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Source: Journal of Ethnobiology, 35(3):519-535.
Published By: Society of Ethnobiology
https://doi.org/10.2993/etbi-35-03-519-535.1
URL: http://www.bioone.org/doi/full/10.2993/etbi-35-03-519-535.1

Journal of Ethnobiology 35(3): 519–535 2015

HUMAN AND CANID DIETARY RELATIONSHIPS: COMPARATIVE STABLE ISOTOPE ANALYSIS FROM THE KODIAK ARCHIPELAGO, ALASKA

Catherine F. West[1*] and Christine A. France[2]

*Stable carbon and nitrogen isotopes are used to address the dietary relationship between humans and two canid species at the Uyak site (KOD-145) on Kodiak Island, Alaska: dog (*Canis familiaris*) and red fox (*Vulpes vulpes*). We assess the relative contribution of marine and terrestrial protein to each species' diet as a measure of their dietary relationship to people, using zooarchaeological data, food web data, and ethnohistoric observations to interpret the results. The results suggest that dogs and foxes had different diets: the dogs are consistently enriched in both ^{13}C and ^{15}N, which indicates a heavy dependence on marine protein, while the fox samples produced both marine and terrestrial isotope values. Data from this project have the potential to expand our understanding of human-canid relationships in this island environment and in the greater context of island ecology, and contribute some of the first isotopic data for small terrestrial mammals in the Gulf of Alaska.*

Keywords: *Stable isotope analysis,* Canis familiaris, Vulpes vulpes, *island ecology*

Introduction

During the last 10,000 years, dogs (*Canis familiaris*) have been found throughout North America, including on many offshore islands (e.g., Brown et al. 2013; Cannon et al. 1999; Haag 1948; Laffoon et al. 2013; Morey 2006; Park 1987; Rick et al. 2008; West and Jarvis 2012). The symbiotic relationship between dogs and humans has been explored at great length, with dogs thought to have been important companions that provided a range of benefits to ancient peoples (for example, traction, protection, assistance in hunting, food, and ritual activity) (Morey 2010). More recently, researchers have begun to explore the potential impact of ancient dogs on ecosystems and organisms (Fiedel 2005; Rick et al. 2008).

One of the key issues in domestic dog research is to understand how dogs may serve as dietary proxies for humans in an archaeological context. To explore ancient dog diets, researchers have studied stable isotopes of carbon (δ^{13}C) and nitrogen (δ^{15}N) in collagen from archaeological bone (e.g., Cannon et al. 1999; Clutton-Brock and Noe-Nygaard 1990; Fischer et al. 2007; Guiry 2012, 2013; Rick et al. 2011). These isotope values have been compared to isotope values from humans, to faunal remains identified in archaeological sites, and to other canids found in archaeological sites.

In coastal and island regions, where there is often a unique mix of marine and terrestrial foods available, studies of dog remains have the potential to shed

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light on the interactions among dogs, humans, and both terrestrial and marine ecosystems. In this paper, we explore the dietary relationship between dogs and people in the Kodiak archipelago, Alaska, by asking the following questions: do dogs and people consume the same trophic level prey in this island environment, and is this reflected in the zooarchaeological and isotope records? How does this compare to other canids in this context, in particular the red fox (*Vulpes vulpes*)? And finally, can these data be used to interpret how humans and canids interacted with one another in this island environment? The Kodiak archipelago is particularly well suited to examine these dietary relationships, given the intense maritime adaptation of the hunter-gatherers, the presence of dogs in the archaeological record, and the suggestion in the ethnohistoric record that foxes may have been tamed or kept as pets by Native people. The results of this study are among the first isotopic data for small terrestrial mammals in the Gulf of Alaska, and while the data presented here come from the Kodiak archipelago, the questions and techniques are broadly applicable in various island contexts where human-canid relationships are of interest.

Background

The Kodiak Archipelago

The Kodiak archipelago is a mountainous island group located in the central Gulf of Alaska in the Northeastern Pacific Ocean (Figure 1). Glaciation and tectonic activity have created a dynamic landform that is characterized by a complex coastline with many bays, lagoons, and river mouths. These areas provide protected environments for rich biological resources and human occupants, which are supported by a productive marine environment. The earliest people arrived on Kodiak by boat, where they built large villages, complex social and political systems, and established seasonal rounds and storage systems designed to support substantial populations year-round (Fitzhugh 2003; Saltonstall and Steffian 2010; Steffian et al. 2006).

Based on zooarchaeological data, this seasonal round seems to have been focused primarily on the marine environment and on the anadromous fish taken from the rivers (Amorosi 1986; Clark 1974; Etnier 2002, 2011; Foster 2006; Hays 2007; Kopperl 2003; Partlow 2000; West 2009, 2014). Based on these previously analyzed datasets, it is clear that people relied heavily on large-bodied marine fish, particularly migratory Pacific salmon species (*Oncorhynchus* spp.) and cod species (Gadidae). In addition, flatfish (Pleuronectidae), greenlings (Hexagrammidae), sculpins (Cottidae), and occasionally herring (*Clupea pallasii*), are found in smaller numbers. While both gastropods and molluscs are found at some of the archaeological sites, shellfish remains tend to be dominated by the butter clam (*Saxidomus gigantea*) when recovered. The mammalian fauna are dominated by marine species: harbor seal (*Phoca vitulina*) are the most commonly recovered marine mammal, but whales (Cetacea), sea lion (*Eumetopias jubatus*), northern fur seal (*Callorhinus ursinus*), dolphin (Delphinidae), and very few sea otters (*Enhydra lutris*) have been identified as well. Bird remains have been understudied in Kodiak, but there is evidence for seabirds in the zooarchaeological material (Partlow 2000; West 2014; Yesner 1989).

