

3. Archaeofaunal Insights on Pinniped-Human Interactions in the Northeastern Pacific

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Human exploitation of pinnipeds has considerable antiquity but shows increasing impacts on population numbers in the Holocene. Pinnipeds are a rich source of fat as well as protein. A few well-documented cases of regional extirpation of seals and sea lions by non-industrial peoples exist. The northeastern Pacific region, from southern California to Alaska, has yielded archaeological evidence for distributions and abundances of eared seals that differ markedly from historically documented biogeography. This is especially true of the northern fur seal (*Callorhinus ursinus*), among the most common pinnipeds in many archaeological sites from the Santa Barbara Channel area through to the Kodiak Islands. This paper reviews contemporary eared seal biogeography, evidence for the earlier timing and extent of occurrence of northern fur seals along the northeastern Pacific coast, zooarchaeological and isotopic evidence for their foraging and probable maintenance of rookeries in lower latitudes, and for their disappearance from the southernmost part of their ancient distribution well before European contact. It also reviews ongoing debates over the behavioral ecology of ancient fur seals and over humans' role in contributing to their disappearance.

Keywords: zooarchaeology, Pinnipeds, Otariidae, *Callorhinus*, paleobiogeography, isotopes, ecology

Introduction

Human exploitation of pinnipeds goes back into the Pleistocene (Klein and Cruz-Urbe 1996). Historically documented, industrial-scale exploitation of seals and sea lions by humans has driven many such species to the brink of extinction within decades of first cropping (Busch 1985). Some well-documented cases show that prehistoric humans extirpated local populations of these marine mammals within a few hundred years of colonizing a new area (Smith 1989, this volume). However, some archaeological records testify to sustained interactions over centuries to millennia, as with the Ozette Site on the Olympic Peninsula of Washington State (Etnier 2002) or with pre-industrial human exploitation of pinnipeds in arctic regions.

From the Santa Barbara Channel Islands to Alaska, the western coast of North America is home to six pinniped species whose fortunes have been altered through their interactions with humans over the Holocene. These comprise two phocid (true seal) species, the harbor

seal (*Phoca vitulina*) and the northern elephant seal (*Mirounga angustirostris*), and four eared seal (otariid) species, the Steller sea lion (*Eumetopias jubatus*), the California sea lion (*Zalophus californianus*), the northern fur seal (*Callorhinus ursinus*, henceforth, in the interests of concision, NFS) and the southern, or Guadalupe, fur seal (*Arctocephalus townsendi*). The southern sea otter (*Enhydra lutris*) is today found along the central to northern California coast, and the northern form ranges from southeast Alaska through the Aleutians. The Steller sea cow (*Hydrodamalis gigas*) occurred in the southern Bering Sea and perhaps beyond prior to its extirpation by hunters in the 18th century (Anderson, 1995). Several of these species, notably the fur-bearing fur seals and sea otters and the oil-yielding elephant seal, nearly shared the same fate, only to increase to considerable numbers in the 20th century once they were protected by conservation legislation.

However, the pre-European archaeological evidence from the northeastern Pacific Rim testifies to changes in

the abundance of taxa exploited by indigenous groups after settlement of the region. Among the most striking observations is that northern fur seal remains, once abundant in archaeological sites from the Santa Barbara Channel to northern California, drop out of the archaeological record around the beginning of the first millennium BP. In California, disappearance of NFS from all but island localities took place well before European contact, raising questions about the nature of indigenous impacts on marine mammal communities. Farther north, NFS and Steller sea lions continue into historic times. As more details are emerging from ongoing research on the species along the Pacific coast of North America, it is becoming clear that indigenous groups followed a number of different strategies, conditioned by latitudinal differences in environmental parameters and subsistence-settlement strategies.

This paper reviews otariid ecology and biogeography, presents the evidence for the occurrence of NFS along the Pacific coast of North America in pre-European times, and introduces the interpretive debates regarding the disappearance of this taxon. It then presents results of our own research, which is aimed at shedding more light on nature of northern fur seal populations in central to northern California and the circumstances under which NFS vanished from the region. We end with a discussion of the implications of our own and others' research findings.

Northeastern Pacific Eared Seal Distribution and Ecology

Biogeographically, modern northeastern Pacific eared seals (Family Otariidae) form two groups. Steller sea lion and NFS have breeding ranges centered at high northern latitudes (Bering Sea, Aleutians, coastal Alaska, with a small population of NFS on San Miguel Island, California), whereas California sea lion and Guadalupe fur seal breed in southern California and Baja California (Fig. 1). Some earlier biologists such as Orr (1972) and Hall (1940, cited in Lyman 1989) suggested that NFS had a broader geographic range and perhaps even bred over a wider area.

All otariids are gregarious breeders, seasonally congregating in terrestrial breeding colonies, or rookeries. Rookeries comprise breeding-age females, their young of the year, and dominant males who stake claim to sections of the rookery through competition with other males before the females' arrival. Subadult males and adult males unable to hold a breeding territory usually haul-out near the rookeries. Lyman (2003) has stressed that these breeding aggregations are less accurately termed "harems," implying male effort to retain females, than "breeding territories," where male effort is invested in defending a tract from other males. Resource-defense polygyny, as opposed to female-defense polygyny, is the

norm among otariids, with the possible exception of NFS under conditions of low female density (Riedman 1990). Contemporary California sea lions breed on islands and remote mainland locales, while Guadalupe fur seals, NFS, and Steller sea lions breed exclusively on islands. All four species may migrate great distances outside their breeding seasons. Lyman (2003) has stressed that understanding human predation opportunities and costs requires that the behavior of each prey species be understood, and, in the case of highly sexually dimorphic marine mammals, this would include differences in male and female behaviors. The following section outlines key differences among the eared seal species (see also Table 1).

Variations in Otariid Range, Reproduction, Ecology

Today, California sea lions are separated into three stocks based on breeding location: the Channel Islands off southern California; islands off western Baja California, and islands in the Gulf of California (Lowry *et al.* 1992). The U.S. stock breeds almost exclusively on the Channel Islands, but outside the breeding season males range as far north as British Columbia. They haul-out in sexually segregated groups on the mainland and offshore rocks through the year (Boyd 1993; Renouf 1991). They feed near shore on pelagic and demersal prey such as small schooling fish and cephalopods (Fiscus and Baines 1966; Ridgway and Harrison 1981). At present, the U.S. stock is stable or increasing (NMML 2003).

Zalophus breed in dense rookeries, with the dominant adult males holding and defending tracts within the breeding ground (Orr 1972). If threatened, females will retreat to the sea but will stay to defend their newborn young during a short interval after birth (Peterson and Bartholomew 1967, cited in Lyman 1989). Although reluctant to move into the sea while at a rookery, repeated human disturbance to a rookery or haul-out locale will result in the species' abandoning it (Peterson and Bartholomew 1967). California sea lions wean their pups gradually over 10–14 months.

Contemporary Steller sea lions are divided into two major populations based on biogeography, population dynamics, and genetics (York *et al.* 1996). The western stock, comprising about half the total population, inhabits the western Gulf of Alaska, with large rookeries on the Aleutians (Loughlin *et al.* 1984) and smaller breeding colonies on islands off southeastern Alaska and northern British Columbia (Figs 1, 2). Rookeries are historically documented as far south as Oregon. Steller foraging zone, prey types, and haul-out behavior are similar to those of California sea lions. They, too, migrate substantial distances from their rookeries outside the breeding season (Ridgway and Harrison 1981; Renouf 1991; Fiscus and Baines 1966). Because of rapid, as-yet unexplained drops in their numbers, the western Steller sea lion stock was

Table 1. Phocids ("true seals") and otariids ("Eared seals") of the north Pacific, showing modal adult weights of female and male adults, and female weight as a ratio of that of the male.

TAXON	ADULT WEIGHT (kg)		
	FEMALE	MALE	FEMALE:MALE
Harbor seal <i>Phoca vitulina</i>	142	185	.78
Northern elephant seal <i>Mirounga angustirostris</i>	900	2300	.39
Northern fur seal <i>Callorhinus ursinus</i>	40	225	.18
Guadalupe fur seal <i>Arctocephalus townsendi</i>	45	165	.27
California sea lion <i>Zalophus californianus</i>	110	400	.28
Steller sea lion <i>Eumetopias jubatus</i>	263	500	.55

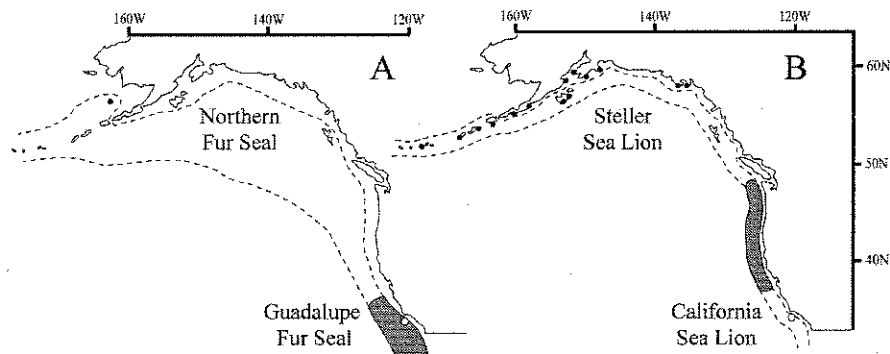


Figure 1. Major breeding locations and foraging ranges for modern NE Pacific otariids. Solid circles represent the Pribilof NFS (A) and active Stellers sea lion (B) rookeries. Open circles represent the NFS and California sea lion rookeries on San Miguel Island. Shaded regions represent overlap in the foraging ranges of species.

classified in 1997 as Endangered under the Endangered Species Act; the eastern stock was classified as Threatened (National Research Council 2003).

Like California sea lions, Steller males are resource-defense breeders, and those males on breeding territories will defend them against human intruders (Orr and Poulter 1967); given the size of a fully adult male, these would be challenging prey. However, recent records show that Steller sea lions will abandon both haul-out and rookery locations if disturbance is high. Steller sea lions wean their pups more slowly than do California sea lions, over 12–36 months.

Guadalupe fur seals occurred historically from the Revillagigedo Islands off central Mexico to the Santa Barbara Channel Islands off southern California. Popu-

lation at European contact is estimated at 20,000–100,000 (Wedgforth 1928; Hubbs 1956; Fleischer 1987), but 19th century commercial sealing drove the species nearly to extinction (Townsend 1931). Today, Guadalupe fur seals have only one substantial rookery, on Guadalupe Island, Mexico, totaling c. 10,000 individuals. Some Guadalupe fur seals are documented as resident in the Channel Islands; individuals have stranded or been sighted at sea as far north as southern Oregon (Steward *et al.* 1987).

Guadalupe fur seals are among the least-studied fur seals. They come to land only to breed and nurse, spending the balance of the year foraging offshore at the continental shelf-slope break, but, given their longer lactation span, females of this species are more terrestrial than are modern NFS populations. They wean their pups

over 8–10 months. While nursing, females make repeated 9–13 day foraging trips to feed on small schooling fish and squid at the continental shelf-slope break (Ridgeway and Harrison 1981; Renouf 1991; Boyd 1993). Guadalupe fur seals are designated as Threatened. Given their current status, little has been published on their responses to human disturbance, but historical records suggest that they were readily clubbed on their rookeries.

