

Chapter 7: Discussion and Conclusions

The research presented here has been designed to test a series of hypotheses proposed to explain discrepancies between historically-documented patterns of fur seal biogeography and the archaeological evidence of such patterns (Burton 2000; Burton and Koch 1999; Burton *et al.* 2002; Gustafson 1968; Hildebrandt 1984a; Hildebrandt and Jones 1992; Lyman 1988, 1989, 1991b, 1995; Lyon 1937; Walker and Craig 1979). These discrepancies indicate major changes in fur seal biogeography sometime during the late Holocene. Determining the extent, the timing, and the cause (or causes) of these discrepancies is directly relevant to a wide variety of archaeological and zoological studies that involve fur seal distributions during the late Holocene.

Three competing hypotheses have been forwarded to explain the cause/s of the late Holocene biogeographic changes:

1. the “historic effects” hypothesis: prehistoric hunting pressure had no effect on fur seal breeding and migration patterns, with all biogeographic changes a consequence of the commercial Russian fur trade
2. the “prehistoric effects” hypothesis: prehistoric hunting pressure had a significant effect on fur seal breeding and migration patterns, with all biogeographic changes predating the commercial Russian fur trade, and
3. the “continuous effects” hypothesis: both prehistoric and commercial hunting combined to cause changes in fur seal breeding and migration patterns

Because the full extent to which fur seal biogeographic patterns changed in the late Holocene had not been documented, the first step in the research presented here required the development of variables with which to measure the age composition of fur seals being exploited, with particular emphasis on identifying the breeding distribution of fur seals. To do this, known-age reference skeletons were measured and growth curves calculated for a wide range of skeletal elements. The resulting demographic data generated from archaeological fur seal skeletal material clearly indicate that the breeding distribution of fur seals was much more widespread than historically documented, with evidence of previously-unidentified rookeries in the vicinity of the Aleutian Islands or Alaska Peninsula, as well as on or near the Washington coast. Furthermore, when the stratigraphic information is taken into consideration, it appears that this breeding distribution was stable until the early historic period (the late 18th or early 19th century). This corresponds closely with patterns documented along the coasts of Oregon (Lyman 1988, 1989, 1991b, 1995) and California (Pyle and Long 2001).

Despite the fact that the breeding distribution of fur seals appears to have been stable until the early historic period, population-level effects of harvest pressure may have pre-dated changes in fur seal biogeography. Therefore, it was also necessary to develop a variable to provide a proxy of relative population size. The specific variable chosen was individual growth rate, which scales inversely with population density (this study; Baker and Fowler 1990; Fowler 1990; Scheffer 1955). Using a combination of tooth sections and mandible measurements, growth curves generated for male fur seals from the Ozette assemblage indicate that after the first year of growth, these animals

tended to be smaller in any given age class than animals collected during the 20th century from the Pribilof Islands population. Although it cannot be determined if this size difference reflects a population level consistently at carrying capacity, or latitudinal differences in body size, the pattern is consistent throughout the Ozette sequence, suggesting once again that prehistoric hunting did not affect fur seal populations over the time period examined.

The three competing hypotheses presented here all focus on human hunting as the main causal mechanism in changes in fur seal biogeography in the late Holocene. Neither the “prehistoric effects” nor the “continuous effects” hypothesis has been supported by the archaeological data. However, before the “historic effects” hypothesis can be considered supported, I must also evaluate the potential role of climatic and/or oceanographic stressors in structuring the demographic patterns documented for fur seals recovered from Late Holocene archaeological sites in the eastern North Pacific.

Anticipated effects of climatic stressors

Climatic stressors can be expected to affect fur seals either directly or indirectly. Direct effects would act on short time scales (<1 year), and may be in the form of reduced survival, for instance through heat stress. Indirect effects would relate primarily to prey availability (e.g., fluctuations in carrying capacity). Indirect effects could operate on a wide range of time scales, from inter-annual to inter-centennial. The ability to detect the effects of specific climatic events will be highly variable given the relatively large temporal periods covered by the archaeological deposits analyzed here (= 50-75 years).

To further complicate matters, climatic events are not expected to have the same effects on high-latitude and mid-latitude fur seal populations (Trillmich and Ono 1991; Trillmich *et al.* 1991). This has been best documented for *El Niño*/Southern Oscillation (ENSO) events, which have resulted in periodic warming of sea surface temperatures (SSTs) along the west coast of North America every 5 to 20 years throughout the late Holocene (Baumgartner *et al.* 1989; Quinn *et al.* 1987; Wells 1987, 1990). The 1982-83 ENSO, for instance, was shown to significantly reduce survival of pups during their first three months on San Miguel Island, California (DeLong and Antonelis 1991). This decrease in pup survival has been attributed to decreased availability of prey for lactating females (DeLong *et al.* 1998; Trillmich and Ono 1991). In contrast, Gentry (1991) found no reduction in pup survival during the same event in the Pribilof Islands, Alaska, population.