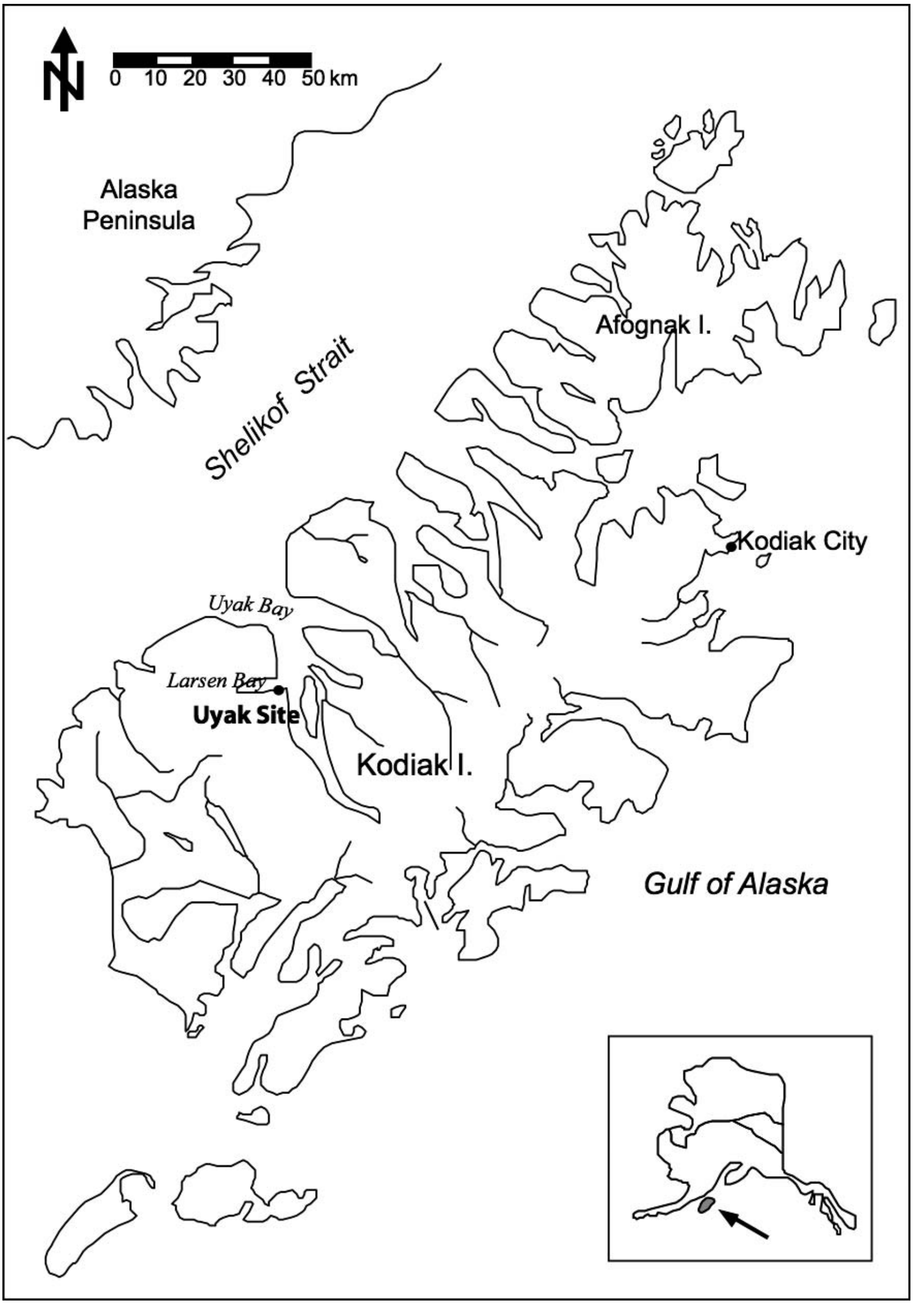

Figure 1. The Kodiak archipelago, showing locations mentioned in the text. Map courtesy of the Alutiiq Museum and Archaeological Repository.

In contrast, there were relatively few terrestrial mammal species available to humans before the Russian and American introductions. These introductions include a variety of small mammals (beaver, hare, red and Arctic ground squirrel, muskrat, and Arctic fox) and game (mountain goat, Sitka black-tailed deer, Roosevelt elk, reindeer/caribou, and moose). There is little evidence that the Kodiak brown bear (*Ursus arctos*) played an important role in subsistence, but people did harvest birds and some small mammals (red fox and river otter) from the terrestrial environment. In sum, the human diet on Kodiak seems to have been dominated by marine fish, with some consumption of marine mammals, birds, and shellfish. Unfortunately, the relative contribution of plant taxa, such as berries and seaweed, is unknown (see Mischler 2003 for an ethnographic perspective).