Northern fur seals have the broadest geographic distribution among NE Pacific otariids, ranging from southern California to the Bering Sea and as far west as northern Japan (Gentry and Kooyman 1986; Gentry 1998). They are the least terrestrial of otariids. During their late June-early November breeding season, about 75% of the global population gathers on the Pribilof Islands in the Bering Sea (Fig. 2), with most of the remainder breeding on other high latitude islands off Siberia and Japan. *Callorhinus* individuals show high natal site fidelity; however, in 1968, a rookery formed on San Miguel Island, one of the Santa Barbara Channel Islands (Peterson et al. 1968). Females founding the San Miguel Island rookery bore tags from both Aleutian and Russian islands, indicating that the species has behavioral mechanisms for expansion into favorable breeding locations. The San Miguel Island *Callorhinus* might be re-establishing a breeding location used in prehistoric times, since their bones are present in the island's archaeological sites (Walker et al. 2000), but evidence for their breeding is equivocal (see below). During the 1990s, intermittent colonization by NFS of South Farallon Island, about 40 km west of the Golden Gate and San Francisco, has been reported as well (Pyle et al. 2001). Tagged animals in this colony originated on San Miguel Island rather than on north Pacific islands. Significantly, historic and archaeological records testify to the existence of earlier NFS breeding colonies on South Farallon Island (Pyle et al. 2001).

Females give birth shortly after coming ashore and nurse their pups for at most 4 months, the shortest weaning interval among NE Pacific otariids. While nursing, Pribilof females make repeated 4–12 day foraging trips and travel up to 200 km roundtrip to feed at the shelf-slope break (Gentry 1998). After the breeding season, Pribilof adult females, subadults, and pups migrate to feed in offshore waters as far south as California; adult males stay north and feed offshore in the Gulf of Alaska. This difference in migratory behavior probably relates to body mass. Smaller adult females and immatures would not be able to meet the energetic demands imposed by cold north Pacific waters, whereas the much larger males (Table 1) have sufficient body mass to cope with these thermoregulatory challenges.

The NFS breeding population on San Miguel Island occupies their rookery for roughly the same timespan as do their conspecifics in the far north Pacific, although as-yet anecdotal evidence suggests that females may be increasing their lengths of stay on the rookery. As winter

approaches, individuals of both sexes may remain at mid-latitudes, venturing as far north as the Oregon-Washington border while feeding offshore (Gentry 1998), but some hold that males of this population migrate to far northern waters, the region used by their conspecifics from the northern island rookeries (Etnier 2002, 9). For the 8 months of each year that all NFS are away from their island rookeries, they do not haul-out on land unless injured or ill. The Pribilof NFS stock has suffered periodic declines since the mid-1970's, when population estimates exceeded 1.25 million. Current population estimates are 800,000–900,000. The San Miguel Island stock has increased steadily since its inception in 1968, with temporary declines due to El Niño events (National Marine Mammal Laboratory 2003; Melin and DeLong 2000).

NFS have been subject to intensive study and ongoing indigenous subsistence harvesting in the Pribilofs. *Callorhinus* males are notorious for their ferocious defense of territory (Bartholomew 1953; Gentry 1998). Although NFS males are smaller than California sea lion males and attain only half the body weight of Steller sea lion males, they displace both species on San Miguel Island (R. DeLong, personal communication 1998) and readily attack and pursue humans who enter their territories. Given their inclination to charge intruders, males would be formidable prey. In contrast, younger males hauled-out in pods near the breeding grounds are readily herded by human hunters, who drive them inland so they can be dispatched with clubs with less loss of individuals during the process (Gentry 1998). Females of the species, weighing well under 50 kg, may be taken more readily, especially in view of the delicate construction of their crania, which can be smashed with a forceful blow.

Pinniped Biogeography in Historic Perspective: Differences Between Present and Past

About 40 years ago, archaeologists began to note striking contrasts between prehistoric and present distributions and abundances of all eared seals (and of northern elephant seals) along the Pacific coast from the Santa Barbara Channel into British Columbia (Fig. 2). It has become clear that Steller sea lion and northern fur seal bones were much more common and geographically widespread in archaeological sites than would be anticipated from their modern distribution. It also became clear that northern elephant seals were rare to absent from sites in areas they have colonized today (LeBouef and Mate 1978; Lyman 1989).

In the 1960s, the first publication appeared on the profusion of remains of *Callorhinus* at the sedentary Makah Indian site of Ozette on the Olympic Peninsula of Washington (Gustafson 1968; see also Etnier 2002). Remains first reported were mainly those of younger

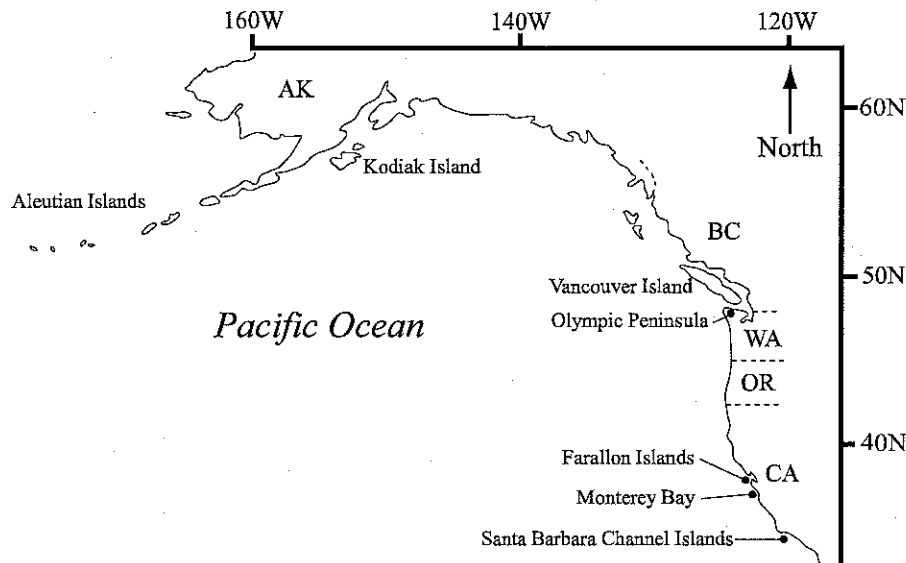


Figure 2. Map of northeastern Pacific region, showing areas mentioned in the text.

males, although other age-sex classes are represented, and evidence exists for the species' persistence into the historic fur sealing era (Etnier 2002). This was the first work since that of Lyon (1937) that indicated that NFS ranges could have extended into zones well beyond those known in historic times.

In the 1980s, other archaeologists discovered bones of NFS and Steller sea lions as substantial components of the marine mammal faunas from coastal sites of central California to Oregon (Table 2). This region appeared to vary more in proportions of these species and the timing of their disappearance. Remains of young-of-the-year raised the question of whether these taxa had ancient breeding sites along the coasts. Hildebrandt (1984; Hildebrandt and Jones 1992) was first to note in print that NFS were present in substantial numbers in northern California archaeological sites dating to the Middle Period (*ca.* 0–300 AD, or 1,700–2,000 BP), but not in later sites they reviewed. Presence of NFS had been noted in a Monterey Bay site simultaneously in a monograph (Gifford and Marshall 1984) on a site artifactually dated to the Early-Middle periods on the northern Monterey Bay coast (Table 2). Soon thereafter, Lyman (1989, 1991, 1995) noted the presence of NFS as well as Steller sea lions in Oregon coastal site assemblages. It was also confirmed that there were *Callorhinus* bones in pre-historic archaeological sites on islands in the Santa Barbara Channel, notably San Miguel and San Clemente Islands (Arnold 1992; Colten 1998; Porcasi *et al.* 2000; Walker *et al.* 2000).

In contrast to the sample from Ozette, most of the NFS specimens recovered from sites in California and Oregon derived from breeding-age females, whose dental,

craniomandibular, and postcranial size and morphology are so distinctive that they cannot be confused with that of other eared seals. Some specimens from adult males and young-of-the-year pups were also reported by Lyman (1991), who used these remains to argue for the presence of a NFS rookery in the region. In the 1990s, more remains of females, subadults, and young-of-the-year pups were recovered in excavations at the Moss Landing Hill Site (CA-MNT-234), at the center of the Monterey Bay coastline (Breschini and Haversat 1995; Burton *et al.* 2001; Milliken *et al.* 1999). This fauna is currently under further National Science Foundation-sponsored analysis by DGG.

Further archaeological research also yielded more definitive evidence of the ubiquity of NFS in the Pacific Northwest in the middle to late Holocene (Table 2). Etnier (2002) summarizes zooarchaeological collections yielding remains of NFS from sites, which include more sites on the Olympic Peninsula, on Vancouver Island, mainland British Columbia, and Alaska away from the Pribilofs, including at least five sites on Kodiak Island, spanning from the first millennium BC through historic time (Clark 1986; Knecht and Davis 2001). In the Aleutian Islands, the large (mammal NISP *c.* 17,000) assemblage from Chaluka, on Umnak Island contains an estimated NFS NISP of 7,000 (Lippold 1966; Etnier 2002), again running into the historic period. Claims for the existence of NFS rookeries in that region have been made by both Crockford *et al.* (2002) and Etnier (2002), based on differing criteria (see discussion of young-of-the-year age determination below).

Farther south in coastal California, remains of NFS tend to drop out of the archaeological record well before

Table 2. Archaeological sites on Pacific coast of North America with northern fur seal (NFS) remains NISP >5. All areas are those where NFS do not breed or haul out in historically documented time. Key to Dates: **bold**: direct AMS radiocarbon dates on NFS bone; **italic bold**: associated dates on mollusk shell; (#): number of dates; regular font: dates from artifacts and/or radiocarbon dates of other materials. All dates calibrated.

SITE	LOCATION	DATES (years BP)	NFS Breeding Males	NFS Breeding Females	NFS Young of Year	Authors Claim Rookery	Sources
CA-SMI-1, SMI-528, SMI-602	San Miguel Island, CA	3500-2300	?	yes	trace	no	Walker <i>et al.</i> 2000
Point Mugu	Ventura CO, CA	400-100 760-825 (4)	?	yes	yes	yes	Lyon 1937
Pacific Grove CA-MNT-115	Monterey CO, CA	1980-1670	no	yes	no	no	Dietz & Jackson 1981
Castroville Bypass Site CA-MNT-1570	Monterey CO, CA	5800-4800	no	yes	no	no	Jones <i>et al.</i> 1992
CA-MNT-234 Moss Landing Hill	Monterey CO, CA	8500-500	trace	yes	yes	yes	Burton <i>et al.</i> 2001, 2002
CA-SCR-35 Edwards Beach	Santa Cruz CO, CA	2200	no	yes	no	no	Gifford & Marshall 1984
CA-SMA-18, Año Nuevo Point	San Mateo CO, CA	<i>1810-1990 (6)</i>	no	yes	?	no	Hylkema 1991
CA-SMA-218, Año Nuevo Point	San Mateo CO, CA	2780-2920 (3)	no	yes	no	no	Hylkema 1991
CA-SMA-118 Bean Hollow	San Mateo CO, CA	900	no	yes	??	no	Hylkema 1991, Hildebrandt & Jones 1992
CA-SON-348H, Duncan's Point Cave	Sonoma CO, CA	1485-8065 (8)	no	yes	yes	yes	Wake & Simons 2000
CA-HUM-129, Stone Lagoon	Humboldt CO, CA	Middle Period	No	yes	no	yes	Hildebrandt & Jones 1992
35-DO-83, Umpqua/Eden	Douglas CO, OR	925-2630 (3)	yes	yes	yes	yes	Lyman 1989, 1991
Seal Rock, 35-LNC-14	Lincoln CO, OR	855-945 (2)	yes	yes	yes	yes	Lyman 1989, 1991
Whale Cove, 35-LNC-60	Lincoln CO, OR	3000-200	tr	tr	yes	yes	Lyman 1989, 1991
Yaquina Head, 35LNC-62, 35LNC- 49 35LNC-50	Lincoln CO, OR	4000-500	?	?	?	yes	Lyman 1995
Bandon, 35-CS-43	Coos CO, OR	1775	?	?	?	yes	Hall <i>et al.</i> 1990, Lyman 1991
Neah Bay, WA-CA-22	Clallam CO, WA	?? to historic	trace	trace	yes	yes	Friedman 1976; Etnier 2002
Tatoosh, WA-CA-207	Clallam CO, WA	920 to historic	yes	yes	yes	yes	Friedman 1976; Etnier 2002
Sooes, WA-CA-25	Clallam CO, WA	1050-historic	yes	trace	yes	yes	Friedman 1976; Etnier 2002
Ozette WA-CA-24	Clallam CO, WA	2000-historic	yes	yes	yes	yes	Gustafson 1968; Friedman 1976; Etnier 2002
Cape Flattery	Clallam CO, WA	?? to historic	yes	yes	yes	yes	Crockford <i>et al.</i> 2002
Aguilar Point DfSg-2	Bamfield, BC	??	?	?	yes	yes	Crockford <i>et al.</i> 2002; Coates & Eldridge 1992
Nintinat Lake DeSf-10	Nitinat Lake, BC	??	yes				Crockford <i>et al.</i> 2002; Eldridge & Fisher 1997
Ts'ishaa DfSi16	Vancouver Island, BC	895-4350 (9) 950-4910 (21) ~5000-250 cal BP	yes	yes	yes	yes	Crockford <i>et al.</i> 2002:152; Frederick & Crockford 2003 in McMillan & St. Claire 2003
DiSol	Hesquiat Peninsula Vancouver Island, BC	~500-1700 AD	yes	yes	yes	?	Calvert 1980: 146-149
DiSo9	Hesquiat Peninsula Vancouver Island, BC	-0-800 AD	yes	yes	yes		Calvert 1980: 144-145