Anne York (1991, 1995) has also demonstrated that the survival of juvenile male fur seals from the Pribilof Islands is positively correlated with SSTs, with juvenile males exhibiting higher survival rates during ENSO events. York (1995) suggests that a possible explanation for these differences is the differential response of fur seal prey species, such as herring (*Clupea pallasii*) to ENSOs. Specifically, York points out that herring stocks in Alaska, British Columbia, and Washington are high in years following ENSOs, while those in California tend to be reduced. Another explanation that has been proposed is that prey availability generally declines at mid-latitude as prey species move northward and/or deeper in the water column in response to warming SSTs (DeLong *et*

al. 1998), potentially affecting the foraging success of mid-latitude fur seal populations (Sydeman and Allen 1999).

Evaluating the role of climatic stressors

To evaluate the potential role of climatic stressors on fur seal populations in the late Holocene, the major climatic events known to have occurred during this period will be reviewed, with emphasis on the effects these events may have had on fur seal populations, and if those events correspond to any observable changes in fur seal demographics documented in Chapters 5 and 6.

Two short-term climatic phenomena are likely to have had significant impacts on fur seal populations in the late Holocene. The first of these, ENSO, has been discussed above. The 20th century record of ENSO events is plotted in Figure 7.1, along with the population histories of the fur seals in Alaska and California. The second climatic phenomenon likely to have impacted fur seal foraging, and therefore population levels, has been termed a “regime shift” (Ebbesmeyer *et al.* 1991; Francis and Hare 1994) or, more formally, the Pacific inter-Decadal Oscillation (PDO: Mantua *et al.* 1997).

The PDO is characterized by an abrupt shift, in either intensity or direction, in dozens of climate-related variables (many related to primary production) in the North Pacific Ocean and Bering Sea. PDOs act on an inter-decadal time scale, with the best documentation for a regime shift in 1977. However, it has been suggested that regime shifts may have also occurred in the North Pacific in 1925 and 1947 (Mantua *et al.* 1997; see Figure 7.1). Although neither the causal factors nor the time depth of the PDO are well-understood, the result is that fish stocks are strongly influenced by the PDO,

including salmon (*Oncorhynchus* spp.), Pacific hake (*Merluccius productus*), and Pacific herring (Francis and Hare 1994; Ware 1991; Mantua *et al.* 1997). All of these species have been documented in the fur seal diet (Antonelis *et al.* 1997; Kajimura 1984; Sinclair *et al.* 1994), suggesting that the PDO may also impact fur seal foraging success.

The two long-term climatic events that may have affected fur seal populations in the late Holocene are the “Medieval Warm Period” (MWP), which lasted from ca. AD 900-1350, and the “Little Ice Age” (LIA), which lasted from ca. AD 1350-1900 (Figure 7.2). As their names suggest, these climatic events resulted in generally warmer and cooler temperatures, respectively, than the “baseline” of the middle of the 20th century. However, the specific ways in which these events manifested themselves varied considerably throughout the world (Crowley and Lowery 2000; Mann and Hughes 2002), even within narrow geographical bounds (Hughes and Diaz 1994). Glacial histories in Alaska, for instance, show that the timing of retreat and advance corresponding to the MWP and LIA differs for continental and maritime glaciers on different sides of the same mountain range (Mann *et al.* 1998). Continental glaciers apparently respond mainly to varying summer temperatures, whereas maritime glaciers respond to changes in winter snowfall (Wiles and Calkin 1994).

In addition to a high degree of spatial variability in the manifestations of the MWP and LIA, different paleoenvironmental temperature histories have been reported for the same region depending on which proxy is examined, and how it is analyzed. The most striking example of this involves reconstructions of SSTs based on ¹⁸O analyses from deep sea cores from the Santa Barbara Channel region of southern California.

Pisias (1978) and Field and Baumgartner (2000) find broad temporal correlations between warmer reconstructed SSTs and the MWP on the one hand, and cooler SSTs and the LIA, on the other. In contrast, Kennett and Kennett (2000), using the same type of analysis, reach exactly the opposite conclusion: during the MWP, SSTs in the Santa Barbara Channel were *cooler*, while during the LIA, SSTs were *warmer*.

Until discrepancies such as this can be resolved, it will be difficult to evaluate directly what the likely effects on specific fur seal populations may have been. Generally speaking, however, we can predict that warmer SSTs would probably favor high-latitude fur seal populations at the expense of the mid-latitude populations. Colder SSTs would benefit mid-latitude populations through increased availability of prey. The response of high-latitude populations will depend on how much colder than “normal” the SSTs were—too cold would eventually begin to reduce juvenile survival (York 1991, 1995).

