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A History of Paleoecological Research on Sea Otters and Pinnipeds of the Eastern Pacific Rim

R. Lee Lyman

TODAY IT IS NOT UNUSUAL to pick up the latest issue of an archaeology journal such as *American Antiquity,* or *Journal of Archaeological Science,* or the like, and to find in the table of contents an article on a topic in zooarchaeology. It is more difficult to find a piece on the zooarchaeology of marine mammals. It is equally difficult to find an article on some prehistoric aspect of marine mammals based on zooarchaeological remains in a natural history journal such as *Marine Mammal Science* or *Oecologia*. These informal observations prompt some musings. Has the history of zooarchaeological research on North Pacific pinnipeds and sea otters (*Enhydra lutris*) been unique, or has it been but a portion of the much larger history of zooarchaeology in general? Have trends in analysis of pinniped and sea otter remains tracked analytical trends in zooarchaeology in general? In this chapter, I provide some initial answers to these questions. In particular, I report and comment on the history of paleoecological research on pinniped and sea otter remains recovered from archaeological sites along the northeastern Pacific coast. I conclude with some observations on potentially significant research topics that have as yet been little explored.

METHODS, MATERIALS, AND CAVEATS

To write the history that follows, I read the published literature only and did not examine unpublished archival records nor did I delve into the extensive unpublished (and thus basically inaccessible) grey literature resulting from CRM projects. Exceptions include several unpublished doctoral dissertations, copies of which I happen to have. Taxonomic abundance data are presented as the number of identified specimens (NISP; Grayson 1984; Lyman 2008). Discussion is limited to the pinnipeds and sea otters; whales and other cetaceans are not considered.

For purposes of this chapter, the northeastern Pacific Rim includes, from south to north,

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TABLE 2.1

Pinniped and Sea Otter Nomenclature for the Northeastern Pacific Ocean

TAXON	COMMON NAME
Enhydra lutris	Sea otter
Phoca vitulina	Harbor seal
Mirounga angustirostris	Northern elephant seal
Callorhinus ursinus	Northern fur seal
Arctocephalus townsendi	Guadalupe fur seal
Eumetopias jubatus	Steller (northern) sea lion
Zalophus californianus	California sea lion

NOTE: Taxonomy after King (1983).

the California, Oregon, Washington, British Columbia, and southeastern Alaskan coasts, both those coasts along the open ocean and those facing the inside passage. The groups of pinnipeds and sea otters discussed comprise seven species (Table 2.1). I mention the paleontological record where pertinent, and focus on the archaeological record of these creatures because that is where the bulk of the pertinent data originates. I mostly restrict discussion to aspects of paleoecology—biogeography, rookery locations, and the like—indicated by the remains of marine mammals. There have been many discussions of the human economic implications of the marine mammal remains recovered from archaeological contexts along the eastern Pacific Rim (e.g., Calvert 1980; Cannon 1991; Colton 2002; Hildebrandt 1981, 1984b; Huelsbeck 1983; Stewart and Stewart 1996; Wigen and Stucki 1988). I do not review these discussions here, as many of the other chapters in this volume cover this topic in detail.

Given the focus of this chapter, it is appropriate to note that natural historian W. J. Wintemberg (1919:63) pointed out nine decades ago that zooarchaeological remains would "give valuable aid to zoology." In particular, Wintemberg noted that zooarchaeological remains would reveal much about prehistoric ranges of taxa, long-extinct and thus zoologically unknown species might be revealed by such remains, skeletal pathologies of taxa might be better documented with zooarchaeological materials, and temporal changes in the size of animals might be revealed by prehistoric faunal remains. Some but not all of these revelations have occurred via study of marine mammal remains recovered from archaeological sites along the northeastern Pacific Rim.

BEGINNINGS

William Healy Dall (1877) excavated several sites in the Aleutian Islands during the late 19th century. He listed the sea mammals represented by faunal remains he found: northern fur seal (*Callorhinus ursinus*), Steller sea lion (*Eumetopias juabutus*), *Phoca* (two species), and walrus (*Odobenus rosmarus*) (Dall 1877:74). Dall was a naturalist of the first rank (Merriam 1927); he did not need to indicate how he identified the remains nor did he list the frequencies of the remains he found. This was typical of the time (Reitz 1993; Robison 1987)—what are pejoratively referred to as "species lists" were the typical result of zooarchaeological work in the late 19th and early 20th centuries, if any such work was done at all. Dall did not mention any paleoecological implications of the remains he reported. This is not surprising for the simple reason that naturalists were still learning about the modern zoological world in the late 19th century and thus did not know what might be unusual in the prehistoric record.

The report on northeastern Pacific Rim marine mammals that most people know about and that can be taken as the seminal modern zooarchaeological study was undertaken by Gretchen M. Lyon in the 1930s. Lyon (1935, 1937) described remains from the Point Mugu shell mound in Ventura County, southern California. She was a zoologist in the natural history sense. She studied living amphibians, mammals, and birds; she illustrated the work of other zoologists; and she did some paleontology (published

TABLE 2.2

NISP and MNI Data for Pinnipeds and Sea Otters Reported by Lyon (1937)

SPECIES	NISP	MNI	PERCENT OF MNI
Enhydra lutris	304	31	13.7
Zalophus californianus	145	19	8.3
Eumetopias jubatus	12	4	1.7
Callorhinus ursinus	57	12	5.2
Arctocephalus townsendi	1557	152	66.9
Phoca vitulina	18	4	1.7
Mirounga angustirostris	21	5	2.2

NOTE: Taxonomy is updated.

under her married name; Burleson 1941, 1948). In her report on the Point Mugu materials Lyon not only provided quantitative data in the form of NISP and MNI (Minimum Number of Individuals) per species (Table 2.2), but she described taxonomically diagnostic morphometric features of some of the bones she identified. Lyon's use of NISP and MNI followed work by paleontologists who were her contemporaries (e.g., Stock 1929). Lyon's description of taxonomically diagnostic anatomical features mirrored some of the seminal efforts of individual researchers to present what can loosely be termed skeletal key-like information that could be used by other archaeologists (e.g., Brainerd 1939). At the time, such information was new and worthy of publication. Lyon's work preceded by more than a decade the more widely known (among archaeologists) efforts of Theodore White (e.g., 1952, 1953a, 1953b), a paleontologist who studied zooarchaeological remains recovered from sites on the Plains and who is typically credited with introducing the concept of MNI to archaeologists. Credit likely should be given to White because he published in *American Antiquity* and other archaeological venues whereas Lyon published her work in zoological journals that were seldom read by archaeologists until about 1980.