Table 2: continued.

SITE	LOCATION	DATES (years BP)	NFS Breeding Males	NFS Breeding Females	NFS Young of Year	Authors Claim Rookery	Sources
DiSo16	Hesquiat Peninsula Vancouver Island, BC	~1300-1700 AD	no	no	no		Calvert 1980:143
Yuquot DjSp1	Nootka Sound, Vancouver Island, BC	~4000-historic	??	yes	yes	no	McMillan 1999:56; Dewhurst 1980:308
Bear Cove EeSu-8	NE Vancouver Island	~5300-1000 cal BP			yes	no	Carlson 2003:79
FbTc1	Bella Bella, BC	~2300-300 C14BP					Hester & Nelson 1978
McNaughton Island (ElTb10)	Central coast, west of Hunter Island	~2300-300 C14BP	??	??	??	no	Pomeroy 1980:327-329,
Prince Rupert Sites	Boardwalk Site (GbTo-33) & Grassy Bay Site (GbTn-1), BC	5500-contact	??	??	??	v	Stewart & Stewart 1996
Three Saints Bay	Kodiak Island, AK	480-historic	subadult	yes	trace		Clark 1986; Etnier 2002
Rolling Bay	Kodiak Island, AK	1010-1085 (3)	subadult	yes	trace		Clark 1986; Etnier 2002
Kiavak	Kodiak Island, AK	480-historic	subadult	yes	trace		Clark 1986; Etnier 2002
Chaluka	Aleutian Islands, AK	830-1385 (3)	yes	yes	yes		Lippold 1966; Etnier 2002
Oglodax'	Aleutian Islands, AK	65-historic	yes	yes	yes		Yesner 1977, 1988

the arrival of Europeans. This fact has led to heated debate among archaeologists over what contributed to the disappearance of *Callorhinus* as a food item, and even whether and where they disappeared. Before discussing these interpretive debates, it is useful to broaden our scope a bit to compare past and present pinniped taxonomic abundances in California, where NFS disappeared from the archaeological record. These comparisons illustrate how different the coastal Pacific was about a thousand years ago.

Today on the Santa Barbara Channel Islands, California sea lions dominate the modern otariid population, with an estimated 80,000-100,000 individuals. In contrast, only 3,000-10,000 NFS inhabit the San Miguel Island colony, which is not yet 40 years old. California sea lions account for only about 14% of identifiable otariid specimens in archaeological occurrences near Point Bennett (SMI-528/602), San Miguel Island, whereas NFS represent about 23% of NISP (Walker *et al.* 2000). Relative abundance discrepancies between the modern and Holocene are even greater for Guadalupe fur seals. They dominate marine mammal faunas at many Holocene sites on the Channel Islands (Walker *et al.* 2000; Colten 2002; Porcasi *et al.* 2000), but are nearly absent there today.

If one considers how species-specific behaviors of these eared seals affect their vulnerability to human predation, the high proportions of fur seal remains in Channel Island archaeological assemblages are all the more striking,

given the limited window of opportunity for taking these animals on land. Modern fur seal behavior suggests that both species would be available to human predators only during their 4-8 month breeding seasons, whereas California sea lions would be more consistently available through the year at their haul-out sites.

The region north of the California Bight is within the foraging ranges of modern northern fur seals, Steller sea lions, and California sea lions, but otariid rookeries are absent from present-day central California to the Pacific Northwest. Marine mammal stranding data from the entire California coast from 1990-1997 show that NFS account for about 1% of the 14,000 animals stranded (Burton *et al.* 1999), probably due to the fact that ill or injured animals die in their foraging zones far out to sea along the continental shelf break. Again in contrast to the present-day record of their presence, NFS are among the most abundant of pinniped taxa in central to northern California coastal archaeological assemblages over 1,000 years old (Hildebrandt 1984; Hildebrandt and Jones 1992; Lyman 1991). At least eight sites on the Monterey Bay shoreline, including one at Moss Landing with young-of-the-year pups, two more at Point Año Nuevo and one at Bean Hollow State Park, on the San Mateo County coast, have yielded NFS remains (Table 2). On the Sonoma coast north of San Francisco, Duncan's Cave yielded elements of northern fur seals, including those of young-of-the-year, prompting analysts to claim the nearby existence of a rookery (Wake and Simon 2000), and in

Humboldt County in far northern California, three sites have yielded bones of *Callorhinus*. In Oregon, at least four sites have yielded remains of NFS (Lyman 1989; Etnier 2002; Table 2).

Interpretive Debates

The ubiquity of NFS bones in archaeological site from the Channel Islands to Alaska stands in a striking contrast to their historically documented occurrence. In historic times, the species was encountered on only a few islands far off the California coastline (the Farallons and San Miguel Island), not at all from the Oregon coast, and possibly from a rookery at the tip of the Olympic Peninsula (Swan 1887). All historically documented *Callorhinus* breeding populations are only terrestrial and hence liable to human predation for four months in their yearly cycle. They are difficult to locate and capture while dispersed at sea. Presence of NFS in so many prehistoric sites over such an area demands an explanation. Several accounts for their presence have been advanced, and these are still subject to vigorous debate, both among archaeologists and between zooarchaeologists and marine mammal biologists. These explanations may be grouped as follows:

(1) *Aborigines with pelagic fishing/sealing technology acquired NFS while they were deep-sea foraging.*

This alternative was articulated by Snyder (1978), who argued that occupants of the Seal Rock site in Oregon had the technological capabilities to procure pelagic prey such as *Callorhinus*. Greenspan (1986, in Lyman 1989) also argued that the presence of NFS elements in Oregon sites reflected the existence of deep seagoing watercraft. This position accepts no necessity for nearshore or mainland rookeries where none were reported historically, nor any other change in NFS behavior from the aboriginal to historic fur seal trade period.

Lyman (1989, 1991, 1995) categorically rejects the argument that artifacts recovered from sites with northern fur seals, as well as the ethnographic record, imply that aboriginal site inhabitants possessed the technology to journey to the continental shelf break or to efficiently harvest NSF and other pinnipeds while they were in the water. This view is also generally seconded by Hildebrandt and Jones (1992), although with the stipulation that rare harpoons in northern California sites might reflect specialized pinniped procurement tactics focused on nearer offshore rocks and islands rather than the open ocean. Although not articulated by any of these authors, yet another alternative is that, in the rare oceanographic settings where deep water is close to land, NFS foraging at the shelf slope break would not be far from shore, which would put the animals within striking distance of human predators. For this circumstance to be a viable predation option for humans, NFS would have to

have been both concentrated and predictable in time and space, as a function of both oceanography and their prey species' habits.

(2) *Ancient NFS rookeries existed within human reach, either on nearshore islands or rock stacks or on the mainland itself*

This alternative has been espoused by Lyman (1989, 1991, 1995), Hildebrandt and Jones (1992) Jones and Hildebrandt (1995), Hildebrandt (1984), Wake and Simons (2002), and those authors of the present paper who published two articles on their preliminary isotopic and osteometric findings on California materials (Burton *et al.* 2001, 2002; see also Burton 2000). This perspective implicitly or explicitly asserts that *Callorhinus* breeding behavior differed from that observed today, with more widespread rookeries at these lower latitudes, rather than just a few on offshore islands. It implies that the mid-latitude population's female and subadult migratory cycle would not include a circuit to the Pribilofs or other far northern Pacific islands. These age/sex classes forage at middle latitudes today and, if breeding colonies were located in the same latitudinal zone as their foraging ranges, a trip to the far northern islands would serve no function. Etnier (2002) raises the possibility that males of such mid-latitudinal breeding populations might forage in the Gulf of Alaska.

In truth, much diversity exists under this heading. Archaeologist Lyman (1989, 1991, 1995) argued that, in the absence of nearshore islands or rock stacks, one must conclude that mainland rookeries of Steller and NFS existed. He contended that this was supported in the case of *Callorhinus* by representation in his sample of (rare) breeding-age males, more numerous breeding-age females, and young-of-the-year. Hildebrandt and Jones (1992), by contrast, argued that presence of NFS in northern Californian and Oregon sites suggested the existence of rock stacks or small islands relatively close to the shore, where the species – today solely an island breeder – could be taken by hunters equipped with relatively simple technologies. Our research group posited the existence of mainland rookeries on the central California coast, albeit in protected locales, based on age-at-death estimates of young-of-the-year, in turn derived from growth curves based on modern comparative specimens (Burton *et al.* 2001, 2002). Etnier (2002) demanded a higher standard of proof than we had originally presented in terms of estimating age-at-death, but he accepted that the Oregon age profile record and that of the Olympic Peninsula testified to the likely presence of regional rookeries.

(3) "Pinniped driftwood," or stranding of ill or starving NFS individuals on mainland beaches from ancient rookeries located only on historically documented island colonies, with subsequent human use.

This alternative, expressed in print only by Etnier (2002) but verbally by some marine mammal researchers, posits that nearly all occurrences of NFS in mainland archaeological sites along the Pacific coast can be accounted for by the buildup of individual strandings from a few very large rookeries on inaccessible islands, such as San Miguel and the Farallons, and perhaps offshore rookeries farther north in Washington and Alaska. This position holds that NFS could indeed establish rookeries in middle latitudes, as demonstrated in historic times, but only far from disturbance by non-human terrestrial predators such as grizzly bears. Human disturbance of such offshore rookeries is also presumed to have been minimal. No aboriginal archaeological sites have been found on South Farallon Island (Pyle *et al.* 2002), implying that inhabitants of the greater San Francisco Bay region lacked the pelagic technology to exploit pinniped colonies there. However, the situation for the Channel Islands is different, and debate exists over whether canoe-using aboriginal peoples depressed eared seal species numbers at any time before historic contact (*e.g.* Porcasi *et al.* 2000). The "driftwood" position asserts that, with larger "breeder" populations than currently extant in the middle latitudes, strandings of sub-vital adults, subadults, and young-of-the-year NFS would have occurred at a higher rate, thus accounting for their ubiquity in coastal sites.