Dogs and Foxes on Kodiak

Both dog and red fox have been recovered from archaeological sites around the Kodiak archipelago (Clark 1974; Kopperl 2003; Partlow 2000; West and Jarvis 2012). Dogs are frequently associated with northern communities, and these animals have become part of the identity and symbolism of many Native groups. However, while dogs are commonly found in the archaeological record on Kodiak, their role in society, their relationship to humans, and how humans treated dogs remain unclear. As Shelikof (in Hrdlička 1944:475) notes about the dogs that lived among Kodiak's Native people, "although there are many dogs they do not use them." This observation is echoed by Petroff, who wrote that, in contrast to the northern people who use dogs for traction, "the native of Kadiak [*sic*] seldom harnesses up his dogs…[t]he people of Kadiak have few sleds…" (in Hrdlička 1944:475). Similarly, Clark (1974:44) writes that he has "not encountered any references to the Koniags using dogs for hunting or as watchdogs," as has been seen among the Eyak and Chugach on the coast of mainland Alaska (Birket-Smith 1953; Birket-Smith and deLaguna 1938). Despite the lack of ethnographic information, the archaeological record contains substantial numbers of dog bones, as mentioned above, and many of these specimens exhibit cut marks. Based on this evidence, both Clark (1974) and West and Jarvis (2012) argue that the dogs may have been used as sources of food or fur. This is supported by ethnographic and archaeological data from mainland Alaska and the Northwest Coast that reference dogs as food and as a source of fur, in addition to their role as work animals and in ritual activity (Birket-Smith and deLaguna 1938; Crockford 1997; Lantis 1980).

Red foxes are also abundant in the archaeological record on Kodiak; Clark (1974:42) argues that "the prehistoric Kodiak emphasis on foxes is exceptional." Like the dog, it is unclear whether they were used for food, harvested for their pelts, or even kept as pets. The red fox is thought to be indigenous to Kodiak, meaning that it likely colonized the area in the early post-glacial period and was present when people arrived in the archipelago (Clark 1958; Rausch 1969). The ethnographic record suggests foxes were taken primarily for their fur, particularly when the practice was industrialized in the historic period (Bailey 1993; Clark 1974; Huggins 1981; Isto 2012). Clark (1974:42) notes Glottof's 1763 observation that he traded for fox pelts during an early visit to Kodiak and that

"Koniags wore garments of the skins of birds, foxes, sea otters, young caribou, and ground squirrels," while both Sauer and Father Gedeon observed that foxes were hunted and their pelts traded with the Russians (Clark 1974). On the other hand, Hrdlička suggests that foxes were "domesticated" (1944:220) and "doubtless kept as pets" (1944:479) and goes as far to suppose that Native people had "[e]vidently some fox cult" (1944:245) based on his excavations at Uyak. In his diary, Huggins (1981:15) also notes that Russian explorers observed, "natives on some of the islands had tame foxes."

Today, red foxes are common throughout the archipelago, where they are hunted for fur. There has been relatively little research on the Kodiak red fox itself, perhaps because the population is so healthy (Larry VanDaele, personal communication); however, their life history has been studied across the Gulf of Alaska, where they are considered an invasive species (Bailey 1993; Ebbert and Byrd 2002). In general, red foxes are adaptable and can be found in many environments, where they are omnivorous hunters and scavengers. This flexibility means their diet is varied and may include both terrestrial and marine animals (hunted or scavenged) and plants, although there is some suggestion that they prefer to hunt small animals (Haltenorth and Roth 1968). On the islands across the Gulf of Alaska, introduced red foxes are known to prey on bird species (adults, young, and eggs) and they have been blamed for the widespread elimination and suppression of local bird populations (Bailey 1993). Red foxes are frequently found near human settlements and in urban areas, where they scavenge in refuse dumps and tend to be gregarious and commensal in some settings (Gloor et al. 2001). Their potential as tame animals or as pets has been demonstrated in Russia, where foxes were successfully domesticated (Belyaev et al. 1985; Trut et al. 2013).

Stable Isotopes in Dietary Reconstruction

Given the abundance of both dog and red fox remains in the archaeological record and the ambiguous understanding of their relationship to people, stable isotope data have the potential to illuminate the dietary relationship. In most animals, the stable isotopes of carbon (^{12}C, ^{13}C) and nitrogen (^{14}N, ^{15}N) fractionate during digestive processes such that the heavier isotope is concentrated in the body tissues, and higher levels of any given food chain are more enriched in ^{13}C and ^{15}N. Stable isotopes are reported in standard delta notation relating the ratio of heavy to light isotopes compared to an international standard:

$$\delta X = \left[\left(R_{\text{sample}} - R_{\text{standard}}\right)/R_{\text{standard}}\right] * 1000$$

where X is the system of interest (i.e., ^{13}C or ^{15}N), R is the isotope ratio (i.e., $^{13}C/^{12}C$ or $^{15}N/^{14}N$), units are per mil (‰), and the standards are V-PDB and atmospheric air for carbon and nitrogen respectively. In general, the isotopic enrichment at each level of the food chain is ~1 ‰ for $\delta^{13}C$ and ~3-4 ‰ for $\delta^{15}N$ (Bocherens and Drucker 2003; DeNiro and Epstein 1981; Minagawa and Wada 1984; Post 2002; Schoeninger and DeNiro 1984; Sutoh et al. 1987). In marine ecosystems where the food chain length tends to be much longer, these