Lyon (1937:163) believed that the remains she described reflected "a changing picture of marine life," and thus, as a biologist, she set a precedent that would not soon be mimicked by zooarchaeologists. Lyon discussed the "past and present status of the species" represented by the faunal remains from Point Mugu. She noted, for example, that though the sea otter was rare in the site area today and that it had obviously been hunted by prehistoric people, the abundance of its remains indicated that it had been "formerly abundant" in the area and that it was "likely the white man" who had decimated the population in the late 18th century and throughout the 19th century (Lyon 1937:163, 164). Lyon noted regarding the northern fur seal that no remains of males had been found; only remains of females were in the collection, and this matched expectations based on the modern migratory habits of this species. The large number of Guadalupe fur seal (*Arctocephalus townsendi*) remains (Table 2.2) was surprising to Lyon (1937:164), who noted that this species was thought to be extirpated "north of the Mexican line." Significantly, Lyon (1937:165) reported that she had examined a small sample of bones collected from a shell midden located at Yachats in Lincoln County, Oregon, and those remains included several specimens of female Guadalupe fur seal. Lyon (1937:165) took those specimens as evidence that this species had once been found that far north, adding that samples from other sites were necessary "to establish with certainty the northern limit of the range of this species." This research avenue would not be exploited until more then 60 years later. Finally, Lyon found that the age-sex demography of the sample suggested that rookeries had been exploited. In offering her biogeographic and biological inferences, Lyon was holding to the natural history tradition in which she was trained.

BIOGEOGRAPHY, DEMOGRAPHY, AND ROOKERIES

Lyon's observations regarding differences between modern and prehistoric distributions of taxa set a standard that would not be diverged from for nearly 65 years. Thirty years after Lyon's report was published, Carl E. Gustafson (1968a, 1968b) noted that his work with the Ozette site zooarchaeological materials from the northwestern tip of Washington State's Olympic Peninsula revealed abundant remains of northern fur seal. Gustafson was a zoologist by training, though throughout his career he was Washington State University's zooarchaeologist in the Department of Anthropology. Gustafson perceived no difference in the relative abundance of fur seal remains from precontact to postcontact time among the remains from Ozette, and this suggested to him that some 2000 years of human predation had not had an impact on the local population. The abundance of male northern fur seals relative to the abundance of females was about 1:1 throughout the stratigraphic sequence, but males were absent from the historic record. Gustafson (1968b:51) attributed this demographic shift to "a change in the migratory pattern of male fur seals." Gustafson's work is noteworthy because it represents an early zooarchaeological study in which an estimate of the ontogenetic age of individual organisms based on tooth development was used. Gustafson (1968b:50) submitted teeth to the "Bureau of Commercial Fisheries, Division of Marine Mammals, for exact age determinations" based on "annual growth rings in the canines (Scheffer 1950)," but in the absence of those data he "constructed relative age categories based on the size of the root canal, which becomes smaller as dentine is deposited with increasing age." Gustafson's research was published in *Science,* yet it seems to have had no more (or less) impact on paleozoology than did Lyon's less widely circulated report. The article was rarely cited by paleozoologists over the next three decades, and many of the insights Gustafson provided were neither replicated nor evaluated in light of other data until early in the 21st century.

A decade after Gustafson's work, Phillip Walker and Steven Craig (1979:50), two archaeologists, reiterated Wintemberg's (1919) six-decades-old statement: zooarchaeological remains can, they said, "provide information concerning the biology of animal species." They described remains from a site on San Miguel Island (part of California's Channel Islands), noting that remains of Guadalupe fur seal were much more abundant relative to the remains of other pinnipeds than would be expected given modern abundances of the taxa in the area. They attributed this difference in observed versus expected abundances to historic "commercial sealing activities" having decimated the metapopulation, and noted that their data matched those described by Gretchen Lyon (Walker and Craig 1979:53). Walker and Craig published their research results in *California Fish and Game,* a regional journal unlikely to have been read by many archaeologists. The interests of archaeologists at the time largely concerned those of artifact-centric culture history or culture process-centric processual archaeology; the paleoecological implications of faunal remains were of little interest to the majority of archaeologists because prior to about 1970 they were asking questions that did not require paleoecological data (Lyman 2007a, 2007b; Lyman et al. 1997). This would change as the population of archaeologists grew and archaeologists diversified and specialized their interests (Reitz 1993; Trigger 2006).

By the end of the 1970s, zooarchaeology had become an important and potentially autonomous research endeavor (Reitz 1993; Reitz and Wing 1999). The likely catalysts for this development were equal parts of processual archaeology's quest for materialist and functionalist explanations including economic variables (see for example Graham's [1979] and Lundelius's [1974] synopses of late Pleistocene paleomammalogy in volumes devoted to Paleo-Indian archaeology), the federal government's mandates for protection of archaeological resources via recovery and analysis of all cultural materials, and a growing population of archaeologists such that intradisciplinary specialization was not only possible but predictable (O'Brien et al. 2005; Reitz 1993). Zooarchaeology along the northeastern Pacific Rim tracked these developments, including an increased rate of publication.

William Hildebrandt (1981, 1984b), an archaeologist, identified and tallied the remains of sea otters and four taxa of pinnipeds recovered from six sites on the northern California coast (ΣNISP = 746) for his doctoral research. Hildebrandt (1984a) observed that the zooarchaeological remains he described "may indicate a former deviation from [the historically documented] pattern" of northern fur seals not frequenting the coast of northern California. Because northern fur seal remains comprised two-thirds of the marine mammal remains from the site of Stone Lagoon, Hildebrandt (1984a:29) hypothesized that prehistoric hunters had obtained these animals from the nearby offshore Redding Rock and that this location "may have been used heavily by the northern fur seal as a hauling ground." Hildebrandt cited Lyon's (1937) work, but not Gustafson's (1968a, 1968b). Importantly, Hildebrandt published his hypothesis in a natural history journal rather than an archaeological journal. It was, however, a regional journal with limited circulation, and thus it is likely that few marine mammalogists were aware of Hildebrandt's significant observations.

Archaeologist Donald Clark (1986:39) effectively reiterated Wintemberg's (1919) notation when he remarked that a "highly effective mode of long-term biological sampling is the analysis of kitchen middens or refuse deposits left at ancient habitation sites." Clark interpreted changing abundances of remains of northern fur seal in archaeological sites on Kodiak Island, Alaska, as indicating that this species had been abundant near the southeastern side of the island during the late prehistoric/earliest historic period. Both prior to and subsequent to a high abundance of northern fur seal remains relative to other pinnipeds, northern fur seal remains were not very abundant. Clark (1986:42) was unsure of the cause of the "blip" in the abundance of fur seal remains, but safely concluded that it could not be presumed that prehistoric maritime ecosystems were stable.