Based on his analysis of the age profile of recent NFS strandings, Etnier (2002) argues that remains of early weanlings and even unweaned pups could have found their ways into prehistoric middens simply through strandings along the California and Oregon shores, carried there by seasonal currents. Etnier's main concern is the low number of young-of-the-year specimens cited in claims for rookeries, including our own study, and whether these simply reflect sampling of a diachronic series of natural strandings.

While we believe this alternative is a viable working hypothesis that merits further study, it requires development of observational predictions. First, there is at present no method for distinguishing scavenged dying or dead animals from those taken as primary prey. Second, an analysis of ocean currents over the span of the year that the Farallons (and perhaps San Miguel) rookeries were occupied needs to be developed, to ascertain the likelihood that distressed animals would reach the Monterey Bay from those islands. One logical problem with this position is that it does not offer an explanation for why eared seals, especially northern fur seals, stopped accumulating in California's coastal sites about 1,000 years ago. If human intervention in the fortunes of rookeries is not involved, what other source of change can be advanced?

NFS Disappearance from the Central to Northern California Archaeological Record: Why?

Despite their differences, all researchers mentioned above agree that some alterations in abundances of marine mammal taxa on the Pacific coast of California took place prior to European entry into the region and to subsequent industrial-scale harvesting of pinnipeds in the 18th and 19th centuries. The question is, what happened to cause this shift? Based on the Oregon record, Lyman (1989; 1995) argued that Steller sea lions and NFS persisted in that region into the 17th or even 18th centuries, or essentially until historic contact. In their 1990s papers, Hildebrandt and Jones (1992; Jones and Hildebrandt 1995) argued that the California record testifies to the disappearance of NFS by the end of what is widely termed the Middle Period in California archaeology, the termination of which is dated roughly to 1,000 BP. Lyman (1995) contended that some of Hildebrandt and Jones' data, when subjected to statistical assessment, do not support this inference.

Hildebrandt and Jones (1992; Jones and Hildebrandt 1995) attributed the disappearance of NFS from archaeofaunas along the California coastline to overcropping, terming it a "tragedy of the commons." Jones and associates have continued to argue for the "tragedy of the commons" scenario in other areas (Porcasi *et al.* 2000). They thus argued for an extreme case of resource depression, where, instead of shifting to lower-ranked prey as the top-ranked pinnipeds became rare, prehistoric hunters extirpated the top-ranked species before moving on to lower-ranked taxa. Contra Lyman, they contend that, at least in part of the range of the disappearance of *Callorhinus*, aboriginal groups had developed more efficient technologies for capturing prey at sea, thus tipping the balance in favor of radical resource depression.

More recently, Lyman (2003) distinguishes varied types of resource depression and re-examines the Oregon archaeofaunas. He infers that, while pinniped metapopulations along the northeast Pacific coast appear to have been depressed over time as a result of human predation, in local cases, specifically that of Steller sea lions in Oregon, a male-centered cropping strategy did not result in resource depression.

Few researchers other than ourselves (Burton *et al.* 2001, 2002) have discussed climatic forcing as a possible factor in the disappearance of NFS from central to northern California, although Jones and Kennett (1999) have contributed to reconstructing ocean paleotemperatures for central California. In a regional overview of the southwestern United States around the first millennium BP, Jones *et al.* (1999) raised the possibility that the Medieval Climatic Anomaly (MCA) caused severe droughts in central California, as well as in better-documented areas such as the Santa Barbara Channel area. This would have drastically affected the subsistence, settlement, and exchange relations of the region's in-

habitants. The MCA is shown to roughly coincide with the end of Middle Period in central California. Jones *et al.* (1999), in fact, assert that the collapse of Middle Period subsistence and settlement patterns, abandonment of long-inhabited sites, and the eventual appearance of the Late Period artifactual and settlement pattern were caused by dislocations set in motion by the MCA. However, their article is mute on the possible concatenation of terrestrial climate change, demographic stress, and the roughly coeval disappearance of NFS from the archaeological record.

To sum up the last two sections, there is ample and geographically widespread evidence that aboriginal peoples all along the eastern Pacific were able to regularly obtain NFS as food items. Although their proportions in local archaeofaunal samples vary from a few to the vast majority of pinnipeds, it is clear that they entered the archaeological record at much greater rates than, say, Steller sea lion in the lower forty-eight states. How to explain both the access that human groups had to *Callorhinus* and their disappearance from different segments of their former range is the matter of ongoing debate. Among the contested assertions is the claim that NFS had rookeries in areas where no members of the species do today, namely nearshore locations or the mainland. Overpredation and climate change have been raised as possible causes of their local extirpation in locations where they disappear before the European fur trade, though exclusively climate-driven models for local extinction are uncommon.

Few involved in these debates have moved beyond reiterating their beliefs in a correlation between patterning in the archaeological data and what they deem an appropriate explanatory scenario. That is, until recently no one has stipulated parallel and independent lines of evidence (*cf.* Gifford-Gonzalez 1991; Lyman 1994) that would hold true, were their scenarios correct, thus enabling them to falsify or continue to support their hypotheses.

Two exceptions, we believe, exist. First, Etnier's (2002) dissertation research refined both age-at-death estimates and the use of derived harvest profiles to diagnose the nature of the source from which the sample was drawn (rookery versus other "pool" of individuals) and the nature of the offtake, in terms of age- and sex-specific predation. Second, our own research has sought to use radiocarbon dating and stable isotope analyses of pinniped bone to shed light on questions about the time of disappearance and foraging behaviors of northern fur seals, and multiple analyses of mollusk shell as an independent index of upwelling and marine paleotemperatures during the timespans that *Callorhinus* were present and when they are no longer in evidence.

Aims of Our Research

The first stage of our research, undertaken over the last six years, has been aimed at more closely addressing the following four questions:

(1) When did NFS disappear from different sections of the California and Oregon coast, and how persistent were they in other areas? Only a few radiocarbon dates were usually available for the sites with and without northern fur seals, and these were nearly all on charcoal or other non-bone materials. Dates for the presence or absence of NFS were therefore associational. Because it is a truism in mainland California archaeology that burrowing rodents mix stratified middens (Erlandson 1984; Porcasi *et al.* 2000), in our initial stage of research, we opted whenever possible to directly date NFS bones.

(2) Were the NFS found in California and Oregon archaeological sites breeding at these latitudes, or were they immigrants from far northern rookeries? This question was best addressed by using stable bone isotopes and a modern reference set (Burton and Koch 1999). This is not a new approach in charting the foraging behaviors of vertebrates, modern or ancient, but it had to be designed to deal with amphibious mammals such as seals and sea lions. The next section details the basic assumptions and procedures of this approach to pinniped synecology.

(3) Regardless of their area of birth, when in middle latitude waters, were NFS foraging closer to land (hence presenting better targets for human predation), or were they feeding offshore, as do all modern representatives of the species? As with the second question, this was best addressed by using stable bone isotopes and a modern reference set.

(4) Was the disappearance of NFS from middle latitude sites associated in time with conspicuous changes in environmental conditions? To assess environmental changes of relevance to *Callorhinus*, we used stable isotope signatures and radiocarbon reservoir effects in marine mollusks, which will be outlined in a succeeding section.

Analytic Results

Question 1: Last Dates of Occurrence of northern fur seals

Figure 3 summarizes dates for NFS in sites from southern California to Alaska, most obtained in our current research. These data show that NFS persisted into historic times along the southern California coast, in Ventura County, at the site of Point Mugu (Lyon 1937). This site faces the Channel Islands, and it is presently unknown whether the numerous bones of NFS at this site result from canoe-based predation on island populations, or

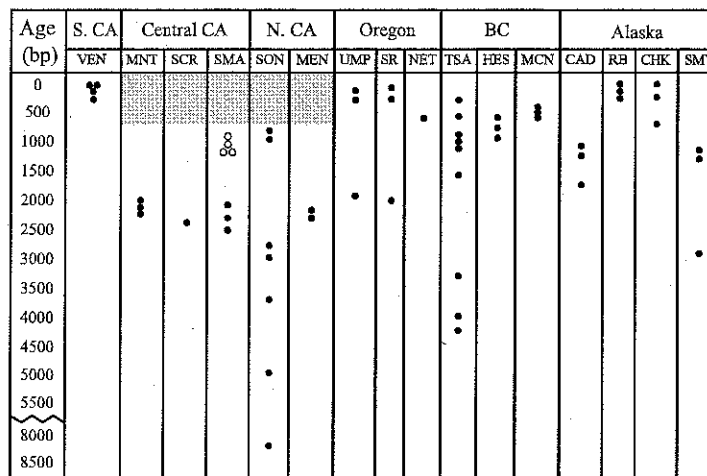


Figure 3. ^{14}C dates for northern fur seals (l) and shells (ê) at sites with NFS. $d^{13}\text{C}$ -corrected ^{14}C ages have been reservoir corrected with Calib (v4.4), using a reservoir age (DR) of 225 ± 35 years (Stuiver & Reimer, 1993, 1998). Each symbol represents the midpoint of the 2s age range calculated using the Calib program. VEN-Ventura Co.; MNT-Monterey Co.; SCR-Santa Cruz Co.; SMA-San Mateo Co.; SON-Sonoma Co.; MEN-Mendocino Co.; UMP-Eden/Umpqua; SR-Seal Rock; NET-Netarts Bay; TSA-Ts'ishaa, Barkley Sound; HES-Hesquiat Harbor; MCN-McNaughton Island; CAD-Cape Addington, RB-Rolling Bay, Kodiak Island; CHK-Chaluka, Umnak Island; SMY-Shemya Island. Shaded region represents sites from central and northern CA that do not contain NFS remains.

from a more proximate source, or from strandings. Our dates from central California support the contention that NFS vanished from the greater Monterey Bay region around 1,000 BP. However, Cultural Resource Management reports on archaeofauna from a site complex at Moss Landing (CA-MNT-234) on the Monterey Bay lists NFS present from Milling Stone Horizon occurrences ca. 8,500–8,000 BP through the Late Period, ca. 500–800 BP (Breschini and Haversat 1995; Milliken *et al.* 1999). Our research group is presently engaged in a second round of direct dating of such “outlier” NFS specimens in the context of a detailed analysis of the MNT-234 archaeofauna. Further north, NFS are present from the early Holocene to 1,000 BP at Duncan’s Point in Sonoma County. We lack sufficient dated specimens from farther north in California to assess the time of disappearance, but we note NFS presence at 2,500 BP in Mendocino.

On the Oregon coast, as deduced by Lyman (1991) from contextual dates, NFS persisted into historic times. Lyman (1991; 2003) also has found evidence for breeding colonies of Steller sea lions in the same period. Our study has not dated materials from the Olympic Peninsula, but Etnier (2002) has demonstrated that NFS persisted into historic times as a major subsistence base at Ozette and nearby sites. Likewise, in dated sites in British Columbia and Alaska, some sites testify to the accessibility of NFS to aboriginal populations into historic times.