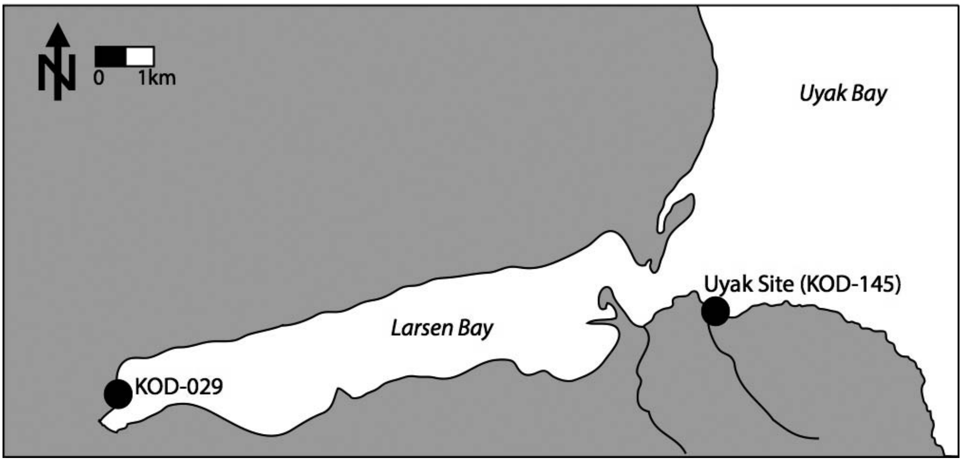

Figure 2. Larsen Bay, showing the location of the Uyak site (KOD-145) and KOD-029 (Yesner 1989).

fractionations are additive and the $\delta^{15}N$ and $\delta^{13}C$ of terminal marine consumers are significantly more positive than consumers in a terrestrial food chain. Mammalian diets derived from marine protein are generally reflected by $\delta^{15}N$ values between +10 and +20 ‰ and $\delta^{13}C$ values between −20 and −10 ‰, while terrestrial diets produce $\delta^{15}N$ values between 0 and +10 ‰ and $\delta^{13}C$ values between –30 and −17 ‰ (Burton et al. 2001; Hobson and Welch 1992; Hobson et al. 1997; Schoeninger and DeNiro 1984). The absolute abundance of the heavier ^{15}N and ^{13}C incorporated in body tissues depends on the amount of marine food consumed. In the case of dogs and foxes on Kodiak Island, those with a diet most similar to humans will likely consume a relatively high marine input given the maritime focus on Kodiak.

The Uyak Site

To address our questions about the dietary relationship between canids and people, we used faunal material collected at the Uyak site (KOD-145) on the west side of Kodiak Island. Physical anthropologist Aleš Hrdlička excavated the Uyak site from 1933 to 1936 (Hrdlička 1944; Figures 1 and 2). Also known as "Our Point," the Uyak site was a substantial midden that formed a peninsula extending into Larsen Bay (Figure 2). The midden deposits were at least three meters deep, and Hrdlička and his team divided the deposits into three layers (lower, middle, and upper) based on the artifact types recovered and on rough deposit descriptions. In addition to extensive faunal remains, the midden consisted of organic and stone artifacts, human remains, slate hearths, and house structures. Because the focus of the excavation was human remains, the team collected select whole mammal bones, including those from dogs and foxes (Allen 1939). Hrdlička (1944:325) and others (Heizer 1956; Steffian 1992) have estimated that the occupations date from 2000 years ago until Russian contact in the mid-eighteenth century. West and Jarvis (2012) present recent Accelerator Mass Spectrometry (AMS) dates taken directly on the dog bones, which confirm that the site was occupied during this time period (Table 1).

Table 1. AMS dates produced by NOSAMS for the Uyak Site on *C. familiaris* left adult mandibles, adapted from West and Jarvis (2012).

NMNH[a] Catalog #	Provenience[b]	NOSAMS[c] #	Material	Radiocarbon age range (BP)	δ13C (‰,V-PDB)	Calibrated age range (cal BP; 2σ)[d]
560028-27	Upper Level	OS-86795	Bone	1270 ± 30	-13.9	560 ± 80
560028-29	Upper Level	OS-86785	Bone	2010 ± 50	-14.7	1230 ± 150
560028-30	Middle Level	OS-86791	Bone	2220 ± 30	-13.6	1440 ± 140
560028-8	Middle Level	OS-86796	Bone	2630 ± 30	-12.8	1940 ± 150
560028-15	Lower Level	OS-86783	Bone	2510 ± 25	-14.7	1780 ± 150
560028-24	Lower Level	OS-86788	Bone	2560 ± 30	-14.6	1840 ± 150

[a] National Museum of Natural History.

[b] Provenience refers to the broad stratigraphic levels defined by Hrdlička (1944).

[c] National Ocean Sciences Accelerator Mass Spectrometry Facility.

[d] Because the stable isotope analysis done for this study indicates the Uyak dogs ate a primarily marine diet similar to other high-level marine predators (Hirons et al. 2001; Misarti et al. 2009), the dates were calibrated using Calib version 6.0 and corrected using the Marine Reservoir Correction Database where ΔR=320±50 for the west side of Kodiak Island (McNeely et al. 2006; Reimer et al. 2004; Stuiver and Reimer 1993) and % marine carbon was 100.

Methods

Faunal Remains Identification and Sampling

As described above, Hrdlička (1944) and his team divided the Uyak midden into three broad levels. Those from the "Deep" or lowest level of the midden were assigned to the Early Kachemak phase (4000-2700 cal BP), the "Intermediate" or middle level contained Late Kachemak artifacts (2700-900 cal BP), and the "Upper" level was interpreted as the latest phase in Kodiak's prehistory, or the Koniag phase (900-200 cal BP) (Hrdlička 1944; Saltonstall and Steffian 2010). Hrdlička (1944) collected dog and fox remains from each of these levels; however, their context was poorly recorded and it is unclear if these animals were intentionally buried or not (Heizer 1956).

