A historical perspective on Pacific foodwebs: insights from stable isotope analysis of ancient sea otters

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Introduction/Research Question. Arguably the most pressing issues ecologists face are quantifying the ability of communities to cope with environmental perturbations and balancing the human need for resources with protection of natural environments. The stability of marine ecosystems is of great concern due to overexploitation and ocean acidification (*1,2*). Nearshore regions are especially vulnerable; important both commercially for their natural resources (*3*) and ecologically as biodiversity hotspots and carbon sinks (*4*). An understanding of how these ecosystems have responded to past environmental change is thus essential for current management strategies.

The sea otter (*Enhydra lutris*) is an apex marine consumer and poster child for conservation. Currently threatened, otters were nearly driven to extinction by historical commercial hunting (*5,6*). Since 1960, otters have been translocated from remnant colonies to historically occupied regions (*6*). However, modern sea otter range is still truncated and recovery in some areas has been slow and hampered by pollution, habitat alteration, and competition with humans for marine resources (6). Sea otters are important sentinels of ecosystem health because of their seminal role in maintaining kelp forests. By regulating invertebrate abundance, sea otters prevent overgrazing and help maintain these coastal ecosystems (*7*). Thus, understanding the response of sea otters to anthropogenic perturbations is beneficial not only for conservation efforts of the species, but in protection/management of a unique and productive suite of habitats. Here, I propose to examine the ecology of sea otters and nearshore ecosystems across time and space by focusing on the following question: *Can we use $\delta^{13}C$ of essential amino acids in ancient sea otter bones to examine the importance of kelp in historic Pacific ecosystems?*

Biotic and abiotic factors create baseline differences in $\delta^{13}C$ values at the base of the food chain (*8*). In Pacific foodwebs, kelp have higher $\delta^{13}C$ than co-occurring red, green, and microalgae due to their ability to uptake bicarbonate (Fig. 1; *9*). Since only producers and microbes can synthesize essential amino acids they are not chemically altered up food chains (*10*). Thus, *variation in $\delta^{13}C$ values of essential amino acids in top consumers like sea otters should record the $\delta^{13}C$ value of the dominant producers.* This should allow me to track temporal baseline shifts in $\delta^{13}C$ and look for the presence of kelp in ancient coastal ecosystems. If the $\delta^{13}C$ of ancient otter essential amino acids values more closely matches that of kelp, and is higher than that of modern sea otter populations from the same area, I can infer that kelp production was historically more important for nearshore foodwebs in the region than it is today.

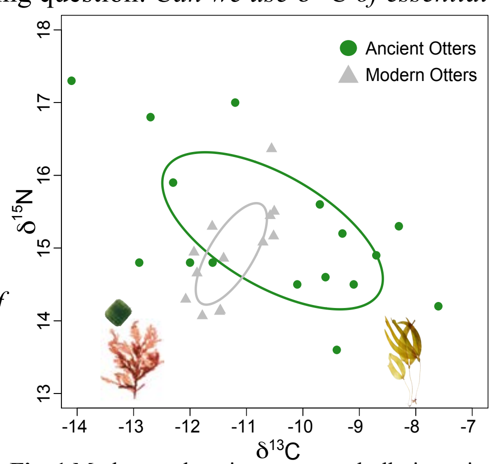

Fig. 1 Modern and ancient sea otter bulk tissue isotope values from San Nicolas Island, CA. Modern otter $\delta^{13}C$ corrected for tissue-specific and temporal discrimination by adding 1.5‰. Symbols for brown, green and red algae indicate approximate $\delta^{13}C$ values.

Methods/Samples. **(PUT IN DETAILS OF ESSENTIAL AMINO ACID PREP/ANALYTICAL TECHNIQUE?)** For this pilot study, I will groundtruth this approach with modern samples and test a few ancient bones of interest. I will analyze macroalgae (red/green/brown) and phytoplankton, as well as ancient and modern sea otters from two coastal regions: southcentral Alaska, and central California. Modern algal and sea otter samples are already available from my USGS/USFWS collaborators. I have obtained archaeological samples from museum collections. At each locale, I will analyze between 5-10 tissue samples of each algal taxa, as well as particulate organic matter (which is typically mostly phytoplankton), to obtain an essential amino acid profile for each primary producer guild. Additionally, I will extract and analyze bone collagen from 10 modern sea otters at each locale. I will compare the $\delta^{13}C$ profile of essential amino acids in modern sea otter tissues to those of producers at sites with and without kelp (*e.g.*, Monterey Bay, CA vs. Prince William Sound, AK). Finally, I will compare modern producer and sea otter values to Holocene (~6-1ka) bone collagen samples from archaeological sites at the same locations, to examine ecological shifts through time.

Implications of Results. If at each locale the $\delta^{13}C$ of modern sea otter essential amino acids matches those of the predominant primary producer, it will strongly support the hypothesis that apex consumers can be used as a proxy to examine ecological shifts in the fossil record. If modern sea otter values are significantly different than archaeological samples from the same locations, it implies a different dominant primary producer, and likely a temporal change in the structure and function of the overall ecosystem. An example of where I might expect to see this comes from my analysis of bulk tissues from ancient SNI sea otters (Fig. 1). These data suggest kelp were locally more prevalent throughout the Holocene than today, as evidenced by ancient otters with higher $\delta^{13}C$ values than their modern counterparts. Essential amino acid analysis will allow me to further explore this trend at SNI and beyond.

This research also has numerous broader impacts for both the scientific and general communities. As a keystone species, sea otters are important in maintaining healthy pacific coastal ecosystems. Understanding their past ecology thus offers insights into protecting productive habitats. Moreover, sea otters share biotic and abiotic resources with humans and their current re-expansion is of concern to fisheries (*11*). With this study I ultimately aim to enhance understanding of organismal response to environmental perturbations, and provide data crucial for balancing the often-conflicting needs of humans and ecosystems.

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