Supporting Text

Controls on Isotope Variations in Marine Ecosystems. Marine phytoplankton have higher $\delta^{13}C$ values in productive nearshore regions than in offshore regions as well as higher values in temperate- than in high-latitude ecosystems (1, 2). Phytoplankton $\delta^{15}N$ values are also higher in temperate- than in high-latitude ecosystems but do not show conspicuous onshore--offshore differences (3-5). Nearshore ^{13}C enrichment may reflect low [CO_2] during blooms, growth rate and substrate effects on isotope fractionation, and the size and type of nearshore algae (1, 2, 6, 7). Latitudinal differences in $\delta^{13}C$ and $\delta^{15}N$ may reflect regional isotopic differences in sources of N and C available to marine plants, perhaps because of differences in water column stratification (1, 4, 5).

Isotopic differences cascade up food webs with C and N fractionations of ≈1‰ and ≈3‰, respectively, for each trophic step (8-10). Studies of modern pinnipeds have shown that bone collagen $\delta^{13}C$ values in nearshore foragers (e.g., HS) are ≈2‰ higher than those from offshore foragers (e.g., NFS), and $\delta^{13}C$ values are 1-2‰ lower in high- versus temperate-latitude offshore foragers (11). For the biogeographic section of our study, we only include data for adult female NFS (SI Fig. 5), which are recognizable by sexually dimorphic skeletal characteristics, to control for isotopic differences between adult males and females related to trophic level (12).

Archaeological Harvest Profiles and $\delta^{15}N$ Ontogenetic Series. The harvest profiles from Umnak Island in Alaska and Olympic Peninsula in Washington (Fig. 2), as well as the $\delta^{15}N$ ontogenetic series from Ozette, Washington (Fig. 3), were constructed entirely from mandible specimens because the mandibular shortlength metric provides the most accurate estimate of age (median SD of age error estimates is ≤2 months). The harvest profile from Moss Landing in California (Fig. 2) and the $\delta^{15}N$ ontogenetic series from Umnak Island were constructed by using multiple element metrics, which results in larger error terms for some age classes (Fig. 3). To ensure sample independence when multiple skeletal elements were used, elements of similar ontogenetic age were drawn from different temporal and/or spatial contexts within the archaeological sites. For the δ^{15}N ontogenetic series, a small fragment of bone was removed from each specimen by using a low-speed cutting tool and prepared for isotopic analysis by using the methods described in the main text.

Modern δ^{15}N Ontogenetic Series. For the modern Pribilof Islands (AK) δ^{15}N ontogenetic series (Fig. 3), bone collagen samples were acquired from archived known-age reference specimens in the California Academy of Sciences (San Francisco, CA), Smithsonian Institution (Washington, DC), and National Marine Mammal Laboratory (Seattle, WA). Only specimens sourced from the Pribilof Islands breeding colonies were analyzed, but it was impossible to determine the exact breeding colony of origin for each specimen. A small fragment of bone was removed from each specimen and prepared for isotopic analysis by using the methods described above.

Ecological Factors Influencing NFS Growth Rates. We assume that the known-age reference samples used in our bone regressions provide an unbiased, accurate estimate of age-at-death for unknown samples, regardless of the temporal and/or spatial origin of those samples. Three ecological factors might influence the validity of this assumption: (*i*) variability in the cause of death of individuals (particularly starvation for YOY), (*ii*) density-dependent variability in growth rates (13, 14), and (*iii*) the potential for latitudinal variability in body size (15).

> (*i*) Nearly all (>90%) of the YOY skeletons in the modern reference sample derive from the Pribilof Islands population and were either killed specifically for ontogenetic studies (16) or were natural mortalities collected opportunistically from the breeding colonies. Because many pup deaths on colonies are the result of trauma (17) and most specimens analyzed in this study (>90%) were killed for scientific purposes, the large majority of individuals in the Pribilof Islands reference sample are from individuals who were healthy at death. Specimens derived from archaeological contexts, however, might represent stranded individuals. Because malnutrition is a common cause of death in stranding cases,

these individuals may be smaller relative to healthy individuals of the same age. Thus, bone regressions that were constructed by using healthy individuals in the modern reference sample would consistently underestimate the true age-at-death of stranded individuals.

(*ii*) Density-dependent variability in growth rates must be considered because the Pribilof population has exhibited significant variability in individual growth rates throughout the 20th century that correlates negatively with population level (14, 18, 19). NFS males collected from 1911 to 1920, during the historic population low, had faster growth rates and grew to a larger overall size than individuals collected from 1940 to 1953, during the historic population high (14). With reference to the growth of YOY, however, most differences appear to manifest themselves after the first year of growth (13, 14).

The effect that density-dependent growth will have on our age estimates will be a complex function of (*i*) population level(s) for the reference collection and (*ii*) population levels of the harvested, unknown samples, such as those that are archaeological in origin. The regressions calculated for the mandible and other skeletal elements are based on large samples that span the entire 20th century. As such, the overall growth curves represent a long-term average characterization of skeletal growth (13). If we can assume that the fur seal populations from which the archaeological samples were drawn were relatively stable, the age estimates based on those regressions should be statistically accurate. Indeed, a recent zooarchaeological evaluation of Umnak Island and Olympic Peninsula archaeological sites found no evidence of fluctuating NFS populations over several hundred years of harvest pressure (13).

(*iii*) Latitudinal variability in body size, and potentially growth rate, could also bias the accuracy of age estimates. Although this idea has not been rigorously explored for modern NFS in the eastern North Pacific, anecdotal evidence suggests that individuals from the Pribilof Islands stock are larger than those from the SMI stock (13). Furthermore, a comparison of mandibles of male NFS from the Ozette archaeological site shows that they are systematically smaller than those of comparably aged males from the modern Pribilof Islands population (13; Fig. 5). This comparison suggests that NFS body size does vary with latitude; however, the geographic distribution of the reference specimens analyzed here is such that, if fur seals exhibit latitudinal differences in body size, our growth curves will systematically underestimate age-at-death for samples deriving from temperate-latitude populations. Furthermore, as with the density-dependent growth response, the latitudinal differences in growth appear to be most strongly manifested after the first year of growth (SI Fig. 5) and do not bias age estimates for NFS YOY.

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