In the late 1980s, zooarchaeologist Lee Lyman (1988, 1989, 1991) reported on remains of sea otters and pinnipeds from three sites on the coast of Oregon (ΣNISP = 3235). He used the sex and age demography indicated by the pinniped remains to determine whether prehistoric hunters were exploiting haul-outs or rookeries. Lyman (1988) inferred the local presence of rookeries for northern fur seal and Steller sea lion. Rookeries for northern fur seal were historically unknown along the Oregon coast, and at least one and perhaps two Steller sea lion rookeries Lyman inferred were historically not documented. Lyman (1988) attributed differences between the prehistoric and historic records to 19th-century commercial exploitation of pinnipeds and the decimation of local populations. His results were published in an international marine mammalogy journal with the explicit purposes of illustrating the precise nature of commercial exploitation on marine mammal populations and contributing pertinent data to biological conservation and management decisions. Such applied zooarchaeological research is increasing with respect to both terrestrial mammals (references in Lyman 2006) and marine mammals (Murray 2008).

In the 1990s, the long-awaited reports on the late-prehistoric archaeological site at Ozette, Washington, were published (Huelsbeck 1994). Only a sample of the mammal remains was described, but that sample was an order of magnitude larger than any other sample from the eastern Pacific (ΣNISP = >48,000). Unfortunately, remains of the two species of sea lions—*Eumetopias jubatus* and *Zalophus californianus*—were not distinguished. The only biological observation offered was that the abundances of the taxa were "very similar to those observed by Gustafson" in a much smaller sample (Huelsbeck 1994:27). A few years later, zooarchaeologist Mike Etnier (2002a, 2002b) studied a sample of the pinniped mandibles from Ozette and found 34 specimens of Guadalupe fur seal mixed with 1374 specimens of northern fur seal. Etnier (2002a:555) drew three conclusions: (1) because all of the Guadalupe fur seal remains seemed to originate from individuals that were a year or less in age, this species likely had no rookeries in the area; (2) despite the historic range of the species being limited to southern California and Baja California, it had until late prehistoric times been found as far north as northern Washington; and (3) this species may have ranged northward outside its modern range coincident with El Niño events. Etnier (2002b) used demographic data to conclude that previously unidentified northern fur seal rookeries had existed prehistorically on or near the Washington coast. Finally, Etnier (2002b) found no evidence that prehistoric human predation had influenced the local population of northern fur seals. He concluded that historic commercial exploitation had altered the biogeography of the species (see also Etnier 2007).

Zooarchaeologist Diane Gifford-Gonzalez and colleagues (Gifford-Gonzalez et al. 2005) summarized the zooarchaeological record for pinnipeds along the northeastern Pacific coast. They noted that remains of northern fur seals were much more abundant prehistorically throughout the area than would be expected given the modern abundances and migratory behaviors of the species. They also pointed out that Steller sea lion rookeries as well as northern fur seal rookeries existed prehistorically in places where there was no historical record of rookeries for these species, but cautioned that additional research was necessary to confirm the occurrence of uniquely prehistoric rookeries. Most recently, archaeologist Torben Rick and colleagues (Rick et al. 2009) compiled and summarized all zooarchaeological data for Guadalupe fur seals on the California coast. The early-19th-century distribution of this species was poorly known given it had nearly been exterminated by the late 19th century. Its zooarchaeological remains indicate it was relatively abundant in southern California, particularly south of 35°N latitude, during the late Holocene (last 3500 years). In producing syntheses, Gifford et al. (2005) and Rick et al. (2009) mimic a trend in zooarchaeology in general. By the end of the 20th century, paleozoological (zooarchaeological and paleontological) data were sufficiently abundant that syntheses of information for numerous taxa in many areas could be written (e.g., Grayson 2005; Lyman 2004).

Pinnipeds are categorized as marine mammals, yet individuals of various taxa are known to occasionally ascend rivers, likely in pursuit of prey such as anadromous fish. This means that remains of marine taxa will potentially be recovered from riverine sites in freshwater settings. So far as I know, only Lyman and colleagues (Lyman et al. 2002) have examined this phenomenon with respect to eastern North Pacific pinnipeds. They found that harbor seals occurred in the lower reach of the Columbia River prehistorically, virtually since the beginning of the Holocene 10,000 years ago. This could be a critical bit of knowledge with respect to damming rivers and industrial alteration of estuaries. Thus far, wildlife managers have focused only on the impacts of such activities to anadromous fish. It may become necessary to monitor as well the impacts of anthropogenic activities on pinnipeds that ascend rivers. Such monitoring may, however, be a long time coming because California sea lions have been observed for the past decade or so preying upon salmon and steelhead—two economically valued fish—below Bonneville Dam on the Columbia River. In light of these observations, state fish and wildlife agencies in Washington, Oregon, and Idaho requested and received federal authorization in early 2008 to remove these pinnipeds by capture and relocation if possible, but by lethal means if necessary (Washington Department of Fish and Wildlife, 2008). The zooarchaeological record suggests pinnipeds have ascended the Columbia River for millennia, so one must wonder if lethal removal is ecologically wise and really the best option, especially in light of the dim future that has been forecast for marine mammals the world over (e.g., Anderson 2001).

CHEMISTRY, GENETICS, AND EXTIRPATION

By the end of the 20th century, zooarchaeology had entered what can be informally labeled the archaeometry stage. Animal bones were not just identified and their macroscopic features recorded; sometimes the chemistry, and sometimes the genetics of particular animal bones, were recorded (Reitz and Wing 1999). Study of eastern Pacific pinnipeds and sea otters followed suit.

ISOTOPES

One of the first studies of the chemistry of archaeological pinniped remains focused on the northern fur seal. Mammalogist Robert Burton, zooarchaeologist Diane Gifford-Gonzalez, and their colleagues (Burton et al. 2001, 2002) studied the stable isotopes of fur seal remains from Monterey Bay, California. They found that the carbon and nitrogen isotopes of the bones indicated that, unlike in the 20th century, the northern fur seal foraged off the coast of central and northern California in the past. The ontogenetic age of some individuals was estimated based on the size of the dentary and indicated that fur seals considerably younger than 3 months of age were represented. Isotopic analysis indicated these individuals had not yet been weaned when they died. Together, these data confirmed earlier suggestions that northern fur seals had reproduced in lower latitudes prior to the 18th century than they did today.