We selected dog and fox mandibles for stable isotope analysis and radiocarbon dating for two reasons: 1) because they were well preserved and suitable for collagen extraction, and 2) because of their prevalence in the Uyak faunal assemblage. While the mandibles had been previously identified as *C. familiaris* and *V. vulpes*, we re-identified the specimens. To distinguish between dog and fox, we used comparative materials in the Archaeobiology Lab at the National Museum of Natural History and identification guides (Crockford, personal communication; Crockford 1997; Gilbert 1990; Miller et al. 1964; Olsen 1980). Specifically, dog and fox mandibles in this region can be distinguished using the following characteristics: 1) the posterior margin of the ramus in dogs is curved and forms a prominent hook on the coronoid process, whereas foxes have a straight margin and a straight coronoid process; 2) the body curves up at a sharp angle in dogs, while the body is straight in foxes; 3) there is a larger gap between the third molar (M3) and the ramus in foxes than in dogs, which show tooth crowding; 4) dogs are frequently missing the first premolar (P1) and occasionally the second and fourth premolars (P2 and P4). Also, the mature dogs are overall more robust than the mature foxes in this assemblage.

Table 2. Carbon and nitrogen isotope values for dog (*C. familiaris*) and red fox (*V. vulpes*) from the Uyak Site (KOD-145).

Sample #[a]	Taxon	Provenience[b]	δ^{15}N (‰, air)[c]	δ^{13}C (‰,V-PDB)	C:N
Uyak 560028-1	*C. familiaris*	Upper level	15.4	-15.4	3.4
Uyak 560028-2	*C. familiaris*	Upper level	16.6	-15.0	3.5
Uyak 560028-4	*C. familiaris*	Upper level	15.2	-14.6	3.4
Uyak 560028-8	*C. familiaris*	Middle level	17.1	-12.9	3.4
Uyak 560028-9	*C. familiaris*	Middle level	15.4	-15.2	3.5
Uyak 560028-12	*C. familiaris*	Middle level	15.8	-14.6	3.4
Uyak 560028-13	*C. familiaris*	Middle level	16.9	-14.1	3.6
Uyak 560028-14	*C. familiaris*	Lower level	14.5	-14.7	3.2
Uyak 560028-15	*C. familiaris*	Lower level	16.0	-14.8	3.5
Uyak 560028-17	*C. familiaris*	Lower level	15.5	-15.2	3.6
Uyak 560028-18	*C. familiaris*	Lower level	16.3	-14.8	3.5
Uyak 560028-21	*C. familiaris*	Middle level	16.0	-13.9	3.4
Uyak 560028-22	*C. familiaris*	Lower level	16.4	-13.0	3.4
Uyak 560028-23	*C. familiaris*	Lower level	15.2	-15.5	3.5
Uyak 560028-24	*C. familiaris*	Lower level	14.7	-14.7	3.4
Uyak 560028-25	*C. familiaris*	Lower level	16.0	-14.3	3.4
Uyak 560028-26	*C. familiaris*	Lower level	15.9	-15.1	3.5
Uyak 560028-27	*C. familiaris*	Upper level	16.7	-14.0	3.5
Uyak 560028-28	*C. familiaris*	Upper level	15.9	-14.8	3.4
Uyak 560028-29	*C. familiaris*	Upper level	15.0	-14.8	3.4
Uyak 560028-30	*C. familiaris*	Middle level	16.4	-13.8	3.4
		Mean	15.8	-14.5	
		Standard Deviation	0.7	0.7	
Sample #[a]	**Taxon**	**Provenience[b]**	**δ^{15}N (‰, air)[c]**	**δ^{13}C (‰,V-PDB)**	**C:N**
Uyak 560028-32	*V. vulpes*	Lower level	8.1	-19.6	3.3
Uyak 560028-35	*V. vulpes*	Upper level	16.7	-11.9	3.4
Uyak 560028-37	*V. vulpes*	Middle level	7.6	-19.7	3.4
Uyak 560028-39	*V. vulpes*	Middle level	12.2	-17.9	3.6
Uyak 560028-40	*V. vulpes*	Middle level	13.8	-14.6	3.5
Uyak 560028-41	*V. vulpes*	Lower level	14.2	-15.3	3.5
Uyak 560028-42	*V. vulpes*	Lower level	7.0	-20.8	3.6
Uyak 560028-43	*V. vulpes*	Lower level	16.0	-13.6	3.5
Uyak 560028-45	*V. vulpes*	Middle level	10.7	-17.6	3.3
Uyak 560028-49	*V. vulpes*	Upper level	13.0	-15.9	3.5
		Mean	11.9	-16.7	
		Standard Deviation	3.4	2.9	

[a] Only well-preserved samples are included in the table.
[b] Provenience refers to the broad stratigraphic levels defined by Hrdlička (1944), which date between 560±80 and 1940±150 cal BP (see Table 1; West and Jarvis 2012).
[c] All δ^{15}N and δ^{13}C values are reported with an error of ±0.2‰ (1σ).

