

Resource depression on the Northwest Coast of North America

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The mammal and fish faunal record from eight sites on the Columbia River (Oregon, USA) dating to the last 2200 years is examined to study subsistence change before and after European contact. Results show an increased use of low-ranked resources before contact and increased use of high-ranked resources after contact, trends that are predicted from changing demography and human predation pressure.

Key-words: North America, zooarchaeology, prehistoric subsistence, prey choice model, resource depression

Introduction

A variety of evidence is accumulating from various parts of the world that suggests past human foragers greatly affected the animal and plant populations they were exploiting (Botkin 1980; Broughton 1997; Holdaway & Jacomb 2000; Nagaoka 1998; Steadman 1995; Stiner *et al.* 1999). Besides identifying prey response to human harvesting pressure, such studies also track ways human predators adjusted to reduced prey abundance, pointing out the dynamic nature of predator–prey interactions. Many studies have been conducted in a theoretical framework derived from evolutionary ecology, particularly foraging theory, and have demonstrated enormous explanatory power in accounting for subsistence change in human economies (e.g. Christenson 1980; Grayson & Cannon 1999; Gremillion 1996; O'Connell & Hawkes 1981).

With some exceptions (Cohen 1981; Croes 1995) researchers reviewing economies in Pacific Northwest North America have not considered whether human foragers altered prey populations. Some workers (e.g. Matson 1992) have expressed the view that key resources, like salmonids, were difficult for humans to 'over-use'. Moreover, the Northwest Coast region has long been viewed as a 'Garden of Eden', where the richness of the resource base was in some measure responsible for the 'exceptional' hunter–gatherers that lived there, known for their relatively high population density, social organization which included slavery, elaborate

art style and sedentary or semi-sedentary settlement patterns — attributes generally linked to agriculture-based societies.

Several conditions suggest it would be useful to re-examine these views. Abundant archaeological evidence shows that human populations were growing and becoming increasingly sedentary, circumscribed and territorial during the late Holocene (Ames & Maschner 1999; Matson & Coupland 1995). Certainly in light of results from other parts of the world, it is reasonable to hypothesize that growing populations of relatively sedentary foragers depleted local food resources. Furthermore, human population size was drastically reduced with the introduction of disease at European contact. Such a decline should result in reduced foraging pressure; prey populations would have the opportunity to rebound and, in turn, human foragers could take advantage of increased prey abundance and shift resource selection.

This paper examines questions of late Holocene subsistence change, particularly the case for human-induced resource depression in the Pacific Northwest. I draw on the prey choice model from foraging theory to derive expectations about resource selection and subsistence change that would result from changes in foraging pressure. I then test this model using the mammal and fish faunal record from several sites on the Lower Columbia River dating to the last 2200 years. Results show an increased

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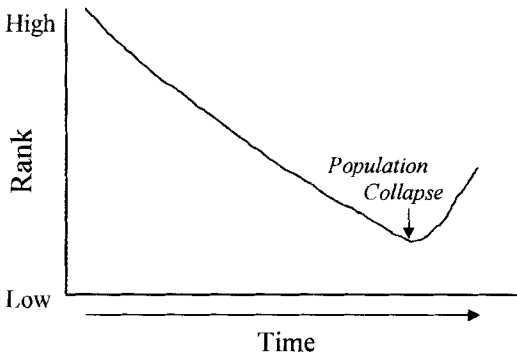


FIGURE 1. *Relative change in contribution of high and low ranked vertebrate resources before and after population collapse.*

use of low-ranked resources before European contact and greater use of high-ranked resources after contact, which are predicted from changes in human demography. The results are provocative, suggesting that historic descriptions of exceptional resource abundance in part may reflect drastically reduced Native population size and that ethnographic records of subsistence practices may not reflect long-term trends.

The model

The prey choice model provides a set of predictions on which prey items a predator should choose when an array of potential choices are encountered (Stephens & Krebs 1986). The model holds that a predator's most efficient strategy is to take the highest-ranked prey when it is encountered. Whether lower-ranked prey is taken depends on the encounter rate with the higher-ranked resources. Encounter rates are based mainly on prey densities; low-ranked prey will enter the diet more frequently as the abundance of higher-ranked prey declines. If mobility is limited or if the predator population increases, or if both occur, then resource depression of the high-ranked prey is likely to occur. Basically, the prey choice model suggests that human foragers will pursue resources that provide the highest energetic returns because natural selection favours predators that operate like this, or predators have sufficiently sophisticated and flexible decision-making skills, or both.

Using the prey choice model requires that food resources be ranked according to their profitability, or their post-encounter return rates.

Based on theoretical modelling and empirical testing of prey selection by human and non-human foragers, a number of studies show that body size is a good proxy measure for prey rank (Broughton 1994). Up to a certain size, the larger the animal, the higher the rank. Madsen & Schmitt (1998) argue that while this relationship may hold when individual organisms are procured, when multiple individuals are captured at one time, as with mass harvesting (e.g. netting), the biomass of the entire group of individuals is the appropriate unit of comparison. Their work highlights the need to consider technology in evaluating resource selection models, which I return to below.