A second study of bone chemistry quickly followed. Etnier (2004a:99) noted that the stable isotopes of the northern fur seal bones from the Ozette site fell midway between those of modern Alaska and the archaeological specimens from California reported by Burton et al. (2001, 2002). In light of demographic data suggesting a local rookery had existed, Etnier (2004a:99) concluded that the isotope data indicated that the Ozette northern fur seals "maintained a foraging pattern distinctly different than those of the California and Alaska populations."

Archaeologist Madonna Moss and colleagues (Moss et al. 2006) examined the stable carbon and nitrogen isotopes evident in northern fur seal specimens from a site in southeastern Alaska and a site on the Oregon coast. They found that although specimens from both sites indicated the fur seals "were feeding offshore," they could not distinguish specimens at either site from modern northern fur seals from the Pribilof Islands of southwestern Alaska (Moss et al. 2006:179). In 2007, the collaborative efforts of several biologists and archaeologists provided resolution to Moss et al.'s (2006) conundrum. Newsome et al. (2007) were able to sort several collections of fur seal remains, both modern and prehistoric, into three geographic groups. Female northern fur seals from central and southern California have the highest isotope values; individuals from northern Oregon, Washington, British Columbia, southeastern Alaska, and the eastern Aleutians have intermediate values; and individuals from the western Aleutian Islands have the lowest isotope values. Newsome et al. (2007:9710) conclude that these distinctions "confirm that prehistoric northern fur seal from California were not immigrants from northern waters but instead were year-round residents." Isotope values also indicate that the northern fur seals in the geographically intermediate group "weaned at a much older age than their modern Bering Sea counterparts." Newsome et al.'s (2007:9711) suggestion that older weaning age is likely a result of less selective pressure from long-duration severe winter weather in southern latitudes relative to northern latitudes has recently received some very suggestive but not quite conclusive confirmation that has implications for conservation biology (Lea et al. 2009). Study of isotopes to detect migration patterns of terrestrial mammals have also been recently undertaken (e.g., Hughes 2004), and though not based on stable isotope analyses, other evidence of prehistoric migration of ungulates has been noted by conservation biologists (Berger et al. 2006). Thus, study of zooarchaeological remains of marine mammals is tracking zooarchaeological research in general.

GENES

Historical records indicate that some populations of eastern Pacific pinnipeds were decimated and others were exterminated by historic commercial exploitation. This well-documented fact provides geneticists with a testable hypothesis—the degree of genetic diversity in descendants of decimated populations should be less than the genetic diversity of descendant populations that did not experience a bottleneck. Similarly, prehistoric, prebottleneck populations should display relatively greater genetic diversity than modern, post-bottleneck populations. Biologist Shawn Larson and colleagues (Larson et al. 2002a, 2002b) found exactly these test implications among eastern Pacific sea otters. Both extant and prehistoric sea otter populations displayed low variability in mtDNA, but sea otter remains from the Ozette site indicate that the population prior to the fur trade had more variation than all tested extant populations.

When Lyman (1988) reported on the phenotypic variation of Oregon's prehistoric sea otters, he implied that some of that variation was the result of genetic variation. The editors of *Marine Mammal Science* requested that discussion of the possible genetic implications of the phenotypic variation of prehistoric Oregon sea otters and of the likely results of transplanting the wrong phenotype (and by implication the wrong genotype) of sea otter to the Oregon coast both be omitted from the manuscript that eventually became Lyman (1988). In the original, unpublished manuscript, Lyman suggested that the Alaskan sea otters transplanted to the Oregon coast in the 1970s may have been doomed from the start because of their phenotypic (and implied genetic) adaptation to a high-latitude habitat and attendant dietary differences from sea otters in more southern latitudes.

Subsequent to Lyman's (1988) research, a collaborative project was undertaken between Oregon biologists and zooarchaeologists who studied ancient DNA extracted from archaeological specimens recovered from Oregon sites. These researchers (Valentine et al. 2008) found that the genetic composition of Oregon's prehistoric sea otters best matches the genetic composition of modern Californian sea otters rather than the Alaskan sea otter population that was exploited for individuals that were moved to other areas along the northeastern Pacific coast.

Moss et al. (2006) examined ancient DNA in a specific attempt to distinguish populations of fur seals among remains recovered from a site in southeastern Alaska (Cape Addington), a site on the west coast of Vancouver Island (Ts'ishaa), and a site on the Oregon coast. Although they found that prehistoric northern fur seals tended to have "a much higher genetic variability" than modern populations, the limited modern data prompted them to conclude that they could not determine "the extent of recent genetic bottlenecks" (Moss et al. 2006:181). Similarly, Moss et al. (2006) could not determine if their specimens represented distinct, prehistorically unique local breeding populations. This sort of research mimics that of others studying paleozoological remains of terrestrial taxa (e.g., Pusch et al. 2003 and references therein).

EXTIRPATION—TIMING AND CAUSE

Historical documents suggest that populations of many northeastern Pacific Rim pinniped and sea otter taxa were nearly extirpated by commercial and bounty exploitation during the 19th and early 20th centuries. Some archaeologists argue that prehistoric hunters drove many populations toward extinction (Hildebrandt and Jones 1992, 2002; Jones and Hildebrandt 1995; Porcasi et al. 2000). Not surprisingly, what we have found is that extirpation is historically contingent; it is population and location specific (Etnier 2002b; Gifford et al. 2005; Lyman 2003; Newsome et al. 2007). Available data suggest that central and southern California populations of fur seals and sea lions were extirpated 800 or more years ago whereas more northern populations of these taxa were extirpated only in the last 200 or so years (Etnier 2002b; Gifford et al. 2005; Lyman 2003).

It has been suggested that terrestrial climatic change in southern California prompted intensified exploitation and eventual decimation of pinniped populations (Colten and Arnold 1998). Detailed paleoclimatic records (e.g., Arnold and Tissot 1993; Jones and Kennett 1999) are required, as are tight chronological controls of zooarchaeological data, in order to establish that climatic variables had causative roles in the decimation of marine mammal populations (e.g., Trites et al. 2007). Coincidentally, it must be demonstrable that humans did not play a significant role in depressing populations of prey animals. Study of the timing of the extirpation of local populations of sea mammals will continue, and debate over the cause—was it natural or was it anthropogenic?—will also continue, just as it is has for the terminal Pleistocene extinctions of North American mammals (e.g., Fiedel and Haynes 2004; Grayson and Meltzer 2003). Hopefully, identifying a human cause of extinctions will not become evidence used for political purposes as it has for the overkill hypothesis regarding Pleistocene extinctions (Grayson and Meltzer 2004).

