churning soil of garden sites to increase porosity and mix in recent estuarine deposits, Nuu-chah-nulth, southern British Columbia (Deur 2005:311–313)	As above	Maintain stream, remove logs from salmon streams (Jones 2002:155–168)
Extend and maintain productive natural habitats			
Burn deliberately	Camas prairies, Puget Sound lowlands; berry clearings (salal, huckleberry, strawberry), coastal British Columbia (Turner and Peacock 2005)	Increase browse for deer, other animals; better hunting access	Fire areas specifically for game—practice unknown

Table 9-1.—*Continued*

Activity Type	*Plant Example*	*Impacts on Animal Resources*	*Parallels for Animal Resource*
Increase wetland, intertidal areas	Sediment traps, retaining walls, and mounding of soil to expand high salt marsh for estuarine rhizomes (*Potentilla, Trifolium*), Kwakwaka'wakw, Nuu-chah-nulth, southern British Columbia (Deur 2005)	Attract geese and ducks, waterfowl traps adjacent to garden plots	Build clam gardens (Williams 2006); herring brush traps (Stewart 1977:124–127)
Transplant	Crabapple, hazelnut to different residential communities, Tsimshian, northern British Columbia (McDonald 2005) Estuarine roots and stinging nettles between group territories, British Columbia (Deur 2005:309; Turner and Peacock 2005:125)	Attract animal species; add opportunities for garden hunting depending on species	Move fish into different water systems (Sproat 1868)
Limit access			
Inherited use areas identified	Camas beds marked by lines of rocks, Northern Straits Salish; Nooksack plots of "carrots" marked with ditches and rocks/stakes at corners (Suttles 2005:185–187)		Clam beds, bird net sites, fish weir and dip net locations; game animal trap sites
Proscribe season of harvest	"First-fruit ceremony" for thimbleberry shoots and later for fruit, time set by chief, Halkomelem, lower Fraser Valley (Turner and Peacock 2005:132)		First salmon, all groups First eulachon, Haisla (Hamori-Torok 1990), Bella Coola (Kennedy and Bouchard 1990)
Proscribe use	Largest springbank clover roots reserved for tribute to chiefly family, Kwakwaka'wakw, southern British Columbia (Deur 2005:302) High bush cranberry patch, each person gave the first bucket to the owner/chief, then could pick any quantity, Nuu-chah-nulth, southern British Columbia (Turner and Peacock 2005:131)		

At the landscape scale, these and other techniques were employed to extend or maintain naturally occurring habitats that were favored by desirable species. Weeding and transplanting were used to increase the relative abundance of favored species within their natural habitats. Burning was used in multiple habitats to maintain clearings by suppressing the growth of shade trees and limiting understory, as well as adding fertilizer, thus enhancing habitat for various berry and root crops. For example, Garry oak (*Quercus garryana*) parklands, a favored habitat for camas, are widely acknowledged to be anthropogenic landscapes maintained by fire (Lepofsky, Hallett, et al. 2005). Most references to burning do not mention a time lag for plant productivity recovery. In discussions with Gitskan and Wet-suwet-en informants in northern British Columbia, Gottesfeld (1994a) learned that berry patches might require several years to return to full productivity after burning. Such a time lag certainly suggests a short-term sacrifice. The rich, productive environment offered by high salt marshes and favored by several estuarine plants valued for their roots (Pacific silverweed; springbank clover, *Trifolium wormskjoldii;* northern rice-root lily, *Fritillaria camschatcensis;* Nootka lupine, *Lupinus nootkatensis*) was extended by adding soil behind retaining walls of stone or logs. Family subplots ranged from 50 m^2 up to 400 m^2 (estimated from Deur 2005:306), often modifying extensive acreage.

Social Control of Plant Resources

Land and resource ownership is a hallmark of Northwest Coast foragers and contributes to their atypical forager status. As Richardson (1982:93) noted, "considerable variation exists in concepts of ownership and territory, specific resources owned, make-up of the owning and exploiting groups, management of owned resources, and regulation of access to known owners." Except in northwest California, where resources were mainly owned by individuals, ownership was by kin groups, which could be matrilineal clans and house groups, ambilineal descent groups, extended families, or multi-kin-group village communities (Richardson 1982); male heads of the kin groups were responsible for managing resources.