In considering the prey choice model and conditions specific to human foragers in particular, I developed a number of predictions regarding changes in human subsistence for the Lower Columbia in the Late Holocene (FIGURE 1). During initial phases of human occupation, human foragers exploit the highest-ranked resources. As human population size increases, predation pressure increases and abundance of locally available, high-ranked resources declines. Foragers could travel to more distant locations to procure higher-ranked resources, but several factors make this unlikely. With overall declines in mobility and territorial circumscription, foragers may not have access to resources outside their territory. If population growth occurs at a regional scale, high-ranked resources in other areas would be depleted as well. Finally, even if higher-ranked resources were available in distant areas and foragers had access to such resources, costs of transporting resources back to a central base would have to be weighed against using local, lower-ranked resources. It is predicted that as encounters with high-ranked resources decline, human foragers would shift to taking lower and lower ranked resources (FIGURE 1). With European contact, infectious diseases are introduced, to which indigenous people have little resistance and populations are drastically reduced. With reduced human predation pressure, density of higher-ranked prey would increase leading to increased encounter rates with higher-ranked resources and human foragers would begin to make greater use of these resources.

Given the relationship between body size and resource ranking, changes in the contribution of high -and low-ranked resources in hu-

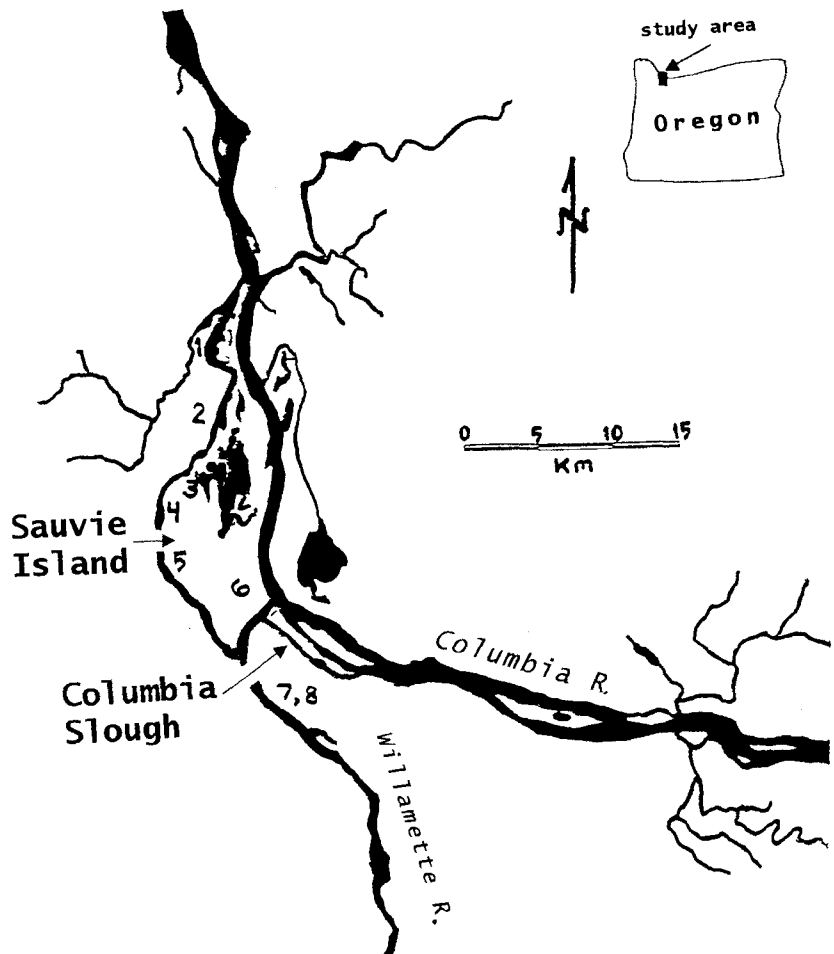


FIGURE 2. Location of sites included in study, Lower Columbia River, OR (Site 1:35 CO 3; Site 2: 35 CO 5; Site 3:35 CO 7; Site 4: 35 MU 1; Site 5: 35 MU 6; Site 6:35 MU 9; Site 7: 35 MU 105; Site 8: 35 MU 112).

man diet can be estimated using archaeological faunal assemblages from dated contexts. Thus the predictions outlined in the model can be tested. The model is by design very simple, suggesting that prey abundance is controlled by the size of the predator population, with independent environmental variation playing a limited role in setting prey abundance and encounter rates.

Faunal data

Faunal data used to test the model are from eight sites located along sloughs and backwater channels adjacent to the Lower Columbia River in the vicinity of modern-day Portland (OR) (FIGURE 2). Here, the Columbia flows through a low-lying alluvial bottomland; extensive wetlands were located across the val-

ley floor before the region was modified by urban/industrial activities (Ames *et al.* 1992). Above the broad valley bottom are numerous ridges and dissected plateaux. All of the sites included in the study are located on the valley bottom in a roughly linear pattern over a straight-line distance of about 25 km (FIGURE 2). Habitats in the area included cold clear rivers, shallow lakes, freshwater marsh, oak woodlands, grasslands and conifer forests that supported a number of species of migratory and resident freshwater fish, terrestrial and aquatic mammals and waterfowl (Saleeby 1983; Ames *et al.* 1996).