Questions 2 and 3: Stable Isotopes and NFS Foraging Patterns

We have exploited naturally occurring gradients in stable isotope values in marine ecosystems as natural labels to study foraging and migratory patterns in Holocene pinnipeds. Studies of modern marine plants have shown that carbon isotope ($\delta^{13}\text{C}$) values are higher in productive nearshore waters (especially upwelling zones) than in offshore waters, and that values are higher in mid-latitude than in high-latitude ecosystems (Goericke and Fry 1994; Clementz and Koch 2001; Rau *et al.* 2001). Nitrogen isotope ($\delta^{15}\text{N}$) values in marine plants are also higher in mid-latitude than in high-latitude ecosystems, but they do not show conspicuous onshore-offshore differences (Saino and Hattori 1987; Altabet *et al.* 1999; Kienast *et al.* 2002). Nearshore $\delta^{13}\text{C}$ enrichment has several possible causes, including low CO_2 during algal blooms, growth rate and substrate effects on isotope fractionation, and the size and kind of nearshore algae (Goericke and Fry 1994; Bidigare *et al.* 1997; Pancost *et al.* 1997; Rau *et al.* 2001). Meridional differences in $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ probably reflect isotopic differences in the sources of nitrogen and carbon available to marine plants in different regions, in part due to differences in the vertical stratification of the water column (Goericke and Fry 1994; Altabet *et al.* 1999; Kienast *et al.* 2002).

Isotopic differences cascade up food webs to top consumers like pinnipeds (Hobson *et al.* 1994, Michner

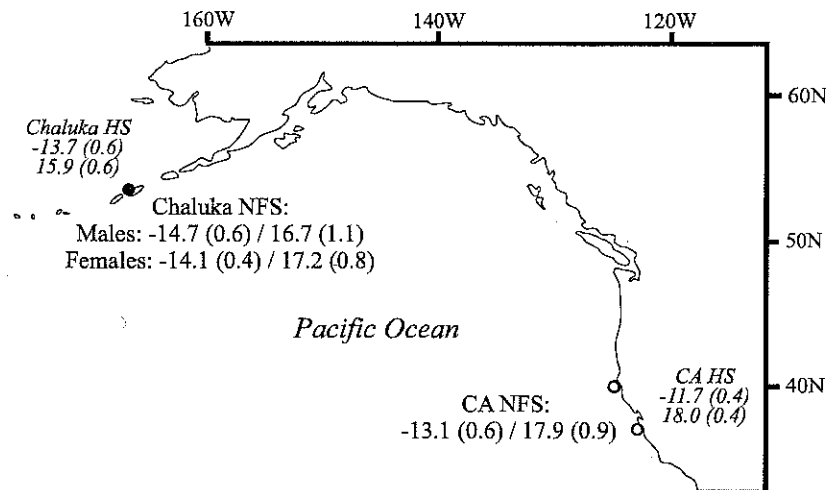


Figure 4. Bone collagen $\delta^{13}\text{C}/\delta^{15}\text{N}$ values ($\pm 1s$) of Holocene pinnipeds. Harbor seal (HS) data record gradients in nearshore ecosystems. NFS are grouped into Chaluka (l) and California populations (m) based on significant differences in $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values (ANOVA, $p < 0.005$). Locality level $1s$ is ± 0.5 and ± 0.8 for C and N respectively.

and Schell 1994), albeit with carbon and nitrogen fractionations of approximately 1 and 3‰, respectively, for each trophic step (Kelly 2000). Burton and Koch (1999) showed that bone collagen $\delta^{13}\text{C}$ values in modern nearshore feeders (e.g., harbor seals) were $\sim 2\%$ higher than those from offshore feeders (e.g., female northern elephant seals and northern fur seals) in waters off California. They detected the same onshore-offshore difference at high latitudes between Alaskan harbor seals and male NFS from the Pribilof rookery. Yet as expected, in both onshore and offshore ecosystems, $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values were 1–2‰ lower in high-latitude pinnipeds than in their middle-latitude counterparts. They argued that these patterns in seals were mainly driven by isotopic differences at the base of food webs, not by local differences in prey type or trophic level.

Burton *et al.* (2001, 2002) used this isotopic approach to explore the ecology of Holocene NFS from California, focusing on animals from CA-MNT-234 in Monterey Bay and on a small sample of individuals from Duncan's Point Cave, in Mendocino County (CA-MEN-828). Their strategy was to compare isotope values in Holocene NFS to harbor seals from the same sites to determine if NFS were foraging close to shore, like harbor seals, or offshore, as NFS do today. To determine whether Holocene NFS were year-round residents in middle latitudes or seasonal immigrants from northern latitudes, they compared values in Holocene NFS to those from modern Alaskan northern fur seals, after adjusting values for temporal isotopic shifts that were most likely the product of modern fossil fuel burning. Here, we update the work presented by Burton *et al.* (2001, 2002) by including data from a Holocene site in Alaska, Chaluka on Umnak Island (Fig. 4).

Our current results support the conclusions of Burton *et al.* (2001, 2002). Holocene NFS in California have $\delta^{13}\text{C}$ values $\sim 2\%$ lower than co-occurring harbor seals, confirming that, as is the case today, NFS foraged offshore. In contrast, $\delta^{15}\text{N}$ values are similar between NFS and harbor seals, indicating that they fed on prey of similar trophic level. The north-south comparison is equally conclusive. NFS at both California localities have $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values that are at least 1.0–1.5‰ higher than their conspecifics in Alaska. Interestingly, females from Chaluka have higher isotope values, more similar to those of California northern fur seals, whereas males have lower values. This pattern is not likely to reflect differences in the trophic level of prey between the sexes, because larger males would be expected to take larger, higher trophic level prey. This feeding pattern would lead to higher isotope values in males, which is opposite the pattern that we detected. A more likely explanation is that females at Chaluka may have been migratory, spending part of the year to the south foraging in food webs with higher $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values, as is the case for female NFS from the modern Pribilof rookery. Significant differences in $\delta^{13}\text{C}$ values ($P < 0.05$) between males (-14.7 ± 0.6) and females (-14.1 ± 0.4) from Chaluka support this explanation. Despite this suggestion of southward migration in females from Alaska, they still have isotope values that are distinct from those of California northern fur seals, which to date include only females and immature males. We conclude that the NFS at these California sites were not seasonal immigrants from high latitude rookeries; instead, they were animals that foraged offshore at middle latitudes throughout the year.

Question 4: Environmental Context of Northern Fur Seals

While most archaeologists have favored human extirpation of NFS as the cause of their disappearance from middens along the California and Oregon coasts, we have begun by not excluding *a priori* the possible effects of climatic forcing. This factor is especially pertinent because the disappearance of *Callorhinus* from central Californian sites appears to coincide with the Medieval Climatic anomaly. This strong climatic perturbation has been seen as the cause of the collapse of regional aboriginal economies and hence might contribute, directly or indirectly, to the regional extinction of fur seals.

To assess the impact of environmental change as a contributor to the decline of middle latitude NFS populations, we have undertaken a study of isotopic variations in mollusk shells from archaeological middens. A large body of prior work has used $\delta^{18}\text{O}$ values in molluscan carbonate as a natural archive of sea surface temperature (SST) variations (Valentine and Meade 1960; Killingley and Berger 1979; Klein *et al.* 1997). These studies have employed either bulk shell samples (representing several years of growth) or intraskeletal growth transects (with each lamina representing days to weeks of growth). The $\delta^{18}\text{O}$ of shell carbonate is a function of the temperature and the $\delta^{18}\text{O}$ of the water in which it grows (Epstein *et al.* 1953; Mook and Vogel 1968). If the $\delta^{18}\text{O}$ value of ocean water is constant, lower $\delta^{18}\text{O}$ values in shells indicate higher temperatures.

Our work to date has focused on mussel shells (*Mytilus californianus*) from middens at Point Año Nuevo, a site of intense upwelling on the central California coast between Monterey Bay and San Francisco. Año Nuevo contains many archaeological sites spanning the middle to late Holocene (Hylkema 1991); we have been systematically dating these using AMS ^{14}C analysis. Our strategy has been to analyze at least 5 shells per midden to monitor within-site time averaging, and to also date associated charcoal, to provide an age estimate for the midden that does not require a marine reservoir correction. The relatively tight clustering of radiocarbon dates on mollusks from each site in the Año Nuevo series indicate the sites, many of them severely wind-deflated, each testify to only a relatively short span of time.

Our reconstructed paleo-SSTs are at the low end of the range expected for annually integrated surface waters at Año Nuevo, but we note that the fractionation relationship we used was not calibrated for this species. Reconstructed temperatures show a weak trend, with slightly lower values at ~2,300 BP, a higher average from 2,000 to 1,000 BP, and slightly lower values from 400 to 200 BP. Overall, however, there are no compelling changes in variability across this interval.

Our pilot research and prior work estimating SSTs from *M. californianus* $\delta^{18}\text{O}$ values highlight three problems that we will address in our future research.

First, no species-specific calibration exists for calculating SSTs from *M. californianus* $\delta^{18}\text{O}$ values. This lack may explain why our reconstructed SSTs are all somewhat lower than modern values. Second, within-midden variation in bulk $\delta^{18}\text{O}$ mussel values (and therefore reconstructed mean SSTs), while not high, is substantial relative to the small changes in mean SST through time. Source(s) of this variation have never been analyzed systematically but may reflect important paleoclimatic information, for example inter-annual variability (Jones and Kennett 1999). Third, the common assumption of an invariant seawater $\delta^{18}\text{O}$ value of 0‰ to calculate paleo-SSTs is often untenable (Klein *et al.*, 1996), particularly in coastal California where winter precipitation and runoff with $\delta^{18}\text{O}$ values of -3 to -10‰ can alter the $\delta^{18}\text{O}$ values of nearshore waters seasonally (Coplen and Kendall 2000).

We are currently attempting to address the first two problems through calibration studies of modern *M. californianus* and will address the latter problem through analysis of shell trace element ratios, which provide a monitor of sea water temperature that is less sensitive to salinity variations than $\delta^{18}\text{O}$ values. Indeed, by analyzing both $\delta^{18}\text{O}$ values and trace elements, our hope is to reconstruct both water temperature and salinity, with the latter serving as a monitor of precipitation and runoff on land.

The promise of this analysis is to create proxies for terrestrial climate, especially rainfall, that could shed light on effects of the MCA on terrestrial environments in central California. The greater Monterey Bay area has few terrestrial paleoenvironmental records, and those that exist, such as a sediment core in the Elkhorn Slough (West 1988), appear to document locally idiosyncratic conditions in the slough, which at times was coterminous with the mouth of the Salinas River, rather than general regional conditions (Jones and Waugh 1997). Therefore any proxy for freshwater runoff will be of great use to researchers in the region.

Ongoing Debate over Existence of Rookeries in California

In extracting NFS specimens for isotopic analysis from as-yet unanalyzed bone materials from CA-MNT-234, we encountered very small bones from young-of-the-year. These suggested to us animals that were under weaning age, and therefore derived from a rookery within range of Moss Landing. To determine whether NFS specimens in an archaeological site reflect offtake from a rookery, it is, however, first essential to age the remains of young-of-the-year specimens. If at least a proportion of the individuals in a sample are of ages younger than typical weaning age, the case of offtake from a breeding colony is strengthened. Two approaches to such aging are possible: analysis of incremental growth structures in the

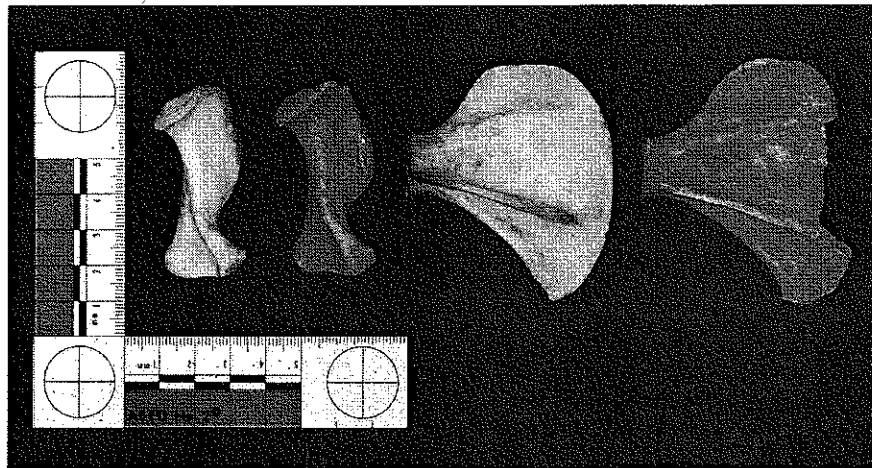


Figure 5. Photograph showing scapula and humerus of young-of-the-year *Callorhinus* from Moss Landing Marine Laboratory site (CA-MNT-234) compared to the same elements from a modern Pribilof individual of less than four months of age.

canines on the one hand, and osteometrically derived age estimates derived from a growth series based on known-age reference specimens. Lyman (1991) used size and state of epiphyseal fusion as a criterion for determining age-at-death of some very young NFS specimens from Oregon sites.