Several social institutions limit and control where, when, and by whom plant resources could be harvested (Table 9-1). Plant resources that were owned in coastal British Columbia included root gardens, berry patches of multiple genera, individual crabapple trees, and stands of western red cedar (*Thuja plicata*). Boundaries were often marked with poles, stakes, rocks, or ditches, but if not marked were recognized and maintained by social sanctions. Chiefly classes might own specific plots and receive portions of harvests obtained by others therein. Some highly valued resources were reserved for chiefs, for example, the first fruits of a season or the best specimens (springbank clover roots). In some cases chiefs received tribute in the form of highly valued resources. Ritual and ceremony associated with first-fruit ceremonies for various taxa had the effect of regulating the timing of harvest. Reprisals for unauthorized use of resources are noted (see Turner et al. 2005:165 for inter-clan example and Deur 2005:305 for intra-clan example). One detailed example from the Gitskan and Wet-suwet-en of northern

British Columbia shows the linkage between ownership and decision making regarding plant harvesting. According to Gottesfeld (1994b), fern rhizome (*Dryopteris expansa*) and rice-root patches were owned by the chief, but he delegated the decision about when to harvest, in this case to elder women knowledgeable about the productivity and last harvest time of specific patches. On this basis, group harvests were rotated to avoid depleting specific productive patches.

Implications for Understanding Sustainable Animal Resource Use

The implications for understanding sustainable animal use are several. First, the production of plant foods is likely to have raised the overall carrying capacity and thus low population levels cannot be used as an explanation for sustainability. Second, landscape modification to extend the habitat of useful plant species may enhance a whole food web as well and increase the concentration or density of certain animal taxa, thus providing low-cost, embedded garden hunting. The nature of ethnobiological knowledge and the technologies employed for plants suggest possible parallel strategies for enhancing or managing animal populations. Social practices discussed for plant management are widely paralleled for animals. Our final discussion concerns the extent to which these practices contributed to sustainability of animal populations.

Population Size/Density Limits

Where human populations are limited by factors other than target prey abundance, they might not grow large enough to permanently depress prey populations; thus sustainability can be an epiphenomenal effect of low population density (Hunn 1982). Hunn argues this specifically for the Fraser/Columbia Plateau, suggesting that low population density combined with seasonal mobility accounts for a persistent subsistence strategy in that culture region. Historic population figures suggest population densities on the order of three times higher on the Northwest Coast (54/100 km^2) than in the Plateau (15/100 km^2) based on Ubelaker's (2006) "most likely" estimates. This significant difference is thought to reflect long-term patterns and carrying capacities. Because of the presumption that marine resources account for the difference, the role of plants in supporting populations in the coastal regions in precontact times has barely been explored.

Previously we suggested that sustainable animal use in the Pacific Northwest might have been due in part to low population density and made a corollary assumption that plant use was not significant in affecting population levels (Butler and Campbell 2004). This interpretation was consistent with the suggestion made by Byers and Broughton (2004) that cases of human-caused resource depression in the American West (Broughton 1994, 1999; Grayson 2001; Janetski 1997) are correlated with high productivity supplied by intensive wild-plant use or agriculture. According to this view, these plant resources supported increasing human populations, which then exerted pressure on animal populations.

The new plant paradigm forces us to reconsider our previous position. The ethnohistoric information provided in Deur and Turner (eds. 2005) certainly suggests the likelihood that plant resources were capable of significantly raising the carrying capacity. Besides sheer quantity and total caloric value, plants may have been particularly important in sustaining or increasing population levels by presenting alternative resources, or fallback foods. Deur (2005), using oral traditions from coastal British Columbia, suggests a risk-reducing role for estuarine roots that balanced less predictable animal resources.