I chose this area to test the prey choice model for several reasons. First, estimates of aboriginal population density of the Lower Columbia Valley are among the highest in North America

taxon	Merrybell	Multnomah I			Multnomah 2			Multnomah 3		
	MU9	CO3	MU1	MU112 ¹	CO5	CO7	MU105 ¹	CO5	MU6	CO7
<i>Odocoileus</i> sp.	2	35	160		50	53		188	22	21
<i>Cervus elaphus</i>		10	40		14	1		72	17	6
<i>Odocoileus/Cervus</i>		6			7	3		17	2	4
<i>Ursus americanus</i>		1	3		5	3		14		
<i>Lynx rufus</i>			2					9		1
<i>Castor canadensis</i>		4	10		1	3		12		5
<i>Procyon lotor</i>		6	32		5	5		10	1	1
<i>Canis</i> sp.	1	4	36		1	3		19		
<i>Erithizon dorsatum</i>							1			
<i>Enhydra lutris</i>		1								
<i>Phoca vitulina</i>					1			2		
<i>Vulpes vulpes</i>					3					
<i>Martes americana</i>								1		
<i>Lutra canadensis</i>					2			4		
<i>Ondatra zibethicus</i>			5		9	2		23		
<i>Mustela vison</i>			3		2			2		
<i>Sylvilagus bachmani</i>								2		
<i>Aplodontia rufa</i>								2		
indeterminate large mammal	12	66	212		85	48		343	23	20
indeterminate medium mammal		7	12			1		37		2
indeterminate small mammal			7		2	2		5		
<i>Ptychocheilus oregonensis</i>			36		5	33		23		13
<i>Mylocheilus caurinus</i>			12		6	2		21	1	2
<i>Acrocheilus alutaceus</i>								3		
<i>Gila bicolor</i>								2		
small Cyprinidae			59			4				29
indeterminate Cyprinidae				2	3		16	5		2
<i>Catostomus macrocheilus</i>			72		31	75	4	40	2	28
Cyprinidae/Catostomidae	2		54	23	45	39	8	50	3	14
<i>Thaleichthys pacificus</i>			1		99		21	1		
<i>Gasterosteus aculeatus</i>				24			147			
<i>Acipenser</i> sp.	7	12	57	6	113	116	29	77	37	35
<i>Oncorhynchus</i> sp.	10	7	150		22	127	32	452	3	61
total NISP	34	159	963	55	511	521	257	1436	111	244

1 Only a very small number of mammal remains could be identified below class and the remains are not considered further.

TABLE 1. Number of Identified Specimens (NISP) by site and component, mammals and fish.

(e.g. Kroeber 1939; Boyd & Hajda 1987). If demographic pressure and human foraging practices caused resource depletion in the Pacific Northwest, it should be evident here. Also, as a consequence of introduced disease, indigenous people in the valley suffered enormous population loss (Boyd 1985). Such a reduction in human foraging pressure should allow me to detect rebound in prey population levels. In addition, the reported sites are located in very similar environments. Thus the kinds of resources available to prehistoric foragers would have been comparable and changes in faunal representation should not reflect ecological differences. Finally, since most of the sites were

excavated and analysed as part of one project, differences seen across assemblages should not reflect archaeological practices.

The faunal data are from two sources. The first is from six sites on or adjacent to Sauvie Island that were tested in the early 1970s mainly to produce a cultural chronology (Pettigrew 1981) (FIGURE 2). Based on house features, modified objects and faunal indicators, all of the sites likely represent year-round residential occupation. Faunal remains were recovered through screening sediments through quarter-inch (6.4-mm) mesh and analysed by Saleeby (1983). The second set of faunal data is from two sites (35 MU 105 and 35 MU 112) located

	site/ component	Merrybell 600 BC–AD 200	Multnomah 1 AD 200–1250	Multnomah 2 AD 1250–1750	Multnomah 3 AD 1750–1835
	MU 9	X			
	CO 3		X		
	MU 1		X		
	MU 112		X		
	CO 5 (Strat 4–5)			X	
	CO 7 (Strat 3–4)			X	
	MU 105			X	
TABLE 2. <i>Chronological assignment of sites and components.</i>	CO 5 (Strat 1–3)				X
	MU 6 (Strat 1–7, unit A) (Strat 1–3, unit B)				X
	CO 7 (Strat 1–2)				X

on Columbia Slough, just south of Sauvie Island, near the confluence of the Willamette and Columbia Rivers (FIGURE 2). These sites probably represent short-term seasonal camps based on artefact and feature character (Ellis 1996; 1998). Faunal remains, mainly fish, were recovered from a series of bulk samples, processed through 1.0-mm mesh, and identified by Butler (1996; 1998).

I focused study on the mammal and fish assemblages, which represent the bulk of the collections. TABLE 1 summarizes the taxonomic frequencies by site and component for sites with more than one time period represented. A common counting unit was available for all the collections, number of identified specimens (NISP); given this and the fact that NISP and another common counting unit, minimum number of individuals (MNI), have been shown to provide similar measure of taxonomic frequency (Grayson 1984), NISP was used in my analysis.

Use of quarter-inch mesh at the Sauvie Island sites very likely resulted in the loss of small specimens, including remains of small-bodied fishes; thus in comparing taxonomic representation between the Sauvie Island data with that from Columbia Slough, differences in screen size used will have to be considered. On the other hand, at least for the Sauvie Island data, given that the bias was consistent, recovery *per se* would not explain differences seen among those site assemblages.

To examine change in resource selection, the faunal assemblages must be temporally ordered. Here, I assigned the faunal assemblages from the Sauvie Island sites (or site components) to one of the four phases constructed by Pettigrew (1981) based on radiocarbon dates, historical types and presence of Euro-American trade

goods (see also Saleeby 1983). I assigned the two Columbia Slough sites to the appropriate phase using radiocarbon dates (TABLE 2).