In spite of the likelihood of a relationship between short-term climatic events such as ENSO and the PDO, examination of Figure 7.1 suggests that the only clear relationship exists between pup survival in the California population and ENSO events. Recall from Chapter 4, however, that a fur seal rookery persisted in the Farallon Islands, California, until it was exterminated by commercial sealers in the early 19th century. If the harvest records are accurate (Bancroft 1885; Elliott 1887; see Table 4.1), the Farallon Islands population must have numbered in the tens of thousands during the initial years of exploitation. Thus, it does not seem likely that ENSOs or PDOs acted as significant regulators of fur seal populations towards the end of the 18th and into the 19th century.

Likewise, the only long-term climatic event that occurs at approximately the same time as the elimination of the rookeries documented in Chapter 5 is the LIA. Given the above discussion, it is difficult to envision a climatic event (either short-term or long-term) that is likely to have extirpated some, but not all, high-latitude populations while simultaneously extirpating some, but not all, mid-latitude populations of fur seals. Yet this is exactly what is required if the historic effects hypothesis is to be rejected.

The objection can still be raised that perhaps the rookeries identified in Chapter 5 represented small, marginal populations highly susceptible to perturbations. Thus, the coincidental beginning of the commercial fur trade and the end of the LIA may have acted in concert to extirpate these rookeries. Until the precise locations and likely size of the breeding colonies are identified, the “small population size” argument cannot be countered. In terms of the possibility that they were “marginal populations,” I will simply point out that geographically speaking, the areas I have proposed as possible breeding sites are well within the geographic range of the current distribution.

Conclusions

In spite of the fact that data to the contrary have been accumulating over several decades (e.g., Gustafson 1968; Peterson *et al.* 1968), the idea that the historically-documented patterns of fur seal biogeography represent the normal pattern persists within both the archaeological and zoological literature. In the final report for the Ozette excavations, Huelsbeck concludes that because “fur seals were most abundant during the spring and fall as they migrated to and from their breeding grounds to the north....the majority were probably taken during the spring” (1994: 74). In point of fact, the age

distribution of young-of-the-year fur seals presented in Chapter 5 suggests that fur seals were taken throughout the year, with relatively large numbers harvested in November and December as well as March and April (Figure 5.17).

Zoologists have also been slow to recognize the many suggestions that fur seal biogeography has changed dramatically in the late Holocene. In his recent treatise “Behavior and Ecology of the Northern Fur Seal,” Gentry (1998) makes only passing reference to the fact that the migration patterns (not to mention breeding distribution) may have been different in the late Holocene.

In contrast to the viewpoint exemplified above, the research presented here and elsewhere (Burton *et al.* 2002; Lyman 1988, 1989, 1991b, 1995; Pyle and Long 2001) suggests that the mid-latitude population/s of fur seals represented a substantial proportion of the basin-wide population prior to the late 18th century. Furthermore, the dramatic changes in the distribution of fur seals have been shown to be the cause of recent anthropogenic factors. Although the possibility exists that other rookeries were eliminated through prehistoric hunting in other areas (e.g., Hildebrandt and Jones 1992; Jones and Hildebrandt 1995), these cases need to be evaluated on a site-by-site basis using an approach comparable to the one used here.

The relatively late presence of mid-latitude fur seal rookeries also raises serious issues for management legislation that uses historic population levels as a baseline against which to measure the present population levels. In particular, the question of how carrying capacity is defined and measured becomes a crucial component of any population status evaluations. When the temporal component accessible through

archaeological evidence is taken into consideration, the complexity of such a determination would seem overwhelming. Nevertheless, as pinniped populations in the eastern North Pacific continue to increase, interactions and competition with humans will undoubtedly increase as well. Therefore, management decisions will have to distinguish between the re-establishment of old patterns of pinniped behavior and behavioral patterns that have only developed recently.

More generally, the research presented here adds a unique viewpoint to a long standing debate regarding the propensity of humans to over-exploit their resource bases (Grayson 2001; Jackson *et al.* 2001; Martin 1967; Mosimann and Martin 1975). Although the best-documented cases of over-exploitation post-date the introduction of a cash economy (Jackson *et al.* 2001; Krech book), an increasing number of archaeological cases (Broughton 1994a, 1994b; Martin and Steadman 1999; Nagaoka 2001; Simenstad *et al.* 1978; Steadman 1995; Steadman and Rolett 1996; Szuter and Bayham 1989) indicates that over-exploitation has been a recurring theme in subsistence economies at different times and in different places throughout the world. While I agree with the conclusion that humans are capable of dramatically affecting the resource bases upon which they depend, the temporal sequences of fur seal exploitation presented here clearly indicate that over-exploitation is not a universal characteristic of subsistence economies.