An excellent example of a plant staple produced in quantity is wapato (*Sagittaria latifolia*), a small, aquatic tuber once common to shallow wetlands on the lower Columbia, Fraser, and Willamette rivers as well as the Puget Sound lowlands before major habitat destruction of the past century. Darby (2005) reviews the biology, ecology, and ethnohistoric records for Native American use: this potatolike plant once grew in locally dense stands several hectares in extent and produced a nutritious, calorie-rich bulb that could be harvested nine months of the year, with minimal pursuit, processing, and handling costs. Darby illustrates the plant's productivity (and potential for supporting large human populations) at one location on the lower Columbia near modern-day Portland, Oregon, Sauvie Island. Before habitat modification, the 9,800-ha island contained close to 3,000 ha of wetlands that could support wapato fields. Based on estimates of density and primary production, Darby suggests this island alone could have provided 17,910 metric tons of wapato each year; 3,940 tons would have been available for human consumption (taking into account waterfowl herbivory and the need to leave bulbs in place for future yields). If wapato represented 20 percent of the diet, Darby estimates that Sauvie Island would have supported 31,000 people (given wapato yields 1.8 cal per gram of fresh tuber and assuming a daily requirement of 2,500 kcal per person per day).

Reconstructions of population size based on such estimates are easy to challenge; for example, ethnohistoric records of the early nineteenth century highlight the regularity with which wapato was traded along an approximately 100-mile stretch of the Columbia River, so the resource was not strictly linked to local population consumption. On the other hand, such trade had the potential to elevate carrying capacity across a much wider region than would be defined by local resource and habitat distribution.

Deur and Turner (2005) give two other estimates that provide some perspective on the sheer numbers of plant resources that might have been harvested: based on descriptions of nineteenth-century Saanich camas harvests, from southern Vancouver Island, they estimate that a single family might have harvested 10,000 camas bulbs per year. Their estimate of 100,000–200,000 salal (*Gaultheria shallon*) berries per year is not fully explained but is intriguing, given that salal is only one of many types of berries harvested in most areas.

Impacts of Plant Management on Animal Resources

Nearly all forms of plant management used to increase plant production in the historic period may have increased animal populations, or at least concentrated them in places easily accessed by people (Table 9.1). This could promote garden hunting (e.g., Linares 1976) where productive plant plots are developed near villages. In most cases the competing animal predators would need to be controlled to reduce their impact on the harvest, but would also be desirable resources themselves. For example, muskrats (*Ondatra zibethicus*) and waterfowl would have heavily competed with humans for wapato (Darby 2005). Darby specifically notes that muskrats would have been particularly valuable as winter food since they did not lose mass over a typical winter. The Nuxalk of northern British Columbia trapped waterfowl attracted to estuarine rhizome gardens (Deur 2005). Native peoples in the Pacific Northwest used fire to enhance plant productivity (Boyd 1999; Williams 2002). Landscape firing is thought to have promoted game populations also, thus it can be considered an animal management strategy as well, although we do not know how to apportion costs to specific resources.

Parallel Strategies for Animal Management

Descriptions of plant management practices demonstrate the level of knowledge about plant growth habits as well as available engineering capabilities. It would be reasonable to assume that similar levels of knowledge of animal behavior and engineering approaches could be applied. However, we expect management strategies would be less common given the greater complexities in animal behavior (life history, migratory patterns). In fact it is harder to find specific cases of strategies involving direct manipulation of organisms (Table 9-1) to increase the chances for organism survival and fecundity. In a well-documented historic incident in 1913 Indians transported live fish around a landslide on the Fraser River caused by railway construction, suggesting that this practice could have been used in the past as well. The idea of pruning plants seems most parallel to culling or selective harvest of animals. It has been suggested that weir and trap technologies allowed for selective escapement (Haggan et al. 2006); the extent to which this was practiced simply to regulate quantities vs. selecting specific individuals is not known. Both would be considered management by our definition. Is there a behavior regarding animals that is parallel to removal of plant competitors by weeding? We know that Native American populations in the Northwest preyed upon carnivores (Butler and Campbell 2004); removal of animal predators is somewhat akin to weeding.