It is critical for testing the resource depression model to include faunal assemblages dating after population decline, which followed introduction of European diseases. There is some controversy in the region over whether this occurred with historically documented face-to-face contact (c. 1750–1775) or centuries before, as a result of pan-hemispheric epidemics associated with the earliest entry of Europeans into the New World (Boyd 1985; Campbell 1989; Dobyns 1987; Ramenofsky 1987). Unfortunately, developing a more refined temporal order for the faunal assemblages that would allow one to test for pre-1750 population loss is not feasible for this project. Here, I assume that Multnomah 3 phase deposits (which are distinguished from the earlier phase by the presence of European trade goods) marks the time of initial disease and appreciate the limitations this may impose on testing the model.

Change in resource selection

There are a number of ways to track changes in faunal resource selection. Drawing on the work of Bayham (1979) and Broughton (1994; 1997), I have created indices that calculate a ratio of high- to low-ranked resources, with rank assigned based on estimates of body size. To rank the fish taxa, I examined body sizes of Lower Columbia fish identified in the faunal assemblages (TABLE 3) and divided the set into ‘large’ and ‘small’ based on rather striking differences in body size. Large taxa include *Acipenser* sp. (sturgeon) that routinely attain lengths of several metres and weights of over 100 kg and *Oncorhynchus* sp. (salmon and trout) that are typically longer than 500 mm and weigh

fish taxon	length (mm)	phase	mammal/ small fish index	fish index
'large' taxa				
<i>Acipenser transmontanus</i> *	800–3400	Merrybell	.88	.89
<i>A. medirostris</i> *	1300–2130	Multnomah 1	.69	.45
<i>Oncorhynchus tshawytscha</i>	750–800	Multnomah 2	.36	.45
<i>O. keta</i>	480–800	Multnomah 3	.79	.74
<i>O. kisutch</i>	450–610			
<i>O. nerka</i> *	610–710			
<i>O. mykiss</i> **	250–750			
<i>O. clarki</i> **	300–485			
'small' taxa				
<i>Ptychocheilus oregonensis</i>	210–300			
<i>Mylocheilus caurinus</i>	160–205			
<i>Acrocheilus alutaceus</i>	150–200			
<i>Gila bicolor</i>	305–356			
<i>Catostomus macrocheilus</i>	200–300			
<i>Thaleichthys pacificus</i>	125–170			
<i>Gasterosteus aculeatus</i> **	30–75			

* refers to fork length

** refers to total length

TABLE 3. Approximate adult body size of Lower Columbia fish (measure is standard length, unless otherwise indicated (data from Lee et al. 1980).

several kilograms. Historically, *O. tshawytscha* (chinook salmon) was far and away the most abundant salmon species in the Columbia Basin (Fulton 1968); this salmonid is much larger than other species with typical weights over 10 kg and some as heavy as 45 kg (Netboy 1980). Because the *Oncorhynchus* archaeological specimens could not be identified to species, the extent to which small forms of *Oncorhynchus* (e.g. non-migratory forms of *O. mykiss*, *clarki*) were used cannot be known from the faunal data itself. However, given the overwhelming predominance of large, migratory salmonids in the region, Native people most likely relied on them. The length of 'small' fishes is generally much shorter than 400 mm (TABLE 3). Two species (*Catostomus macrocheilus*; *Ptychocheilus oregonensis*) sometimes attain weights of 2–3 kg and lengths of half a metre (Wydoski & Whitney 1979), but are usually much smaller than this.

Almost all of the mammal taxa present in the archaeological assemblages reach much greater size than the small fish taxa. Except for three taxa (see below), mammals typically weigh more than 3 kg and most attain much larger size than this. Only three taxa (*Martes americana*, *Mustela vison*, *Ondatra zibethicus*) generally weigh less than 1 kg and overlap in size with the small fish. Since these small mam-

TABLE 4. Indices determined in aggregate by phase.

mal taxa only represent about 2% of the mammal assemblage, this should not affect the comparisons. Remains of small, burrowing rodents and mole (*Scapanus*) are likely to be intrusive and are not included in comparisons.

The first index, referred to here as the *mammal/small fish index*, provides a ratio of large prey (mammals) to mammal and small-bodied prey (small fishes); the larger the ratio, the greater the contribution of large, higher-ranked prey:

$$\frac{\Sigma \text{NISP mammal}}{\Sigma \text{NISP mammal} + \Sigma \text{NISP small fish}}$$

This index was calculated in the aggregate (combining all faunal assemblages for each phase) as well as for each site or site component included in the study (TABLE 4, TABLE 5).

To examine changes in rank of fish used specifically, I calculated the *fish index*, which is the ratio of large fish to large fish and small fish taxa; as before, the larger the ratio, the greater the contribution of large, higher-ranked fish. The ratio

$$\frac{\Sigma \text{NISP large fish}}{\Sigma \text{NISP large fish} + \Sigma \text{NISP small fish}}$$

also was calculated in the aggregate (combining all faunal assemblages for each phase) as well as for each site or site component included in the study (TABLE 4, TABLE 5).