A good way to sum up the discussion thus far concerns an ontological point basic to modern ecology. When studying the history of multiple taxa, no matter how related they might be in an ecological or phylogenetic sense, each taxon's history will be more or less independent of every other taxon's history. This ontology, known as the "individualistic hypothesis," grew from botanist Henry A. Gleason's (1926) observations (Nicolson 1990). It's general acceptance among ecologists grew in part from increasing amounts of paleontological data that contradicted notions of static interspecies associations and interlinked ecologies and histories thereof (e.g., Hewitt 2000; King and Graham 1981). Hanson and Kusmer (2001) exemplify this taxon-specific approach, examining all faunal collections in the Strait of Georgia region to determine if sea otters were historically absent from the area as a result of historic overhunting or if some environmental factor precluded use of the area by this marine mustelid. They found no evidence of the former, and postulated that the sea otter's ability to detect and avoid paralytic shellfish toxins caused them to avoid the area. What distinguishes Hanson and Kusmer's analysis is their choice of a very narrow research question concerning a single taxon in a geographically limited area, and their intensive analysis of all available data that bears on their research question. This is not to denigrate or discourage multitaxon analyses, but rather to emphasize that different taxa have different physiologies, ecologies, and the like, making the individualistic species model the most viable initially. Further, my comments are not meant to deny that the presence or the absence of particular marine mammal taxa could have significant cascading ecological effects on littoral biotic communities; interestingly, one of the seminal studies to demonstrate this built its case on zooarchaeological data (Simenstad et al. 1978). Large zooarchaeological samples are necessary for studies of prehistoric species interactions, and those samples must span sufficient temporal durations and occur in sequent, sufficiently short-duration assemblages that the signal of the ecological cascade effects is not muted. Sadly, few samples with all of these characteristics presently exist.

MORPHOMETRICS

The potential implications of zooarchaeological data for wildlife management were particularly evident in Lyman's (1988) examination of phenotypic differences between prehistoric and modern sea otter populations. Lyman (1988) noted that Oregon's prehistoric sea otters displayed some characteristics of 20th-century Alaskan sea otters and other characteristics of historic California sea otters. These characteristics ranged over simple qualitative traits such as the angle of the ascending ramus of the mandible, to quantitative features such as size and shape of teeth. In light of a recent failure of efforts to re-establish an Oregon sea otter population with transplanted Alaskan sea otters, Lyman suggested that further study of prehistoric sea otter remains might prove informative to wildlife managers and conservation biologists. The morphometry of prehistoric sea otters has not been pursued and remains a wide-open research avenue. This is not unusual; bone size tends to be minimally exploited in zooarchaeology generally, except for the use of allometric relationships between bone size and body size for purposes of estimating biomass (e.g., Reitz et al. 1987).

Mike Etnier (2002b, 2004b) examined the size of male Alaskan northern fur seals in the 20th century and found that the fur seals collected between 1911 and 1920 were larger than individuals collected from 1940 through 1953. He attributed this shift in size to coincident changes in the density of the fur seal population. When the population was more dense, intraspecific competition was greater and fur seals tended to grow slower and be smaller as adults; when the population was less dense, intraspecific competition was less and fur seals grew more rapidly and were larger as adults. Etnier (2004b:1624) suggested that "long-term data on relative population levels [might be provided by] paleontological or archaeological samples." In his unpublished dissertation, Etnier (2002b) reported that the Ozette northern fur seals were smaller than the Alaskan individuals throughout the archaeological sequence. The archaeological specimens were smaller either because the prehistoric Washington population was denser than the 20th-century Alaskan population, or because the two populations were not only distinct in terms of size but latitudinally distinct as well (Etnier 2002b:227). This issue has not yet been resolved. The correlation of population density and individual body size is a phenomenon that is beginning to be regularly used in the zooarchaeology of terrestrial mammals (e.g., Wolverton 2008).

Etnier (2002b, 2004b; Newsome et al. 2007) also used bone size to develop growth curves that allow determination of the ontogenetic age of northern fur seals. Such determinations are more exact than earlier ones based on much smaller samples of known-age individuals for other pinniped species (Lyman 1991). Assessment of ontogenetic age is critical to evaluation of whether or not rookeries may have been near archaeological sites that produce remains of immature pinnipeds (Lyman 1988). Using bone or tooth size (e.g., crown height) to estimate ontogenetic age is not unusual in zooarchaeology in general (e.g., Klein et al. 1981; Munson 1984).

A unique use of morphometric data is found in Crockford et al.'s (2002) suggestion that a previously unknown and now-extinct species of fur seal occupied the Barkley Sound–Cape Flattery area of southwestern Vancouver Island and the northwestern Olympic Peninsula of Washington state. Ethnohistoric data they consulted indicate a form of fur seal that was not only unique in terms of its reproductive behaviors but also its pelage. These data in combination with slight differences in the morphology of archaeological remains of newborn fur seals relative to modern comparative specimens suggested to Crockford et al. (2002) that a unique, now-extinct species of fur seal occurred around the western end of the Strait of Juan de Fuca until recent historic times. Crockford et al. wisely note the small size of their sample and suggest testing the validity of the proposed unique taxon with ancient DNA. Crockford et al.'s use of morphometric data to identify previously unknown extinct taxa is part of a long history of such in zooarchaeology and paleontology (Mead et al. 2000 and references therein).

The paucity of morphometric studies on northeast Pacific sea otters and pinnipeds mirrors the paucity of such studies in North American zooarchaeology in general. A difference exists, however, in the fact that most morphometric research away from the Pacific Rim has involved converting bone size to biomass (e.g., Emerson 1978; Purdue 1987; Reitz et al. 1987). No such algorithms have yet been developed for pinnipeds along the northeastern Pacific Rim.

DISCUSSION

Moss et al. (2006) point out that they misidentified several specimens of pinniped and detected the mistakes only when ancient DNA revealed the errors. They attribute the misidentifications to the "fragmentary and juvenile [character of the archaeological] skeletal remains" and the lack of "comparative specimens [of known taxonomy] representing the full range of morphological pinniped species" (Moss et al. 2006:179). This episode in the history of zooarchaeological study of northeastern Pacific Rim marine mammals tracks similar episodes with terrestrial fauna and marine fishes and prompts the same conclusion—extensive comparative collections of known taxonomy are mandatory to accurate identifications of zooarchaeological remains (e.g., Driver 1992; Gobalet 2001; Lyman 2005).