Parallels involving landscape modification are more abundant. One recently highlighted example is deliberate construction to extend intertidal habitat productive for preferred clams. Over 400 rock-walled features on the northeast side of Vancouver Island in the Broughton Archipelago have been identified as constructed clam "gardens" (Williams 2006). The terraces appear to have been created in a similar manner to estuarine root gardens, although lower in the intertidal zone. More information about the function of these features, previously seldom documented, is needed. The placement of brush or branches in the intertidal zone to create an attractive environment for herring (*Clupea pallasii*) to deposit their eggs during spawning is an example of controlling a resource's location for ease of access. Maintenance of salmon streams by removing debris, a form of habitat enhancement, is reported for the Heiltsuk of northern British Columbia by Jones (2002). There is an early historic record of the Nuu-chah-nulth of Vancouver Island transporting fish eggs between water systems (Sproat 1868). This is different from transporting adult fish around a landslide, as egg transfer has the goal of increasing stream productivity rather than increasing survival times for individual organisms.

Access and Control via Social Institutions

Documents and oral tradition show that ownership of capture locations and social regulations regarding animal harvesting were ubiquitous on the Northwest Coast (Richardson 1982). One of the most commonly cited examples concerns catch locations and constructed facilities that target locations where salmon (*Oncorhynchus* spp.) are concentrated and accessible. Social regulations at such sites not only involved who had the right to fish there but also when they had access. Blukis Onat (2002) suggests that the construction of traps ranging from the intertidal zone, to rivers, sloughs, and streams and inland lakes represented a high degree of control and selectivity over the population. Traps interfered with freedom of movement of anadromous fish populations, provided access, allowed selectivity in the take, and extended the time period of control when used for live storage. She compares these traits to those in a model developed by Hecker (1982), who offers the concept of *cultural control* as a more useful term than *domestication* to describe human-animal relationships in a variety of environmental settings. In his terms, cultural control has four aspects: active and deliberate interference, extended period of control, control over a population, and enhancement of accessibility to humans. Blukis Onat points out that in managing salmon populations along a spawning drainage, social relationships are also being managed. She suggests that applying Hecker's model extends the concept of cultivation not only to salmon but also to shellfish, camas, and cedar, all of which are considered "wild," rather than "domesticated."

Ownership among the Salish peoples of the Gulf of Georgia/lower Fraser River of southern British Columbia (Richardson 1982) also included horse clam (*Tresus* spp.) and butter clam (*Saxidomus giganteus*) beds, raised duck nets, sturgeon dip net locations, certain fishing streams, and reef net locations for sockeye salmon (*O. nerka*). Additional owned resource locations noted for more northern groups (Turner et al. 2005) included halibut (*Hippoglossus stenolepis*) and herring fishing banks, gooseneck barnacle (probably *Pollicipes polymerus*) areas, sea lion (Otariidae) hunting locations, bear trails, and geese locations—Nuu-chah-nulth; mountain goat (*Oreamnos americanus*) hunting areas and eulachon (*Thaleichthys pacificus*) fishing sites—Kwakwaka'wakw; sea bird nesting sites—Haida; and beaver (*Castor canadensis*) and other fur-bearing animal hunting areas—Tsimshian. There were social regulations regarding timing and degree of use for animals occupying a range of habitats (marine, terrestrial, lowland, upland) and with varying migratory habits (sedentary clams to migratory fishes). As in the case of plants, social regulations and rituals structured the timing of harvests, the most notable being the extremely widespread "first salmon ceremony" (e.g., Gunther 1926). In many cases chiefly managers gave permission for use of capture locations or gear and expected a share of the harvests in return for use (Johnsen 2001; Trosper 2002).

Tracing the Evolution of Sustainable Practices in the Archaeological Record

The new plant paradigm supports the idea that plants contributed to the high population densities on the Northwest Coast. Our review suggests that populations were sufficiently large to have depleted animal resources. This leads us to search for cultural practices to explain sustainability.