To avoid sampling the same individual twice, we selected only left mandibles (Table 2). We chose those that showed full tooth eruption to avoid sampling immature animals whose isotope values could be affected by nursing or weaning (Fogel et al. 1989; Katzenburg et al. 1996). We selected a total of 30 dogs and 20 foxes (N=50): 10 dogs from each stratigraphic level, 6 foxes from the lower and middle levels, and 10 foxes from the upper level.

Stable Isotope Methods

Solid bone chunks (~500 mg) were separated from mandibles using a rotary tool and coring bit. Collagen was extracted from solid bones pieces using a modified Longin (1971) method. Bone pieces were sonicated in ultra-pure water to remove sediments and labile salts, then rinsed. Samples were decalcified in 0.6M HCl at 4°C for 24 hour increments (acid replaced daily) until reaction ceased. Samples were rinsed to neutrality then soaked in 0.125M NaOH for 24 hours at room temperature to remove humic and fulvic contaminants. The crude gelatin was rinsed and reacted in 0.03M HCl at 95°C for 24 hours to denature the protein. The resulting supernatant was freeze-dried to produce a purified collagen extract.

The extracted collagen samples were weighed into tin cups and combusted in a Costech 4010 Elemental Analyzer (EA) with a zero blank autosampler. The resulting N_2 and CO_2 gases were analyzed for $\delta^{15}N$ and $\delta^{13}C$ values in a Thermo Delta V Advantage mass spectrometer coupled to a Conflo IV interface. Raw data was linearly corrected to a calibrated acetanilide and urea standard. All $\delta^{15}N$ and $\delta^{13}C$ values are reported with an error of ± 0.2 ‰ (1σ) which is based on reproducibility of repeated standard and sample measurements. The atomic C:N ratios of the collagen were also calculated based on calibration to a homogeneous acetanilide standard. C:N ratios between 2.8 and 3.6 indicate good preservation for isotopic analysis (Ambrose 1990; DeNiro 1985; Table 2). Those with values outside of this range were eliminated from the analysis.

Results

The results of the stable isotope analysis are presented in Table 2 and in Figure 3, showing a difference in variability between the dogs and the foxes. Among the 30 dog specimens sampled, 21 produced viable collagen; 10 of the 20 red fox specimens produced viable collagen. Samples in this study showing good preservation had a C:N value range of 3.2-3.6. The isotope results show the following ranges: dog $\delta^{15}N$ = +14.5 to +17.1 ‰, fox $\delta^{15}N$ = +7.1 to +16.7 ‰, dog $\delta^{13}C$ = −15.5 to −13.0 ‰, fox $\delta^{13}C$ = −20.9 to −11.9 ‰ (Table 2). The error reported is ± 0.2 ‰ (1σ).

The results presented in Table 2 and Figure 3 show the differences in domestic dog and red fox $\delta^{15}N$ and $\delta^{13}C$ values. Dogs show relatively little variability in both carbon and nitrogen isotope ratios ($1\sigma = 0.7$ for both $\delta^{15}N$ and $\delta^{13}C$) and reveal a distinct marine signature. The foxes, in contrast, show significant variability and produced values along the continuum from an exclusively terrestrial diet to one dominated by marine protein ($1\sigma = 3.4$ and 2.9 for $\delta^{15}N$ and $\delta^{13}C$, respectively). A Mann-Whitney U Test suggests the distributions of $\delta^{13}C$ and $\delta^{15}N$ values between dogs and fox differ significantly (Mann-Whitney U = 155.5 and 178.5 for $\delta^{13}C$ and $\delta^{15}N$ respectively, $n_{dog} = 21$, $n_{fox}=10$, $P < 0.03$ in all comparisons). Given the excavation and sampling methods, it is impossible to assess change over time in stable isotope values at this site.

Discussion

The stable isotope data statistical comparisons presented above suggest that the dog diet at the Uyak site was relatively homogeneous when compared to the red fox. More specifically, dogs were likely consuming a large proportion of marine resources, while foxes were consuming resources from both the terrestrial and marine environments. Because stable isotope data alone are inadequate to make detailed dietary reconstructions for each species, we turn to existing stable isotope data for Gulf of Alaska fauna and human stable isotope data from the Larsen Bay region to interpret the results. In combination with the zooarchaeological data and canid stable isotope results presented above, this information may be used to address our questions about the dietary relationship between canids and people.

To estimate which resources are reflected in the dog and fox isotope data, we must understand the isotopic profile of the local food web. Because we are not aware of a detailed published dataset for Kodiak, we turn to isotope data produced using modern samples across the Gulf of Alaska and the Bering Sea, which include marine mammals, fish, and primary producers (Burton and Koch 1999; Hirons et al. 2001; Hobson et al. 1997; Misarti 2007; Misarti et al. 2009; Satterfield and Finney 2002; Figure 3). Figure 3 displays these values as reported by Misarti (2007) and Misarti et al. (2009), which have been corrected for the Suess effect and for the isotopic differences between bone and tissue (Misarti 2007), as well as values reported by Satterfield and Finney (2002). The results are certainly influenced by geographic variables, inter-lab error, and differences in sex, age, and migration patterns within individual species (Misarti et al. 2009; Newsome et al. 2007); however, these values provide a rough estimate of what a generalized Kodiak food web might look like isotopically. According to the authors of these studies, these data suggest that in this region an animal's $\delta^{13}C$ value reflects near shore versus offshore feeding habits, and that the $\delta^{15}N$ value reflects trophic level, as expected. Lacking from the literature, however, are samples of terrestrial mammals commonly found on Gulf of Alaska islands (i.e., ground squirrel (*Spermophilus parryii*), tundra vole (*Microtus oeconomus*), and ermine (*Mustela erminea*); therefore, we are unable to produce a quantitative mixing model for the dog and fox diets and rely on the qualitative understanding that terrestrial resources are less enriched in both ^{13}C and ^{15}N than marine resources.