To repeat expectations, if late Holocene human foragers caused resource depression of high-ranked taxa, we should see a progressive decline in frequency of high-ranked mammals (relative to small-bodied fish) and a decline in large-bodied, high-ranked fish (relative to lower-ranked fish) until European contact. With contact and decline in human population levels, the record should show an increased use of high-ranked resources (mammals and large fish) and decline in use of small, lower-ranked fish.

phase	mammal/ small fish index	fish index	salmon index	sturgeon index
Merrybell				
MU 9	.88	.89		
Multnomah 1				
CO 3	1.0	1.0		
MU 1	.69	.47	.40	.20
MU 112	-*	.11		.11
Multnomah 2				
CO 5	.45	.42	.10	.37
CO 7	.45	.61	.45	.43
MU 105	-*	.24	.14	.13
Multnomah 3				
CO 5	.84	.78	.75	.35
MU 6	.91	.87	.33	.86
CO 7	.41	.52	.41	.28

TABLE 5. Indices by site and component and phase.

* index not calculated given extremely small number of mammal remains recovered

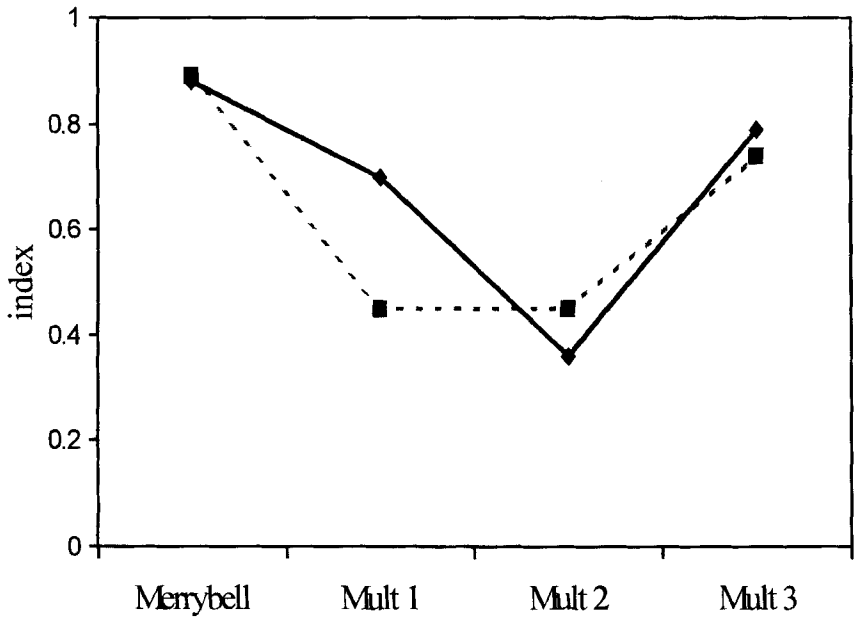


FIGURE 3. Plot of indices, based on aggregate NISP by phase. Solid line: mammal/mammal+small fish index; broken line: large fish/large fish+small fish.

Were the expectations met? Based on aggregated data, trends in the mammal/small fish index (FIGURE 3) match the expectations, showing a progressive decline in use of mammals in the earliest three phases and then, in the post-contact phase, an increase in mammal use. The aggregate fish index declines after the initial phase and increases after contact, which supports the predictions (FIGURE 3). However, the fish index is similar during the two middle, pre-contact phases, which suggests that after an initial decline about AD 200, large fish population size remained relatively consistent until European contact.

To examine variation in prey selection across sites and time period, the indices were calculated and plotted for each faunal assemblage. As shown in FIGURE 4 for the mammal/small fish index, most assemblages follow the predicted pattern, with the exception of one assemblage in the post-contact phase (35 CO 7). This site shows the continuing importance of small fish, when the expectation is for such resources to be dropped from use. I tested to insure that the ratios obtained for the assemblages were not affected by sample size; the two variables are not related ($r_s = -.452, .5 < p < .20$).

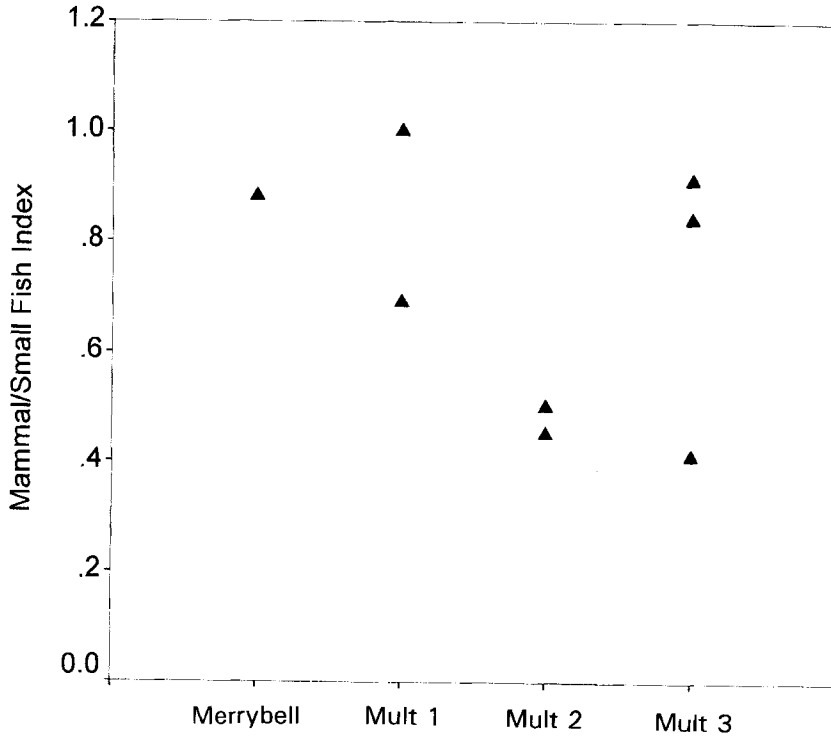


FIGURE 4. Plot of mammal/mammal+small fish indices by site and phase.