Can the practices described above for both plants and animals be used to explain sustainability of animal resource use on the Northwest Coast? Practices that are designed to increase yields (fish weirs, burning, gardening, and embedded garden hunting) might well contribute to resource depletion rather than sustainability. On the other hand, if these practices developed over time in pace with human population growth and were socially regulated, they might help to sustain higher human population densities without depressing animal populations. A number of researchers (e.g., Gottesfeld 1994b; Hunn 1982; Hunn et al. 2003; Johnsen 2001; Trosper 2002; Turner et al. 2000) have looked specifically at regulations associated with ownership on the Northwest Coast and suggested that reciprocity, contingent proprietorship, and socially monitored restraint in consumption led to sustainable use of the resources. This is consistent with global patterns that show the effectiveness of control or exclusive-access rules governing resource harvest for common pool resources to promote long-term resource sustainability (e.g., Smith and Wishnie 2000).

The management practices for salmon and other resources described above represent the endpoints of long-term evolutionary process, but we are not in a position yet to document their antiquity or relate them to our long-term record of sustainable animal use. To understand how management practices might have evolved, we need to look at the prehistoric record. This requires a theoretical framework that defines analytic variables and test implications and lets us develop bridging arguments that link abstract concepts like ownership and social regulation of resource use with physical artifacts and facilities.

Making such links is more complex than simply finding archaeological correlates of specific practices like burning or gardening or fish capture at weirs. Given our interest in ownership and how it relates to sustainability, all manner of facilities are important because they are secondary resources that can themselves be owned or regulated and their frequency in time and space may reflect developing systems of resource ownership. At the same time, we recognize that physical records have complex significance. Facilities indicate a certain level of investment in resource procurement or processing, but that investment reflects multiple factors including the degree of mobility, delayed consumption, and resource sharing, as well as the scale of the social unit.

Behavioral ecology is a well-developed theoretical structure from which to formulate deductive hypotheses. Drawing on Smith and Wishnie (2000), conditions relevant to the Pacific Northwest likely to foster social regulations for conservation include confined resource populations to which controlled access can apply; resilient or rapidly renewing resources likely to respond to management controls; low discount rates; and small group size and stable membership (for effective monitoring). Factors that might undermine development of conservation behavior include acquisition of novel technology, acute resource scarcity, and adequate substitutes for threatened resources. Combining these concepts with Richardson's (1982) model relating variation in resource structure to the nature of kin groups and ownership of resources on the Northwest Coast, we suggest the following examples of hypotheses regarding where certain management strategies would develop, or for which resources.

> 1. Within a single subregion, we would expect that management systems would develop for clustered and restricted resources such as oak groves or shellfish beds before those for more unbounded habitats such as foothill artiodactyl hunting areas.
> 2. Because patchiness creates bounded resources and because the patchiness increases from south to north (Richardson 1982; Schalk 1981; Suttles 1990), we would predict that systems of social regulation inversely relate to the north–south gradient. One measure of this would be in procurement facilities such as fish weirs that target patchy resources, like salmon or coastal schooling fish; these require significant communal organization and capital investment. We would expect the distribution of such facilities to be inversely related to latitude, with weirs developing earlier and being more abundant to the north. This is the trend currently apparent in radiocarbon dates compiled by Erlandson and Moss (1999:Figure 3) for the southern and northern coasts, although, as the authors point out, preservation biases due to strikingly different geomorphic histories cannot be ruled out. Local variation at the same latitude would also be expected, such as that created by exceptionally large river systems with large salmon runs like those on the Fraser and Columbia rivers.
> 3. As group size increases and elites attempt to extend control over larger areas, development of mechanisms for monitoring group identity would be predicted. Archaeologically visible examples would include labrets or other body ornaments or cranial modification.
> 4. Socially regulated access will more likely occur for resources that represent wealth or those more regularly traded to external markets. Regulated access might be visible for items of restricted distribution within households.
> 5. At choke points such as rapids where salmon or other resources are concentrated seasonally, we would predict that over time, people would come earlier to the location and stay longer to establish a presence and monitor the use by others. This would be indicated by increasing within-year occupation duration, measurable by seasonal indicators.