Because we had two mandibular canines but more edentulous mandibles, we opted for the osteometric course. In an attempt to refine Lyman's criteria for determining pre-weaning age, we undertook osteometric research on comparative specimens of known age at death, especially those of younger animals in museum collections in California and Washington (Burton *et al.* 2001, 2002). From these data, we constructed age and sex-specific growth curves, using dentary short length as the key measurement. Having established the dentary growth series from known-age-at-death specimens, we assessed dentary short lengths from a small sample of young-of-the-year in the Moss Landing archaeological collection. According to this analysis, the dentary short lengths of the Moss Landing archaeological specimens fall well within the range of animals in the first four months of life; in fact, they clustered around two to three months. We concluded, based on this fact, plus the distinctive isotopic signatures of the Moss Landing bones, that we were dealing with offtake from a regional rookery (Fig. 5).

More recently Etnier (2002) has argued that our age estimates may underestimate the ages of the pups in the Moss Landing sample. From his more extensive program of osteometrics and age-estimation on northern fur seals, Etnier raises two objections. First, our growth curves were derived from comparative specimens predominantly

from far north Pacific rookeries, where animals of all age classes might be larger because Bergmann's rule might apply. Moreover, Etnier contends that some comparative specimens were taken during times of low NFS population levels, when systematic study has demonstrated that individual NFS achieve greater adult size than during times of high population numbers. In either case, if archaeological specimens were from smaller or slower growing population, smaller individuals might be older than we estimated using the modern "northern" regression.

This is a valid point to raise, as are reservations about sample size in the original analysis. However, the Moss Landing specimens fell nearer to the two-month age point in the size series, rather than near the four-month cut-off, which implies a substantial difference in size would be necessary to cause such an error in estimates. Now that a fuller analysis of the many NFS specimens from Moss Landing is under way, we will be able to assess whether adult females at the site are significantly smaller than their conspecifics from the far north Pacific, and thereby ascertain whether we need to develop more realistic, locally-calibrated growth curves to age the immatures in the sample. Likewise, the sample of young-of-the-year is being substantially augmented in the present analysis, which should yield more definitive results (see Ongoing Research).

Other objections voiced to the existence of a nearby rookery stem from ecological parameters known for the species, are less specific, and will be dealt with in the Discussion below.

Ongoing Research

A second phase of research, just begun in 2003, attempts to specify even more closely the overall strategies of animal use before, during, and after the disappearance of fur seals from the central California coast. We have used several tactics to accomplish this goal. First, we are undertaking comprehensive zooarchaeological analyses of larger archaeofaunal samples in which NFS are abundant, those at the CA-MNT-234 (Moss Landing, California) site complex, to assess whether either the faunal component or other assemblage traits suggest resource intensification. Second, because NFS constitute at least 90% of several thousand bone specimens recovered from the Middle-Late Period midden deposit, the site offers the opportunity to use direct radiocarbon dating of specimens to ascertain a *terminus post quem* for their disappearance in the Monterey Bay. Third, the abundance of *Callorhinus* bones at MNT-234 will also permit us to assess whether these animals, like those from other parts of the California coast, exhibit distinctive local isotopic signatures or perhaps a diversity of signatures among adults. Finally, in collaboration with Michael Etnier, we intend to assess growth rates and achieved female size (male remains are rare and fragmentary), and to construct harvest profiles for the assemblages. As part of this effort, we are investigating collateral evidence for paleoenvironment at Elkhorn Slough/Moss Landing.

Separate projects by Koch, Newsome, and collaborators aim to use isotopic and a relative abundance time series from southern California, coastal Oregon, the U.S.-Canadian border (Vancouver Island, Olympic Peninsula), and the eastern Aleutians (Umnak and Unalaska Islands) to address when modern migratory and foraging ecology emerged among Pacific coast otariids. Other questions to be explored through dental annular growth analysis and isotopic microsampling include whether NFS age at weaning, a key attribute of its reproductive ecology, varies in temporally and geographically. We will continue to ask if observed changes in pinniped range, relative abundance, migration, and breeding correlate with, and thus could be seen as a response either to oceanographic change, to exploitation by human hunters, or to some combination of these or other factors.

Discussion

Our initial research focused on putting the disappearance of NFS into a more closely controlled temporal and marine environmental framework, using multiple, independent lines of evidence to contextualize the geographic and temporal occurrence and disappearance of the species along the coast of the north Pacific. Our direct radiocarbon dating program has established that, along the central coast of California, NFS did disappear by the

beginning of the first millennium BP, although we await further dating of individuals from the large assemblage of *Callorhinus* from Moss Landing (CA-MNT-234) to establish the dates of disappearance from the Monterey Bay region more definitively.

Bone geochemistry has offered a novel range of insights into the foraging behaviors (nearshore/offshore and latitudinal) and has the potential to characterize local foraging populations of northern fur seals. Comparison of the Moss Landing NFS female isotopic "signatures" with those from females from the historic South Farallon rookery (Pyle et al. 2002) – as yet not undertaken – as well as those from San Miguel Island might indicate whether the Monterey Bay *Callorhinus* are part of a metapopulation including all these samples or whether they display regionally distinct modal assays.

At present, we are still in the process of using multiple lines of evidence to establish the presence or absence of rookeries proximate to central and northern California archaeological sites. This is still an open question, and we believe that the most productive way of arriving at more definitive answers is to stipulate data relevant to the question, to frame alternative hypotheses that implicate these data, and to submit the hypotheses to the test of those data. The current state of the debate includes objections raised informally by marine mammal biologists working with modern NFS populations.

Because there are no islands or isolated rocks close to the Moss Landing Site, the Farallons being the closest islands, we raised the possibility of a mainland-based NFS rookery somewhere in the vicinity of the site. Although no systematic refutations of this inference have been published, it was met with informal expressions of skepticism from marine mammal biologists. The main objection is that, nowhere in the contemporary range of NFS does the species establish rookeries on the mainland. Behind this objection is the reasoning that the species has evolved to select islands and rock stacks for its rookeries, thereby avoiding predation by large non-human carnivores.

In the interest of brevity, we will simply note that "mainland" need not imply readily accessible. The north coast of Monterey Bay is bounded by tall cliffs with intermittent coves and estuaries. Some modern coves are accessible only at low tide, while others are accessible only by boat or by artificial stairways cut into cliff faces. Such protected beaches would have presented grave impediments to access by native grizzly bears or pumas, but not to human hunters using ropes or simple watercraft. At 5,000–3,000 BP, the high stabilized sand dune containing the Moss Landing site stood in the middle of the mouth of the Salinas River, which today debouches several kilometres to the south but which is known from pollen and sedimentary evidence to have flowed through the mouth of Elkhorn Slough over that timespan (Jones and Waugh 1997). Under such a fluvial regime, the barrier dunes to the west of the site could have been

accessible only by watercraft, even at low tide. Our next round of dating is aimed at ascertaining whether the preponderance of NFS specimens coincide in time with the span when the Salinas River debouched at Elkhorn Slough.

Another objection informally raised was the probable intolerance of NFS to air temperatures along the central California coast. However, there exist localities, such as Point Año Nuevo, where pinnipeds have thrived historically. Año Nuevo is favored with brisk onshore winds during most of the year, allowing Steller sea lions and northern elephant seals, each with much greater body mass than *Callorhinus*, to haul-out and, in the case of the latter, to breed. The deep submarine canyon west of Moss Landing today conditions a locally distinctive fog zone around Elkhorn Slough, especially in the summer to early fall, when NFS are on their rookeries in other parts of their range, with mid-day temperature around 14–15 degrees Celsius. Air temperatures and insolation are consistently affected, in contrast to areas only a few kilometers north or south along the coast. Whether this temperature range falls within that tolerated by NFS at San Miguel Island, and whether a climatic regime similar to that observed today would have obtained in the time-span the NFS bones accumulated at Moss Landing, are empirical questions that can be answered through further research.

One topic not dealt with in any detail since Lyman's (1989, 1991) and Hildebrandt's (1984: 1992) original work, is precisely how the NFS were procured by humans. Aspects of acquisition would ultimately affect the age-sex profile of archaeofaunal materials. Historic records of aboriginal and even European sealing focus on the clubbing of vulnerable animals on their rookeries or haul outs. A focus on subadult males and adult males unable to defend territories that haul-out together in pods, as seen among modern subsistence harvesters on the Pribilofs, will produce a male-dominated sample. Cropping from a rookery will yield mainly females and their young-of-the-year, with perhaps an occasional adult male. By contrast, under the "pinniped driftwood" hypothesis, recently dead or moribund animals would wash up on beaches and be dispatched. Etnier (2002) argues that this is not a random sample of the population as a whole, since young-of-the-year and juveniles appear to be more at risk of stranding. If migration and foraging patterns for *Callorhinus* remained the same in times past, we would expect few if any adult males to strand south of Washington State. In some cases, where more intentional acquisition of specific age-sex classes by hunting is thought to have been the case, as at Ozette (Etnier 2002), no opinions were offered on whether and how NFS were intercepted at sea while migrating or were taken on land. Historic Makah Indians had ocean-going canoes capable of whaling, so pelagic predation cannot be excluded. In sum, this is another area of research that would repay closer attention to the age/sex profiles and perhaps even

element frequencies that would be expected with different acquisition tactics.

Finally, with regard to existing archaeological scenarios for the extirpation of regional populations of northern fur seals, it is not clear that behavioral ecological theory predicts a "tragedy of the commons" (cf. Hildebrandt and Jones 1992; Jones and Hildebrandt 1995) outcome for pinniped haul-outs or rookeries. Pinniped breeding colonies are rich, localized patches of animal protein, fat, and useful hides and are highly predictable in time and space. They are thus a resource that repays investment in territorial defense (Krebs and Davies 1993, 110–113). The resource thus would not be a common good but one defended by a smaller subset of the regional population. Given the realities of defending an attractive resource, one would expect the "owners" to use a mix of strategies, including aggregation in considerable numbers near the source, and, because we are dealing with human beings, tactics aimed at mitigating perceptions of deprivation on the part of others. Exchange of selected pinniped products, as hypothesized for emergent Channel Island elites (Arnold 1992a; 1992b), would be one means of maintaining control over a resource while defusing others' motivations to attempt to seize it. We would therefore predict that, if further research establishes NFS rookeries indeed existed along central and northern California's Pacific coast, there would be differentially large village sites with evidence for substantial exchange relations nearby.

Conclusion

Radiocarbon dates directly on their bones indicate that NFS disappeared from central California well before the arrival of Europeans, perhaps as much as 1,000 years ago. However, other populations of *Callorhinus* survived to be cropped up until historic contact farther north, most notably on the Olympic Peninsula of Washington State, where they were sustainably cropped by sedentary hunter-gatherers until the advent of the European fur trade.