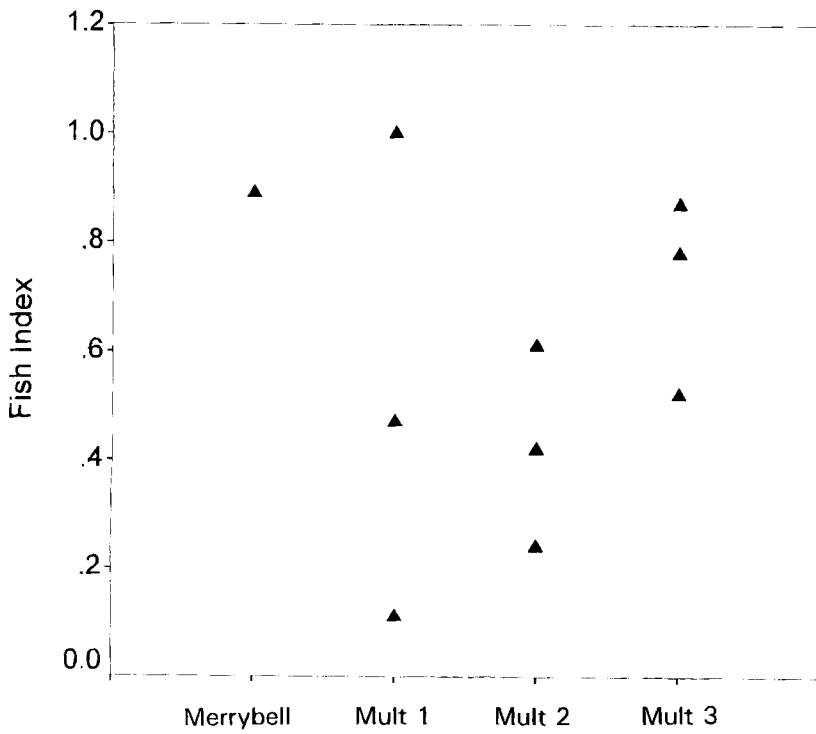


FIGURE 5. Plot of large fish/large fish+small fish indices by site and phase.

FIGURE 5 plots the fish index for each faunal assemblage and, again, the predicted trends are expressed, although variation in resource use among sites in a given time period is sometimes quite high. For example, during Multnomah 1, indices range from 1.0, at 35 CO 3, where large fish were exclusively used, to .11 at 35 MU 112, where small fish absolutely dominate the fish assemblage. Some of the variation in Multnomah 1 and 2 is explained probably by recovery methods. The lowest fish indices (that would indicate greatest representation of small fish) were obtained for sites 35 MU 112 and 35 MU 105. These were the only sites in the study where 1.0-mm mesh was used, mesh size that would favour recovery and representation of small-bodied fishes. Assemblage sample size and fish index value are not related ($r_s = -.395, .5 < p < .20$).

Overall, when *Acipenser* and *Oncorhynchus* remains are aggregated as 'large' fish, their taxonomic frequency increases after contact (FIGURES 3 & 5), which supports the notion that these fish populations were rebounding following human population decline and lowered predation pressure. However, the picture becomes more complex when one considers temporal variation in faunal abundance of each large taxon relative to small fish frequency. I calculated the Salmon index ($\Sigma \text{NISP } \textit{Oncorhynchus} / \Sigma \text{NISP } \textit{Oncorhynchus} + \Sigma \text{NISP small fish}$) and the Sturgeon index ($\Sigma \text{NISP } \textit{Acipenser} / \Sigma \text{NISP } \textit{Acipenser} + \Sigma \text{NISP small fish}$) for each site and site component (TABLE 5) to examine in more detail whether the two taxa behave in similar ways and according to the model predictions. (I excluded MU 9 from the Merrybell Phase and CO 3 from Multnomah 1 from the comparison, given very small sample sizes.) The pre-contact assemblages from Multnomah 1 and 2 are dominated by small-bodied fish (FIGURE 6 and TABLE 5), which follows the predicted pattern. On the other hand, during Multnomah 3 evidence for rebound in the form of high sturgeon and salmon indices are not consistent across site assemblages. Only at CO 5 is the salmon index high; only MU 6 provides a high sturgeon index, and at CO 7, as noted above, small fish continue to dominate the assemblage (TABLE 5). These data suggest site-specific functional variation in resource use that is not accounted for by the simple model considered

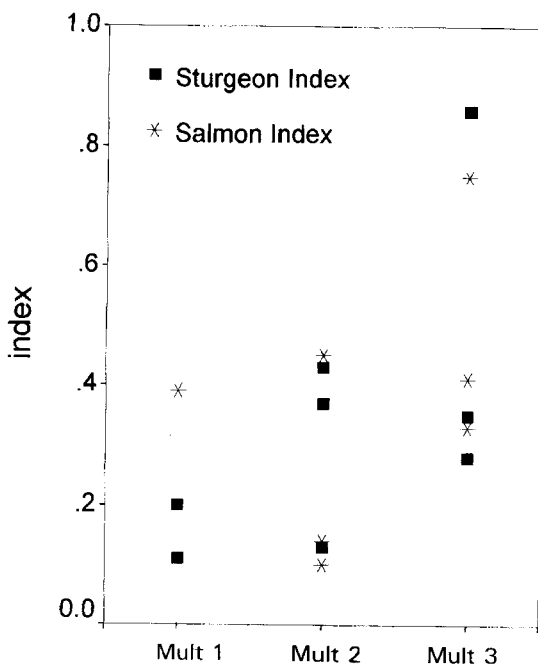


FIGURE 6. Plot of sturgeon/sturgeon+small fish and salmon/salmon+small fish indices by site and phase.

here. That said, it should be noted that the indices from the post-contact assemblages CO 5 and MU 6 are the highest of the sequence, which is predicted from the model, and suggests human foragers began to target large-bodied, higher-ranked fish in response to changing prey density.