Two variables exacerbate the identification problem along the northeastern Pacific Rim. First, with respect to pinnipeds, relative to the terrestrial interior, few natural history museums are located in coastal settings where skeletons of sea mammals are likely to be housed. The land-locked comparative collection I visit most often—the University of Kansas Museum of Natural History, where the world famous mammalogist E. Raymond Hall (1981) once worked—has thousands of mammal skeletons but only a couple marine mammal skeletons. The second variable that influences our ability to correctly identify remains of pinnipeds is that marine mammals are, by and large, now under strict international protection, so building comparative skeletal collections presents unique logistical problems above and beyond the more typical one of traveling to a comparative collection of sufficient size to adequately facilitate identification.

Correct taxonomic identification is critical to any zooarchaeological endeavor. Consider, for example, the walrus, a pinniped taxon that has not often been associated with the Northwest Coast culture area. More than 15 years ago, Harington and Beard (1992) reported the recovery of a walrus skeleton from Vancouver Island. A radiocarbon date on bone collagen from the skeleton assayed at greater than 40,000 BP (see also Harington 1984:516). Four paleontologists recently reported geological trace fossils of walrus in Willapa Bay, southwestern Washington (Gingras et al. 2007). These trace fossils may be more than 190,000 years old (Gingras et al. 2007). Nevertheless, the recovery of walrus remains from Vancouver Island, southwestern Washington, and even from San Francisco Bay (Harington 1984) indicates that paleozoologists should keep their eyes and their minds open when identifying pinniped remains from the Northwest Coast. Do not allow modern biogeography to bias your taxonomic-search grid (Driver 1992). Even if walrus were extirpated on the Northwest Coast prior to the arrival of humans, it is particularly important to not completely exclude them from consideration given that prehistoric peoples utilized fossil bone (e.g., Nelson et al. 1986).

Part of the solution to difficulties with taxonomic identification resides in adequate reporting (Butler and Lyman 1996), in particular, describing the morphometric criteria used to distinguish taxa, sexes, and ontogenetic cohorts (Lyman 2005). Such reporting would allow zooarchaeologists to evaluate identifications made by others; this is what paleontologists do, and for good reason. But with respect to reporting the morphometric criteria used to make taxonomic identifications, zooarchaeological research on northeastern Pacific pinnipeds is no different than that anywhere else in the world; basically, very few people report the criteria they use to make identifications. Editorial concerns with per-page publication costs may be a limiting factor, but if so, then we simply haven't done our job in terms of convincing editors of the necessity of describing the criteria we used to identify a particular taxon. In fact, this lacuna in our reporting is mirrored in archaeology generally. Can anyone tell me where the definitive morphometric characteristics of a Clovis projectile point are published? To be sure, many points given the name "Clovis" have been described, but the necessary and sufficient attributes a specimen must possess in order to be given the name "Clovis" are not generally agreed upon nor are they well known (e.g., Howard 1990).

Accurate and well reported taxonomic identification is critical to many kinds of

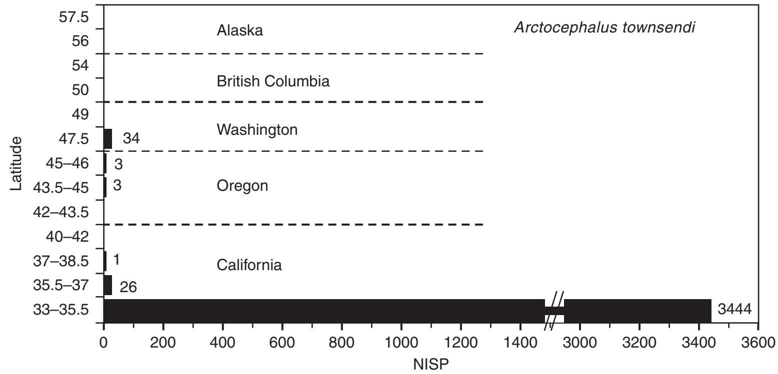

FIGURE 2.1. Frequency (NISP) of Guadalupe fur seal (*Arctocephalus townsendi*) remains relative to latitude. The absence of remains from 40 to 43.5 degrees is likely the result of failure to identify Guadalupe fur seal remains and to distinguish them from northern fur seal (*Callorhinus ursinus*) remains. Data from Table 2.3.

paleobiological analyses. Consider the likely artifact of incorrect identification of fur seal as *Callorhinus ursinus* rather than *Arctocephalus townsendi* apparent in Figure 2.1. One would expect that the biogeographic border for a taxon would not be abrupt in terms of relative abundance of that taxon but rather geographically gradual (Brown and Lomolino 1998). Data on all sea otter and pinniped remains identified between Kodiak Island and the California-Mexico border were compiled to generate Figure 2.1. The Guadalupe fur seal's frequency distribution should gradually taper off north of the southern California area given the occasional presence of vagrant individuals (e.g., Gaston 1996). Instead, there are no remains of this species explicitly reported for the area between southern California and central Oregon; fur seal remains are reported as just that—"fur seal"—without species designation (e.g., Hildebrandt and Jones 1992). The only reason Guadalupe fur seals are found in central and northern Oregon is because Gretchen Lyon (1937) reported them in the former area based on skeletal morphology and Moss et al. (2006) identified them in the latter area based on ancient DNA. I predict that if extant collections from northern California and southern Oregon are reexamined with a critical eye, remains of Guadalupe fur seal will be detected.

The data on which Figure 2.1 is based are given in Table 2.3. While compiling those data, it was found that many such data were not reported in a manner useful to this sort of biogeographic analysis. Rather than reporting pinniped remains as to genus or species represented, several authors simply reported "phocids," or "fur seals," or "sea lions." Each of these folk taxa is polytypic—each comprises more than one genus or species. Such reporting may suffice for assessing prehistoric human subsistence, but it simply won't allow detailed paleoecological and paleobiological research. Taxonomically ambiguous reporting is, sadly, a characteristic of zooarchaeological research in non-coastal contexts as well. For better or worse, we are keeping pace with the discipline at large.

Zooarchaeological research on eastern North Pacific sea otters and pinnipeds focusing on biological issues has centered on the northern fur seal, likely because remains of this species have been so often out of place biogeographically relative to modern times—something recognized initially by Gretchen Lyon 70 years ago and still the center of attention today. Lyon also noted the unexpected abundance of Guadalupe fur seals in southern California, something only recently pursued with intensity (Rick et al. 2009). Ignoring the likely bias

TABLE 2.3
Summary of Taxonomic Abundance Data (NISP) by Latitude.
List Reads from North to South.