Stable isotope analyses of archaeological bones of NFS along the Pacific coast suggest that females did not migrate to, and forage in, the far north Pacific. Mollusk shell $\delta^{18}\text{O}$ assays from the Point Año Nuevo site time series suggest no changes in sea surface temperatures over the time that *Callorhinus* disappears from local site inventories. However, we are treating these data with caution until advancing further research on the meaning of small differences in $\delta^{18}\text{O}$ values in our study samples.

Ongoing research is now broadening in several directions: (1) charting the paleobiogeography, life history parameters, and population dynamics of NSF around the northeastern Pacific, from Alaska to central California; (2) developing and refining means for measuring terrestrial freshwater runoff rates over the Holocene, with special attention to the Medieval Climatic Anomaly; (3)

broadening zooarchaeological analyses to include other species and assessing changes, if any, in resource use over the timespans when NFS were present and those when they disappeared from site archaeofaunas in different parts of the region.

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Bibliography

- Altabet, M. A., Pilska, C., Thunell, R., and Pride, C. (1999) The nitrogen isotope biogeochemistry of sinking particles from the margin of the Eastern North Pacific. *Deep-Sea Research Part I* 46, 655-679.
- Anderson, P. K. (1995) Competition, predation, and the evolution and extinction of Steller's sea cow, *Hydrodamalis gigas*. *Marine Mammal Science* 11, 391-394.
- Arnold, J. (1992) Cultural disruption and the political economy in Channel Islands prehistory. In Jones, T. L. (ed.) *Essays on the Prehistory of Maritime California*, 129-144. vol. No. 10. Davis, University of California Center for Archaeological Research.
- Bartholomew, G. A. J. (1953) Behavioral factors affecting social structure in the Alaska fur seal. In Tretethen, J. B. (ed.) *Transactions of the Eighteenth North American Wildlife Conference*, 481-502. Washington, D.C., Wildlife Management Institute.
- Bigdare, R. R., Fluegge, A., Freeman, K. H., Hanson, K. L., Hayes, J. M., Hollander, D., Jasper, J. P., King, L. L., Laws, E. A., Milder, E. A., Millero, F. J., Pancost, R., Popp, B. N., Steinberg, P. A. and Wakeham, S. G. (1997) Consistent fractionation of ^{13}C in nature and in the laboratory: growth-rate effects in some haptophyte algae. *Global Biochemical Cycles* 11, 279-292.
- Boyd, I., editor (1993) *Marine Mammals: Advances in Behavioral and Population Biology*. London, Oxford University Press.
- Breschini, G. S. and Haversat, T. (1995) *Archaeological Evaluation of CA-MNT-234 at the Site of the Proposed Moss Landing Marine Laboratory, Moss Landing, Monterey County, California*. Report submitted to ABA Consultants.
- Burton, R. K., Gifford-Gonzalez, D., Snodgrass, J. J., and Koch, P. L. (2002) Isotopic tracking of prehistoric pinniped foraging and distribution along the central California coast: preliminary results. *International Journal of Osteoarchaeology* 12, 4-11.
- Burton, R. K. and Koch, P. L. (1999) Isotopic tracking of foraging and long-distance migration in northeastern Pacific pinnipeds. *Oecologia* 119(4), 578-585.
- Burton, R. K., Snodgrass, J. J., Gifford-Gonzalez, D., Guilderson, T., Brown, T., and Koch, P. L. (2001) Holocene changes in the ecology of northern fur seals: insights from stable isotopes and archaeofauna. *Oecologia* 128(1), 107-115.
- Busch, B. C. (1985) *The War against the Seals: A History of the North American Seal Fishery*. Kingston, McGill-Queen's.
- Calvert, S. G. C. (1980) *A Cultural Analysis of Faunal Remains from Three archaeological Sites in Hesquiat Harbour*. Vancouver, University of British Columbia.
- Carlson, Catherine C. (2003) The Bear Cove fauna and the subsistence history of the Northwest Coast maritime culture. In Carlson, R. L. (ed.) *Archaeology of Coastal British Columbia: Essays in Honour of Professor Philip M. Hobler*. 65-86. Burnaby BC, Archaeology Press, Simon Fraser University.
- Clark, D. W. (1986) Archaeological and historic evidence for an 18th-century "blip" in the distribution of northern fur seal at Kodiak Island, Alaska. *Arctic* 39(1), 39-42.
- Clementz, M. T. and Koch, P. L. (2001) Differentiating aquatic mammal habitat and foraging ecology with stable isotopes in tooth enamel. *Oecologia* 129, 461-472.
- Coates, D. C. and Eldridge, M. (1992) *Banfield Highways Aguilar Point Road Allowance Impact Assessment (Aguilar Inn Site DfSg-2)*. Unpublished report, Permit 1992-67. Victoria, BC, Archaeology and Outdoor Recreation Branch.
- Colten, R. H. (2002) Prehistoric marine mammal hunting in context: two western North American examples. *International Journal of Osteoarchaeology* 12, 12-22.
- Colten, R. H. and Arnold, J. E. (1998) Prehistoric marine mammal hunting on California's northern Channel Islands. *American Antiquity* 63, 679-701.
- Coplen, T. B. and Kendall, C. (2000) Stable hydrogen and oxygen isotope ratios for selected sites of the U.S. Geological Survey's NASQAN and Benchmark stable surface-water networks. *U.S. Geological Survey Open-File Report* 00160, <<http://water.usgs.gov/pubs/of/00160/>>
- Crockford, S., Frederick, G. and Wigen, R. (2002) The Cape Flattery fur seal: An extinct species of Callorhinus in the eastern north Pacific? *Canadian Journal of Archaeology* 26(3), 152-174.
- Dewhurst, John (1980) *The Indigenous Archaeology of Yuquot, a Nootkan Outside Village*. Ottawa, National Historic Parks and Sites Branch, Parks Canada.
- Dietz, S. A. and Jackson, T. L. (1981) *Final Report of Archaeological Excavations at Nineteen Archaeological Sites for the Stage 1 Pacific Grove-Monterey Consolidation Project of the Regional Sewerage System*. Santa Cruz, Report submitted to Engineering-Science Inc.

- Eldridge, M. and Fisher, T. (1997) *Archaeological Data Recovery from Wet-site Components at the Dididaht Sites of Wikpalhuus (295T, DeSf-9) and Hit'ihia7sak (296T, DeSf-10), Nitinat Lake, B.C.* Victoria, B.C., Archaeology and Outdoor Recreation Branch.
- Epstein, S., Buchsbaum, R., Lowenstam, H. A. and Urey, H. C. (1953) Revised carbonate-water isotopic temperature scale. *Geological Society of America Bulletin* 64, 1315–1326.
- Erlandson, J. M. (1984) A case study in faunalurbation: delineating the effects of the burrowing pocket gopher on the distribution of archaeological materials. *American Antiquity* 49, 785–790.
- Etnier, M. (2002) *The Effects of Human Hunting on Northern Fur Seal (Callorhinus ursinus) Migration And Breeding Distributions in The Late Holocene*. Seattle, Ph.D. dissertation, University of Washington.
- Fiscus, C. H. and Baines, G. A. (1966) Food and feeding behavior of Steller and California sea lions. *Journal of Mammalogy* 47(2), 195–200.
- Fleischer, L. A. (1987) Guadalupe fur seal, *Arctocephalus townsendi*. In Croxall, J. P. and Gentry, R. L. (eds) *Status, Biology, and Ecology of Fur Seals*. Washington, D.C., National Marine Fisheries Service.
- Friedman, E. (1976) *An Archaeological Survey of Makah Territory: A Study of Resource Utilization*. Ph.D. Dissertation, Pullman, Washington State University.
- Gentry, R. L. (1998) *Behavior and Ecology of the Northern Fur Seal*. Princeton, Princeton University Press.
- Gentry, R. L. and Kooyman, G. L. editors (1986) *Fur Seals – Maternal Strategies on Land and at Sea*. Princeton, Princeton University Press.
- Gifford, D. P. and Marshall, F. A. editors (1984) *Analysis of the Archaeological Assemblage From CA-SCR-35, Santa Cruz County, California*. Salinas, CA, Coyote Press.
- Gifford-Gonzalez, D. (1991) Bones are not enough: analogues, knowledge, and interpretive strategies in zooarchaeology. *Journal of Anthropological Archaeology* 10, 215–254.
- Goericke, R. and Fry, B. (1994) Variations of marine plankton $\delta^{13}\text{C}$ with latitude, temperature, and dissolved CO_2 in the world ocean. *Global Biogeochemical Cycles* 8, 85–90.
- Greenspan, R. L. (1986) Aboriginal exploitation of vertebrate fauna. In Minor, R. and Toepel, K. A. (eds) *The Archaeology of the Tahkenüch Landing Site: Early Prehistoric Occupation on the Oregon Coast*. vol. 46. 57–72. Eugene, OR, Heritage Research Associates Report.
- Gustafson, C. E. (1968) Prehistoric use of fur seals: evidence from the Olympic coast of Washington. *Science* 161, 49–51.
- Hall, E. R. (1940) Pribilof fur seal on California coast. *California Fish and Game* 26, 76–77.
- Hall, R., L. Lindsay and Vogel, B. (1990) Southern Oregon prehistory: excavations at 34CS43, Bandon, Oregon. *Pacific Coast Archaeological Quarterly* 26(1), 60–79.
- Hester, J. J. and Nelson, S. M. (1978) *Studies in Bella Bella Prehistory* 5. Burnaby, BC, Department of Archaeology, Simon Fraser University.
- Hildebrandt, W. R. (1984) Archaeological presence of the northern fur seal (*Callorhinus ursinus*) along the coast of northern California. *The Murrelet* 65, 28–29.
- Hildebrandt, W. R. and Jones, T. L. (1992) Evolution of marine mammal hunting: a view from the California and Oregon coasts. *Journal of Anthropological Archaeology* 11, 360–401.
- Hobson, K. A., Piatt, J. F. and Pitocchelli, J. (1994) Using stable isotopes to determine seabird trophic relationships. *Journal of Animal Ecology* 63, 786–798.
- Hobson, K. A., Sease, J. L., Merrick, R. L. and Piatt, J. F. (1997) Investigating trophic relationships of pinnipeds in Alaska and Washington using stable isotope ratios of nitrogen and carbon. *Marine Mammal Science* 13, 114–132.
- Hubbs, C. L. (1956) The Guadalupe fur seal still lives. *San Diego Zoological Society* 29, 6–9.
- Hylkema, M. G. (1991) *Prehistoric Native American Adaptations along the Central California Coast of San Mateo and Santa Cruz Counties*. San Jose, M.A. thesis, San Jose State University.
- Jones, T. L., Brown, G. M., Raab, M., McVickar, J. L., Spaulding, W. G., Kennett, D. J., York, A., and Walker P. L. (1999) Environmental imperatives reconsidered. Demographic crises in western North America during the Medieval Climatic Anomaly. *Current Anthropology* 40(2), 137–170.
- Jones, T. L. and Hildebrandt, W. R. (1995) Reasserting a prehistoric tragedy of the commons: reply to Lyman. *Journal of Anthropological Archaeology* 14, 78–98.
- Jones, T. L. and Kennett, D. J. (1999) Late Holocene sea temperatures along the central California coast. *Quaternary Research* 51, 74–82.
- Jones, T. L. and Waugh, G. (1997) Climatic consequences or population pragmatism? A Middle Holocene prehistory of the central California coast. In Erlandson, J. and Glassow, M. (eds) *Archaeology of California Coast During the Middle Holocene*, 111–128. Perspectives in California Archaeology. vol. 4. Los Angeles, University of California, Los Angeles Institute of Archaeology.
- Jones, T. L., Van Buren, T., Grantham, S., Huddleson J., and Fung, T. (1992) *Phase II Archaeological Investigations for the Castroville Bypass Project, Monterey County, California*. Report submitted to California Department of Transportation, Sacramento, California.
- Kelly, J. F. (2000) Stable isotopes of carbon and nitrogen in the study of avian and mammalian trophic ecology. *Canadian Journal of Zoology* 78(1), 1–27.
- Kienast, S. S., Calvert, S. E., and Pederson T. F. (2002) Nitrogen isotope and productivity variations along the northeast Pacific margin over the last 120 kyr: surface and subsurface paleoceanography. *Paleoceanography* 17(1055), 7–1–7–17.
- Killingley, J. S. and Berger, W. H. (1979) Stable isotopes in a mollusk shell: detection of upwelling events. *Science* 205, 186–188.
- Klein, R. G. and Cruz-Urbe, K. (1996) Exploitation of large bovids and seals at Middle and Later Stone Age sites in South Africa. *Journal of Human Evolution* 31, 315–334.
- Klein, R. T., Lohmann, K. C., and Kennedy, G. L. (1997) Elemental and isotopic proxies of paleotemperature and paleosalinity: climate reconstruction of the marginal Pacific ca. 80 ka. *Geology* 25, 363–366.
- Knecht, R. and Davis, R. A. (2001) A prehistoric sequence for the eastern Aleutians. In D. Dumond (ed.) *Archaeology in the Aleut Zone of Alaska*. Eugene, University of Oregon Press.
- LeBoeuf, B. J. and Mate, B. R. (1978) Elephant seals colonize additional Mexican and Californian islands. *Journal of Mammalogy* 59(3), 621–622.
- Lippold, L. K. (1966) Chalukal: the economic base. *Arctic Anthropology* 3(2), 125–131.
- Loughlin, T. R., Rugh, D. J., and Fiscus, C. H. (1984) Northern sea lion distribution and abundance: 1956–1980. *Journal of Wildlife Management* 48, 729–740.
- Lowry, M. S., et al. (1992) Status of the California sea lion (*Zalophus californianus californianus*) population in 1992. *Southwest Fisheries Science Center Administrative Report* LJ-92–32, 34.
- Lyman, R. L. (1989) Seal and sea lion hunting: a zooarchaeological study from the southern Northwest Coast of North America. *Journal of Anthropological Archaeology* 8, 68–99.
- Lyman, R. L. (1991) *Prehistory of the Oregon Coast*. Orlando, Academic Press.
- Lyman, R. L. (1994) *Vertebrate Taphonomy*. Cambridge, Cambridge University Press.
- Lyman, R. L. (1995) On the evolution of marine mammal hunting