Given the coarse-grained approach taken, the closeness of fit between the model and the results is remarkable. Unfortunately, the statistical significance of these trends cannot be evaluated given the small number of data points and thus the trend cannot be evaluated in a rigorous sense. Nonetheless, the results are certainly provocative and suggest the need to test with additional samples.

Other considerations

While the results are generally consistent with the prediction that human exploitation pressure caused the decline in abundance of high-ranked prey, prey abundance could also decline because of climatic or other environmental change independent of cultural factors. While climatic variation associated with the Medieval Climatic Anomaly or Little Ice Age may have occurred, detailed local records are lacking and

it is not possible to determine whether mammals or large fish would have been differentially affected by such changes.

It is also important to consider whether subsistence changes are linked to technological change in prey capture. Use of body size as a measure of prey rank presumes that individuals are the target rather than a mass of individuals (Madsen & Schmitt 1998). Calling on the prey choice model, I have suggested that the shift from large (high-ranked) to small (low-ranked) prey occurred during late prehistoric times because of reduced encounters with larger prey, caused by human foraging pressure. However, if technological change occurred, such as mass harvesting of small fish with nets or weirs, then the rank of small prey could be elevated relative to larger fish. In other words, humans may have increased their use of small fish not because large fish became scarcer (owing to foraging pressure) but because small fish captured in mass provided higher energetic returns (relative to large fish caught individually).

This explanation is unlikely for several reasons. First, it is not consistent with the increased use of large fish after European contact. If small fish taken with nets were targeted because they provided greater energetic returns (than large fish taken singly) in late prehistoric times, then why did use of small fish (captured with nets or otherwise) in several instances *decline* after European contact as indicated from the archaeofaunal record? Further, large fish, particularly salmon and trout, were probably captured at least some of the time using mass harvesting gear. Ethnohistoric sources emphasize that Columbia Basin Indians were 'well equipped to catch large quantities of fish' (Craig & Hacker 1940: 142), using seines, weirs and other methods. While several fishes were taken using mass capture, most descriptions mention the taking of salmon (Craig & Hacker 1940). By all accounts, indigenous people took advantage of salmon and trout life history, through mass capture of fishes that were part of large runs that were migrating to the spawning ground (Rostlund 1952).

The question of technological change in fish capture could also be examined using the artefact record. While it is difficult to link specific prey to technology used to capture them, one can estimate change in capture technology at some scale, by examining the modified objects

from the archaeological record. Evidence for mass harvesting, inferred from so-called net weights — girdled, notched or perforated pebbles and cobbles — is present from sites as old as 7000–10,000 years in the Columbia Basin (Johnston 1987). Closer to the study area, net weights were recovered from several of the sites included in this study but, unfortunately, the small sample size recovered prevents tracking changes in capture technology used in the region. Overall however, there is no evidence from the study area or Columbia Basin for innovations in fishing technology in the last 2000 years.

Discussion

My analysis shows some striking changes in human subsistence in the Lower Columbia Valley in the late prehistoric and early historic period. Using the prey choice model, I have suggested that decline in use of high-ranked resources like mammals and large fish — sturgeon and salmon — reflect human-caused resource depression of these prey. Researchers in the Pacific Northwest have rarely considered the possibility that indigenous people overexploited prey populations. One exception to this is Hewes (1947; 1973) who asserted that Native people over-fished salmon stocks. He based his thesis on comparative analysis of 19th-century commercial fisheries data (see also Craig & Hacker 1940). Hewes suggested that exceptionally large commercial catches on the Columbia in the 1860s were possible because aboriginal fishing pressure was much reduced in the early 1800s, as a result of population collapse due to introduced European disease. Thus according to Hewes, in the early 1800s, salmonid stocks were in a 'resting period'. (In a similar way, the effects of over-fishing are inferred from comparing ocean fishery yields before and after World Wars I and II. Prior to both wars, fishery yields were limited and during the wars, fishing itself was curtailed. In the three years following wartime, fishery yields were significantly higher than the pre-war condition, suggesting the abundance was the 'surplus' resulting from reduced wartime fishery (Beverton & Holt 1957; Cushing 1975).) Fishery scientists Craig & Hacker (1940) also speculated that aboriginal fishing methods such as weirs had the potential to reduce severely or eliminate salmon runs. They note ethnohistoric sources for the Columbia Basin, which describe

the construction of weirs across tributary streams; upstream-swimming fish were diverted into baskets or underwater pens where they could be easily netted or speared. Such methods could effectively block most of a run on its way to the spawning ground. They further note that migrating adult chinook (*Oncorhynchus tshawytscha*) and sockeye (*O. nerka*) salmon mainly return to their natal spawning ground (there is limited amount of 'wandering' or 'straying' of adults); thus it might take many years for new populations to become established in the event of a spawning population being severely depleted.