As we outline hypotheses, we need to develop middle-range arguments for measuring relevant variables. We assume that group size might be reflected in house size, group structure in internal distribution of resources in households, and social group membership and degree of territoriality in patterns of artifact stylistic variation. Identification of situations in which naturally occurring habitats were extended or maintained is possible, partly through facilities such as retaining walls, but will also benefit from new methods such as landscape scale studies, soil micromorphology, and genetic biogeography. Physical facilities such as huckleberry trenches (Mack and McClure 2002), camas ovens (e.g., O'Neill et al. 2004), retaining walls, and plot markers (Deur 2005; Moss 2005) are detectable and may provide clues to changes in extent of habitats that were artificially maintained. For example, camas ovens could be associated with a relict forest-prairie ecotone some distance from current edges of a prairie no longer maintained by deliberate burning. Archaeologists have used frequency of roasting pits to interpret trends in intensity of geophyte use in the Willamette Valley and the Fraser/Columbia Plateau (Ames 2005; Ames and Marshall 1980; Lepofsky and Peacock 2004; Thoms 1989). Genetic analyses of camas and Garry oak and other edible plant species are a promising route to recognize the role of humans in extending the distribution of these taxa. Using known village locations as a starting point to search for evidence of gardens, especially more subtle clues such as altered soils makes this practical (Deur 2005; Moss 2005). Intertidal aerial surveys show promise for mapping modifications of the intertidal and salt marsh zones (see work by John Harper, cited in Williams 2006). Archaeologists, paleobotanists, and forest managers are currently focusing on understanding fire frequency over time and attempting to develop comparative measures that help separate the role of human agency from the effects of long-term climate change, which also affects forest composition and fire frequencies (e.g., Lepofsky, Hallett, et al. 2005; Lepofsky, Lertzman, et al. 2005; Whitlock and Knox 2002). Chapter 8 in this volume is an example of such an approach; Roos and co-authors discuss the inherent difficulties and apply a creative strategy for recognizing human-induced burning in an area of the American Southwest.

Conclusions

Because of the connection we have drawn here between resource structure and ownership structure, and in turn to conservation and sustainability, we must emphasize that our faunal data are from the middle latitudes on the Northwest Coast, where the greatest resource predictability and relatively high terrestrial productivity occurred, and the trends we observed are not expected to be replicable everywhere. We also emphasize the importance of examining better resolved chronologies to examine the possibility of serial resource depression and recovery.

The use of plants documented for the Northwest Coast goes beyond the use of wild resources. The cultivation practices seen challenge the dichotomy traditionally held between foragers and farmers, and also the HBE generalizations, on their own terms, about the rarity of conservation among foragers. The protection and propagating of plants are categorically accepted by Smith and Wishnie (2000) as conservation behavior, and are comparable to the husbandry practices associated with the Neolithic revolution by Alvard (1995).

Habitat manipulation and increased plant production are sometimes associated with environmental degradation and resource depression. It is significant to note, therefore, that the two habitats best demonstrated to have been modified to improve plant production, deltaic wetlands and forest clearings, are successional and/or shifting in nature. Such environments offer the possibility of enhancing production of plant and animal resources with less risk of environmental degradation, which has implications for understanding the evolution and stability of different subsistence strategies. Encouraging native species might increase yields in a way that is sustainable over a long period of time, in contrast to creating artificial environments for exotic species that give very high short-term yields that might not be sustainable over the long run.

Our chapter has focused on the empirical and theoretical implications of the new "plant paradigm," but there are methodological implications as well. It is clear that plant and animal use need to be better integrated in modeling adaptation and social developments, and also that archaeologists need to find creative analytic ways to overcome the methodological noncomparability in measurements of plant and animal use. It has been easy for archaeologists to fall into the habit of underemphasizing plants because archaeological recovery and analysis of plant remains has lagged behind that of animal remains. Nevertheless, it is primarily long-held and seldom-examined beliefs about the behavior of Northwest Coast foragers that have led to the omission of plant use even from model development. We need models that consider a wide range of resources, correcting not only the plant omission but also the historical overemphasis on salmon. For example, Lepofsky, Lertzman, and colleagues (2005) make the point that the strategy for intensifying plant resources could involve enhancing the resource abundance directly, not just through technological innovations for harvesting and processing, drawing a contrast with salmon. Other animal resources, such as shellfish and terrestrial game, might offer avenues for intensification more parallel to plants.

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