- on the west coast of North America. *Journal of Anthropological Archaeology* 14, 45–77.
- Lynan, R. L. (2003) Pinniped behavior, foraging theory, and the depression of metapopulations and nondepression of a local population in the southern Northwest Coast of North America. *Journal of Anthropological Archaeology* 22(4): 376–388.
- Lyon, G. (1937) *Finnipeds and a Sea Otter from the Point Mugu Shell Mound of California*. Publications of the University of California at Los Angeles in Biological Sciences 1(8), 133–168.
- McMillan, A. D. (1999) *Since the Time of the Transformers: The Ancient Heritage of the Nuw-chah-nulth, Ditidaht, and Makah*. Vancouver, Pacific Rim Archaeology Series, UBC Press.
- McMillan, A. D. (2003) The early component at Ts'ishaa, an outer coast site on western Vancouver Island. In R. L. Carlson (ed.) *Archaeology of Coastal British Columbia: Essays in Honour of Professor Philip M. Hobbler*. Burnaby, BC, Archaeology Press.
- McMillan, A. D. and St. Claire, D. E. (eds) (2003) *Ts'ishaa: Archaeology and Ethnography of a Nuw-chah-nulth Origin Site in Barkley Sound. (Report of the Tseshaht Archaeological Project, 1999 to 2001)*. Report submitted to: Tseshaht First Nation (Port Alberni), Parks Canada (Victoria & Calgary), Pacific Rim National Park Reserve (Ucluelet), British Columbia Heritage Trust (Victoria).
- Melin, S. R. and DeLong, R. L. (2000) Population monitoring studies of northern fur seals at San Miguel Island, California. In Sinclair, E. H. (ed.) *Fur Seal Investigations, 1998*, 87–102. Seattle, NOAA.
- Michner, R. H. and Schell, D. M. (1994) Stable isotope ratios as tracers in marine aquatic food webs. In Lajtha, K. and Michener, R. H. (eds) *Stable Isotopes in Ecology and Environmental Science*, 138–157. Boston, Blackwell Scientific Publications.
- Milliken, R., Nelson, J., Hildebrandt, W. R., and Mikkelsen, P. (1999) *The Moss Landing Hill Site. A Technical Report on Archaeological Studies at CA-MNT-234*. Report submitted to the California State University System and Federal Emergency Management Agency, Davis, CA, Far Western Anthropological Research Group, Inc.
- Mook, W. G. and Vogel, J. C. (1968) Isotopic equilibrium between shells and their environment. *Science* 159, 874–875.
- National Marine Mammal Laboratory (2003) *Marine Mammal Stock Assessment Reports*. Seattle, National Oceanographic and Atmospheric Administration.
- National Research Council. (2003) *Decline of the Steller Sea Lion in Alaskan Water – Untangling Food Webs and Fishing Nets*. Washington, D.C., National Research Council.
- Orr, R. T. (1972) *Marine Mammals of California*. Berkeley, University of California Press.
- Orr, R. T. and Poulter, T. C. (1965) The pinniped population of Año Nuevo Island, California. *Proceedings of the California Academy of Sciences* 32(13), 377–404.
- Pancost, R. D., Freeman, K. H., Wakeham, S. G., and Robertson, C. Y. (1997) Controls on carbon isotope fractionation by diatoms in the Peru upwelling region. *Geochimica et Cosmochimica Acta* 61, 4983–4991.
- Peterson, R. S. and Bartholomew, G. A. J. (1967) Natural history and behavior of the California sea lion. *American Society of Mammalogists Special Publication* 1.
- Peterson, R. S., LeBoeuf, B. J. and DeLong, R. L. (1968) Fur seals from the Bering Sea breeding in California. *Nature* 219, 899–901.
- Pomeroy, J. A. (1980) *Bella Bella Settlement and Subsistence*. Burnaby, B.C., Unpublished PhD dissertation, Department of Archaeology, Simon Fraser University.
- Porcasi, J. F., Jones, T. L. and Raab, L. M. (2000) Trans-Holocene marine mammal exploration on San Clemente Island, California: a tragedy of the commons revisited. *Journal of Anthropological Archaeology* 19(200–220).
- Pyle, P., Long, D. J., Schonewald, J., Jones, R. E., and Roletto, J. (2001) Historical and recent colonization of the South Farallon Islands, California by Northern Fur Seals (*Callorhinus ursinus*). *Marine Mammal Science* 17(2), 297–402.
- Rau, G. H., Chavez, F. P., and Friederich, G. E. (2001) Plankton 13C/12C variations in Monterey Bay, California: Evidence of non-diffusive inorganic carbon uptake by phytoplankton in an upwelling environment. *Deep-Sea Research Part I Oceanographic Research Papers* 48(1), 79–94.
- Renouf, D. editor (1991) *Behavior of Pinnipeds*. New York, Chapman & Hall.
- Riedman, M. (1990) *The Pinnipeds – Seals, Sea Lions, and Walruses*. Berkeley, CA, University of California Press.
- Rick, A. M. (1980) Identification of and biological notes on selected bone and tooth artifacts from Yuquot, British Columbia. In Folan, W. J. and Dewhurst, J. (ed.) *The Yuquot Project* vol. 2. Ottawa, National Historic Parks and Sites Branch, History and Archaeology.
- Ridgway, S. H. and Harrison, R. J., (eds) (1981) *Handbook of Marine Mammals*. I. Academic Press, London.
- Saino, T. and Hattori, A. (1987) Geographical variation of the water column distribution of suspended particulate organic nitrogen and its 15N natural abundance in the Pacific and its marginal seas. *Deep-Sea Research* 34, 807–827.
- Smith, I. W. G. (1989) Maori impact on the marine megafauna: pre-European distributions of New Zealand sea mammals. *New Zealand Archaeological Association Monograph* 17, 76–108.
- Snyder, S. L. (1978) Osteo-Archaeological Investigation of Pinniped Remains at Seal Rock, Oregon State University.
- Stewart, F. L. and Stewart, K. M. (1996) The Boardwalk and Grassy Bay Sites: patterns of seasonality and subsistence on the northern Northwest Coast, B.C. *Canadian Journal of Archaeology* 20, 36–60.
- Stewart, B. S., Yochem, P. K., DeLong, R. L., and Antonelis, G. A. (1987) Interactions between Guadalupe fur seals and California sea lions on San Nicholas and San Miguel Islands. In Croxall, J. P. and Gentry, R. L. (ed.) *Status, Biology, and Ecology of Fur Seals*. Washington, D.C., National Marine Fisheries Service.
- Swan, J. G. (1887) The fur seal industry of Cape Flattery, Washington Territory. In Goode, G. B. (ed.) *Fisheries and Fishery Industries of the United States*, 393–400. vol. 7, 8. Washington, D.C., U. S. Government Printing Office.
- Townsend, C. H. (1931) The fur seal of the California islands with new descriptive and historical matter. *Zoologica* 9, 443–457.
- Valentine, J. W. and Meade, R. F. (1960) Isotopic and zoogeographic paleotemperatures of California Pleistocene Mollusca. *Science* 132, 810–811.
- Wake, T. A. and Simons, D. D. (2000) Trans-Holocene Subsistence Strategies and Topographic Change on the Northern California Coast: The Fauna from Duncans Point Cave. *Journal of California and Great Basin Anthropology* 22(2), 295–320.
- Walker, P. L., Kennett, D. J., Jones, T. L. and DeLong, R. (2000) Archaeological investigations of the Point Bennett pinniped rookery on San Miguel Island. In D. R. Brown, K. C. Mitchell and H. W. Chaney (eds) *The Fifth California Islands Symposium*, 628–63. U.S. Department of the Interior Minerals Management Service, Pacific OCS Region.
- Wedgforth, H. M. (1928) The Guadalupe fur seal (*Arctocephalus townsendi*). *San Diego Zoological Society* 3, 4–9.
- West, G. J. (1988) Exploratory pollen analysis of sediments from Elkhorn Slough. In S. A. Dietz, W. R. Hildebrandt, and T. L. Jones (eds) *Archaeological Investigations at Elkhorn Slough, CA-MNT-229, A Middle Period Site on the California Coast*, 25–56. Berkeley, Papers in Northern California Anthropology No. 3, University of California, Berkeley.
- Yesner, D. R. (1977) *Prehistoric Subsistence and Settlement in the*

Aleutian Islands. Doctoral dissertation, Storrs, University of Connecticut.

Yesner, D. R. (1988) Effects of prehistoric human exploitation on Aleutian sea mammal populations. *Arctic Anthropology* 25(1), 28–43.

York, A. E., Merrick, R. L. and Loughlin, T. R. (1996) An analysis of the Steller sea lion metapopulation in Alaska. In McCullough, D. R. (ed.) *Metapopulations and Wildlife Populations*, 59–292. Covelo, CA, Island Press.

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