Schalk (1986; see also Rostlund 1952) has challenged the notion of the 'resting period', pointing out that reduced predation pressure (of the early 1800s) would actually lead to reduction in salmonid stock size, not a surplus. Schalk considers that with reduced post-Contact aboriginal fishing, more adults would return to the spawning ground than could successfully spawn; in turn, excessive competition among developing young could lead to fewer individuals actually migrating to sea, and overall decline in salmonid abundance. Rostlund dismissed out-of-hand Hewes' view that aboriginal fishers overexploited salmon by noting 'there is no evidence' (1952: 17) for such action. Importantly, it is hard to imagine the kind of evidence that would have satisfied Rostlund: given significantly reduced post-Contact aboriginal population levels, Native peoples would not likely overexploit salmonid stocks, so evidence would not be expected from ethnographic or historic documents. Furthermore, evidence from archaeofaunal assemblages would not be available, given the lack of systematic concern for recovery and analysis of faunal remains half a century ago, when Rostlund carried out his work.

Clearly a primary way explicitly to test the thesis that native populations over-exploited prey uses the archaeological faunal record. In a series of faunal studies of coastal and inland California sites, Broughton (1994; 1997) has documented striking patterns in subsistence changes in the late Holocene which, he argues, reflect human-induced resource depression. At several sites along the Sacramento River, he found an increase in use of small-bodied mammals and small, resident freshwater fish over time (1994). In his faunal analysis of the

Emeryville Shell Midden, located near Oakland (CA), he documented a decline in abundance of large fish, particularly sturgeon, and an increase in smaller-bodied fish over time (1997). In high elevation sites in the western Great Basin, Grayson (in press) found a decline in mountain sheep and increase in marmot over time, which, he argued reflects depletion of the larger mammal by prehistoric hunters.

Results presented here suggest a similar pattern of human-induced resource depression for the Lower Columbia. A number of additional tasks should be carried out to substantiate this claim. Analysis of assemblages from other sites in the region is needed, particularly those dating between 3000–2000 years ago, for which there is very little faunal material to date. It will also be necessary to directly measure exploitation pressure, through study of demographic structure of prey populations. Abundant research has demonstrated that human predators can alter prey population dynamics, causing reduction in maximum and average size of prey (e.g. Beverton & Holt 1957; Moreno *et al.* 1984). Measuring skeletal elements (Broughton 1997; Butler in press; Casteel 1976) from well-dated contexts provides an indication of changes in demographic structure of exploited populations that can be linked to predation pressure.

Conclusions

Calling on the prey choice model, this study predicted changes in human subsistence patterns associated with demographic change in the Lower Columbia, which were confirmed through study of mammal and fish remains from dated contexts. These results are provocative — and certainly suggest that other regional sequences be examined for similar patterns. This study also provides empirical support for the view that Native subsistence systems underwent significant *change* as a result of European contact. In a very real sense, ethnographic or early historic descriptions of Native American resource use may not reflect practices of decades or centuries before, given the profound consequences of depopulation and subsistence reorganization (see also Ames 1991; Broughton 1997; Campbell 1989; Cannon 1995; Ford 1989).

This conclusion challenges some common conceptions about the role of salmon in Northwest economies. Ethnohistoric descriptions often emphasize the abundance of salmonids

and the importance of such fish to Native American diet (Gibbs 1877). Early anthropologists in many areas of the Northwest also viewed salmon as a major staple — and that countless aspects of lifeways (complex social organization, art, over-wintering strategy) were made possible by the catching, drying and storing of salmon (e.g. Post 1938). Archaeologists, in turn, have often presumed that salmon was the mainstay in prehistoric times, often in the absence of empirical evidence of salmon use (Monks 1987). Matson noted, ‘given that salmon is the most important resource on the Northwest Coast, the outstanding question is: How did this come to pass?’ (1992: 371). And without agreeing with his colleagues, Ames noted the general opinion that ‘virtually all workers accept the crucial role of salmon intensification in socioeconomic evolution on the coast’ (1994: 211).

Undoubtedly salmonids were important food resources to Northwest peoples for millennia before contact. My study shows, however, that on the Columbia River, what has often been described as the premier salmon-producing river in the world, lower-ranked resources (small fish) were becoming an increasingly important resource during the late Holocene. Further, it suggests that the ethnohistoric record that emphasizes salmonids may be a product of reduced foraging pressure as a result of depopulation. Reviewing subsistence issues on the

Plateau, Campbell suggests ‘the nearly universal economic specialization on fish emphasized in descriptions of Plateau subsistence and adaptation may be partially an artifact of drastically lowered population levels in the 18th and 19th centuries’ (1989: 189). She offers that the pre-decline populations would likely have been more dispersed across the landscape, utilizing a greater range of habitats and resources, and were less reliant on salmonids than post-decline populations. Her suggestion is certainly supported here.

This study more generally illustrates the utility of foraging models to understanding subsistence change at the regional scale. The last 25 years has seen a tremendous growth in zooarchaeology and, in many regions of the world, detailed faunal records are beginning to accumulate from sites excavated for a variety of research or heritage management goals. Notwithstanding issues of assemblage comparability, such samples have tremendous value for addressing questions of subsistence change and variation and are particularly useful when coupled with simple but powerful models from foraging theory.

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