Using the isotopic data presented in Figure 3 and the assumption that with each trophic level carbon enriches by ~1 ‰ and nitrogen by ~3-4 ‰, the Uyak dogs appear to have been eating a relatively large proportion of high trophic level foods and are consuming primarily marine protein, which is consistent with the stable isotope values for marine mammal and marine fish available in the Kodiak archipelago. However, the variability in $\delta^{15}N$ and $\delta^{13}C$ among the dog samples suggests that some are eating at least one full trophic level higher than others, and dogs have enriched $\delta^{13}C$ values. As Guiry (2012) argues, this variability may be explained by cultural factors that influence human-dog relationships. Ethnographic data suggest it is common practice among northern people to feed dogs salmon (Anderson 1992; Lantis 1980), though some Alaskan dogs are reported to have been fed bone (Birket-Smith and Laguna 1938) and "parts of the game not destined for human consumption," such as guts and skins (Spencer in Lantis 1980), as well as feces (Lantis 1980). Misarti et al. (2009) observe that in both cod and salmon, the $\delta^{13}C$ values of bone collagen are almost

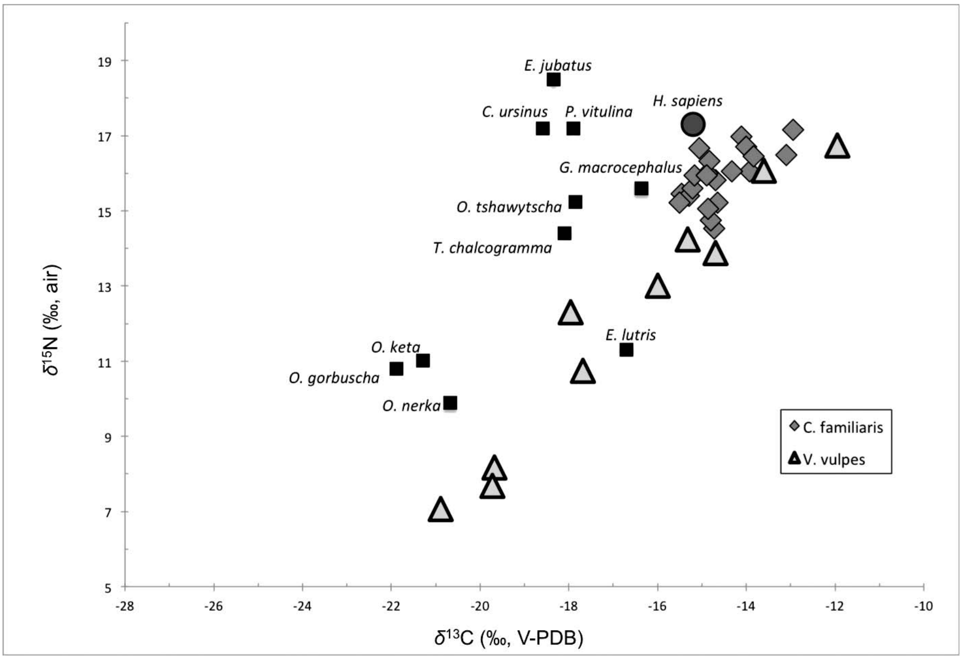

Figure 3. Carbon and nitrogen isotopes values for the archaeological samples of dog (*Canis familiaris*) and fox (*Vulpes vulpes*) collagen produced by this study, the single archaeological human collagen sample from KOD-029 (Yesner 1989), as well as values for modern marine mammal and fish muscle samples reported by Misarti (2007), Misarti et al. (2009), and Satterfield and Finney (2002). These include: Steller sea lion (*Eumetopias jubatus*), harbor seal (*Phoca vitulina*), northern fur seal (*Callorhinus ursinus*), sea otter (*Enhydra lutris*), Pacific cod (*Gadus macrocephalus*), walleye pollock (*Theragra chalcogramma*), king salmon (*Oncorhynchus tshawytscha*), chum salmon (*O. keta*), pink salmon (*O. gorbuscha*), and sockeye salmon (*O. nerka*).

2.5 ‰ higher than muscle, and Schoeninger and DeNiro (1984) report that mammal collagen $\delta^{13}C$ is 4 ‰ higher than muscle. Therefore, dogs with enriched $\delta^{13}C$ values may have been consuming substantial amounts of bone in addition to muscle or other flesh, while those with enriched $\delta^{15}N$ values may have been consuming more marine mammal than fish.

We can use these results to address the first question posed in this paper: do dogs and people consume the same trophic level prey in this maritime-oriented community, and is this reflected in the isotopic and zooarchaeological records? To answer this question, we first compare the dog and food web isotope values to the $\delta^{13}C$ and $\delta^{15}N$ values of a single human element from nearby archaeological site KOD-029 in Larsen Bay (Yesner 1989; Figures 2 and 3). The results suggest this person's diet was heavy in marine protein: $\delta^{13}C = -15.2$ ‰ and $\delta^{15}N = +17.3$ ‰. As described above, the Kodiak zooarchaeological record is dominated by marine fish, particularly Pacific salmon (*Oncorhynchus* sp.) and cod species (Gadidae), as well as some marine mammal. Mixing these resources would result in the human signature seen in Figure 3: less enriched in both ^{13}C and ^{15}N than marine mammals and more enriched than marine fish.