AREA (LATITUDE)	*E. l.*	*P. v.*	*M. a.*	*C. u.*	*A. t.*	*E. j.*	*Z. c.*	DATA SOURCE
Kodiak Isl. (57.5)	8	664	0	354	0	19	0	Clark (1986)
Angoon (57.5)	476	166	0	0	0	9	0	Moss (1989)
Cape Addington (56)	n.d.	97	0	20	0	52	0	Moss et al. (2006)
Prince Rupert (54)	1915	564	0	44	0	59	0	Stewart and Stewart (1996)
Queen Charlottes (53)	719	662	0	104	0	108	0	Orchard and Clark (2005)
Hesquiat Harbor (50)	158	124	1	329	0	41	31	Calvert (1980)
Ts'ishaa (49)	n.d.	43	1	250	0	19	1	Moss et al. (2006)
N.W. Washington (47.5)	45	57	7	1923	0	42	0	Friedman (1976)
Ozette (47.5)	501	377	2	47,296	34	10	1	Huelsbeck (1994), except *A. t., E. j., Z. c.* data from Etnier (2002b)
N. Oregon (45–46)	724	317	0	186	3	584	29	Lyman (1995), Colten (2002), Moss et al. (2006), and Minor et al. (2008), except *A. t.* data from Moss et al. (2006), and Moss et al. (2006) do not report data for *E. l.*
Central Oregon (43.5–45)	222	264	0	135	3	1047	42	Lyman (1995), except *A. t.* data from Lyon (1937)
S. Oregon (42–43.5)	329	1332	3	73	0	146	22	Lyman (1995)
N.N. Calif. (40–42)	483	116	0	259	0	975	250	Hildebrandt and Jones (1992) and Whitaker (2008)
S.N. Calif. (38.5–40)	185	155	1	93	0	311	126	Hildebrandt and Jones (1992), Wake and Simmons (2000), and Whitaker (2008)
N. Cent. Calif. (37–38.5)	5057	549	0	312	1	296	304	Simmons (1992) and Broughton (1999), except *A. t.* from Rick et al. (2009)
S. Cent. Calif. (35.5–37)	744	103	0	292	26	9	26	Hildebrandt and Jones (1992), except *A. t.* from Rick et al. (2009)
S. Calif. (33–35.5)	1609	275	51	128	3444	22	364	Lyon (1937), Walker and Craig (1979), Colten and Arnold (1998), Porcasi et al. (2000), Walker et al. (2002), and Jones et al. (2008), except *A. t.* from Rick et al. (2009)

NOTE: Latitude is approximate. Data not reported, n.d.

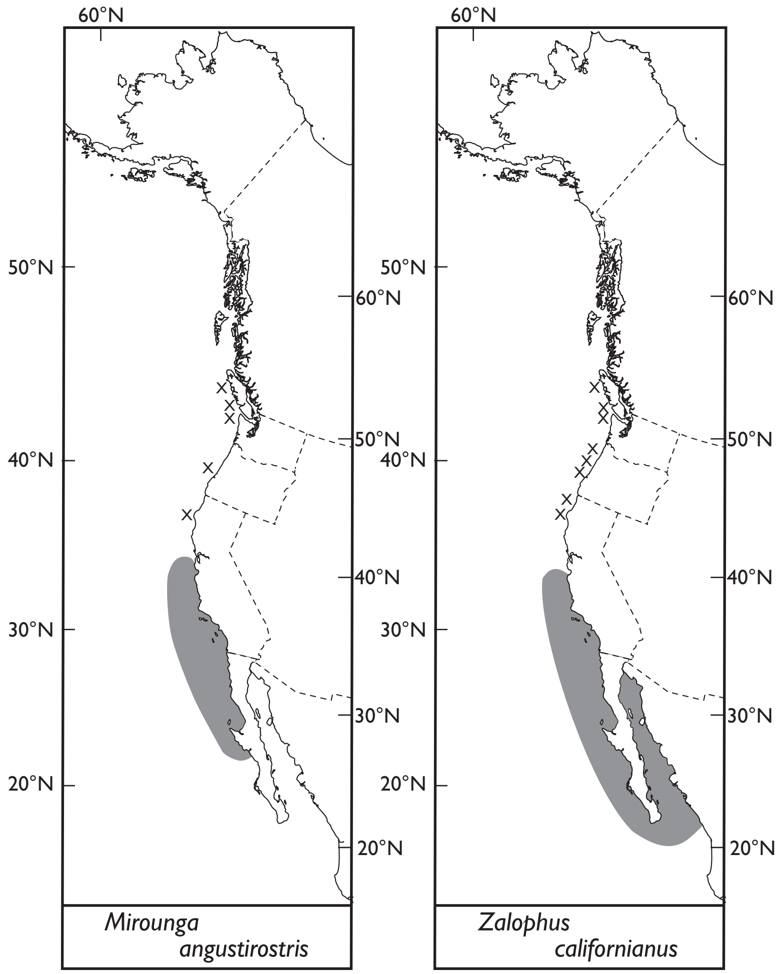

FIGURE 2.2. Modern breeding ranges of northern elephant seal (*Mirounga angustirostris*) and of California sea lion (*Zalophus californianus*) (shaded), and locations of archaeological remains of each (x) outside of the breeding range. Based on data in Table 2.3.

with respect to taxonomic identification of Guadalupe fur seal remains, the biogeographic implications of Figure 2.1 are that during the late Holocene (last 3500 years), this species, like today, seldom ventured north of the latitude of the Channel Islands (33–34°N). Although a historic, commercial-exploitation–related population bottleneck for this species is likely, the prehistoric record suggests relative stasis in its distribution and, perhaps, migratory habits. And this is not the only taxon whose prehistoric remains suggest stasis.

By stasis I mean relative to, particularly, northern fur seals. Despite the commercial exploitation of all pinniped taxa, there are few biogeographic differences between what we know of the 20th century and what the prehistoric record implies for some taxa. This is particularly evident with northern elephant seals (*Mirounga angustirostris*) and California sea lions (*Zalophus californianus*). Today both species breed in latitudes south of the vicinity of San Francisco Bay at about 37°N (King 1983:23, 125), but both are occasionally observed in waters to the north of that bay (Figure 2.2; references in Lyman 1988). Reports of northern elephant seals establishing a more northern breeding and pupping location or rookery

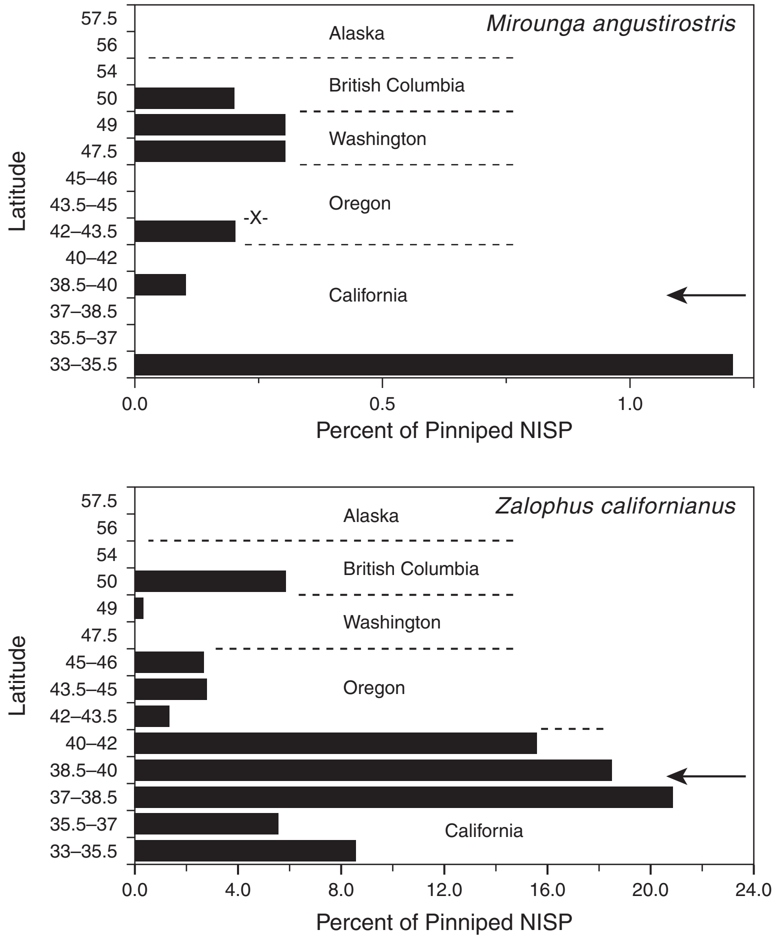

FIGURE 2.3. Relative frequency (percent of all pinniped remains) of northern elephant seal (*Mirounga angustirostris*) and of California sea lion (*Zalophus californianus*) remains relative to latitude. Arrows denote the northern limit of the modern breeding range (see Figure 2.2); "x" in the *Mirounga angustirostris* graph denotes approximate latitude of a newly established rookery. Data from Table 2.3.

(Hodder et al. 1998) at approximate latitude 43.2°N may represent recolonization of previously abandoned rookeries or invasions. This species today migrates north to south-central Alaska (Stewart 1997; see also Crocker et al. 2006). Only study of the paleozoological record will clarify which possibility applies in the case of northern elephant seals (Campbell 1987) and in the case of California sea lions (Bigg 1987).

Zooarchaeological remains of northern elephant seals suggest they occasionally could be found north of 37°N prehistorically, but were only abundant south of that latitude just as they are today, perhaps because that is where they were accessible to humans. Remains of both taxa are abundant in sites within the modern geographic breeding range relative to remains of all other pinniped taxa, but they are relatively rare in sites in more northern latitudes (Figure 2.3). Why these taxa may not have been noticeably affected by historic commercial exploitation whereas sea otters and northern fur seals were markedly influenced—the latter two were extirpated from large expanses of their prehistoric ranges—remains an open question. Part of the answer may reside in the fact that only sea otters and northern fur seals were exploited for their furs; the other taxa were exploited for

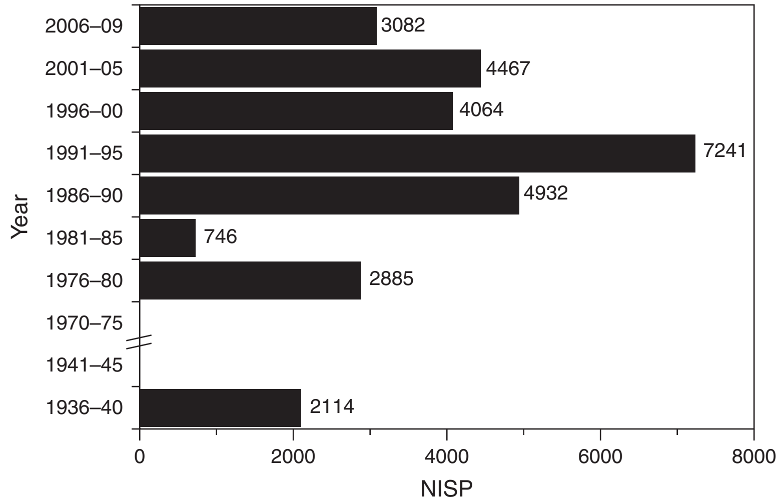

FIGURE 2.4. NISP of sea otter and pinniped remains reported over the last 70 years. The trend to increase over time is real, but the trend to decrease after 1995 may be the result of unpublished data that has not been widely circulated.

other reasons. Whatever the case, this difference between taxa with respect to the degree to which their populations were affected highlights the earlier point regarding the Gleasonian model of taxonomically individualistic histories.

CONCLUSION

By and large, zooarchaeological research on eastern North Pacific sea otters and pinnipeds seems to be closely tracking analytical trends in more land-locked loci. By way of conclusion, there is another arena where study of marine mammal remains is tracking study of terrestrial mammal remains. Analysis of zooarchaeological remains from the North Pacific coastal zone began slowly, with an early, relatively large sample. It was some years before the next sample was studied, but once that second sample was described, sample sizes per 5-year bin have, in general, increased (Figure 2.4). The apparent decrease in NISP over the past decade or so is likely an artifact of the fact that many data, particularly those in the CRM-generated grey literature, have not yet entered the published record (a prime example is Rick et al. 2009). This, too, tracks the character of how the general archaeological record is known in the literature (e.g., Lyman 1997).

There are few documented paleontological remains of any of the taxa listed in Table 2.1 (see Harington et al. 2004 and Ray 2008 for notable exceptions), so I have focused here on what zooarchaeological remains can tell us about the paleoecology of marine mammals. The problems of studying the marine mammal paleorecord of the northeastern Pacific Rim are not insurmountable. The questions driving research on those mammals are interesting and significant. Let us hope that the next 70 years will be as equally exciting as the first 70 years.

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