Based on the data presented in Figure 3, the human bone is similar isotopically to the dog remains from Uyak. We know very little about this single human sample (for instance, its age, sex, condition, and analytical methods), but the results do suggest that while dogs and the single human were consuming foods from a similar trophic level overall, many of the dogs have less negative $\delta^{13}C$ values. Given the differences between bone and muscle values discussed above, this may be because humans were eating the filets and feeding their dogs the bony remnants after fish processing (or dogs were scavenging bone from the middens); similarly, the dogs show less positive $\delta^{15}N$ values, which may mean they had access to less marine mammal protein or large-bodied marine fish.

To address our second question, how dogs compare to other canids in this context, we turn to the results of the fox analysis. In contrast to the dogs, the fox remains show significantly more isotopic variability, as seen in Table 2 and Figure 3. While some foxes are clearly eating marine foods similar to dogs and the single human, others are eating exclusively terrestrial protein. Some of the foxes are consuming a mix of marine and terrestrial protein (Figure 3).

Finally, to address our third question: can these data be used to interpret how humans and canids interacted with one another in this island environment? Given the red fox behaviors, habitat requirements, and flexibility described above, the red fox data suggest several types of human-animal interaction. First, the isotope results may reflect natural variability in Kodiak red fox diet: some foxes live inland where they hunt small mammals (the tundra vole [*M. oeconomus*], primarily) and others live closer to the coastline where they scavenge a variety of marine and terrestrial resources. This behavior is observed in the Arctic fox (*Vulpes lagopus*) in other northern island environments, where this comparable species has adapted to both coastal and terrestrial ecological niches and this adaptation is reflected in their isotope profiles (Dalerum et al. 2012; Tarroux et al. 2012). Red foxes tend to have a home range of 2-5 km^2 and are unlikely to travel long distances (Haltenorth and Roth 1968); therefore, these fox diets may actually reflect human hunting strategy and suggest that people traveled around the landscape to collect the foxes. The position of the Uyak site at the mouth of Larsen Bay inside the larger Uyak Bay afforded people easy access to both inland and coastal environments. The second possibility is that some of these foxes lived in direct contact with people and were not simply prey items. Those foxes with diets enriched in ^{15}N and ^{13}C ate a high proportion of marine foods. Together with the ethnohistoric data, this suggests that they could have been fed by people and possibly kept as pets, or they were scavenging marine resources from human-deposited middens. Given the high enrichment of some of the foxes and their reputation as scavengers, the most parsimonious explanation is that some foxes took advantage of the massive midden at Uyak for food.

In terms of the dogs, the ethnographic data for coastal Alaska and the dietary data produced by this study together suggest that dogs were likely somewhere on the commensal spectrum, whether as pets, companions, or in another role. While the dietary data do not offer a clear explanation of the nature of the dog-human interaction in this region, it is clear that dogs were brought to Kodiak by people and that the Uyak dogs maintained a homogenous marine diet relatively similar to people. Given our broader understanding of dog-human interactions in the Gulf of Alaska, therefore, the dogs were likely fed by people directly or scavenged from the middens deposited by the people living at the Uyak site. The cut marks on the dog remains suggest this symbiotic relationship may have been complicated, and will be the focus of future research.

Conclusions

The results presented above suggest that the dogs and foxes sampled in the Uyak assemblage had different diets: the carbon and nitrogen isotope data indicate that the dogs sampled were all eating a similar high-trophic, marine diet, while the foxes sampled represent broad diets that included both terrestrial and marine resources. We interpret these results to suggest that these canid species had different dietary relationships with people at the Uyak site: the dogs were living in close proximity to people and were either being fed by people from their own set of marine resources, or they were scavenging in the Uyak midden. Further, among the dogs there was variable resource consumption, although they were all eating a high proportion of marine foods. On the other hand, while their diets suggest that some of the foxes may have been living closely with people either as tame pets or scavengers, others were relying primarily on scavenged or hunted terrestrial resources.

This broad difference is significant because it illustrates the possible relationships between humans and individual animal species on this island landscape, as visible through dietary reconstruction. The relationship between dogs and people on Kodiak has been difficult to understand, and these data provide a glimpse into the close relationship of these two groups with each other and with the landscape; further research on the dog skeletal elements will help to illuminate the nature of this close relationship (e.g., West and Jarvis 2012). On the other hand, the foxes both underscore what we see in the dogs and offer a contrast: those foxes that are similar to dogs isotopically were potentially scavenging only from the marine environment; however, given their presence in the archaeological record, their gregarious behavior, and the historic references to foxes on Kodiak, it is possible that they were living closely with people. In contrast, those that recorded a terrestrial diet may have simply been a prey species. Again, further analysis of the skeletal remains, including cut marks, body size, and pathologies, will help to inform this interpretation.

From a regional perspective, the Kodiak sample supports conclusions made by Cannon et al. (1999) and Rick et al. (2011), who found that dogs and humans were eating similar marine diets, and it adds to the growing body of literature that compares dogs and humans in the North Pacific. In great contrast to the California Channel Islands foxes sampled by Rick et al. (2011), these data suggest that humans and foxes have lived in close proximity on Kodiak for at least 2000 years and that foxes took advantage of the human presence. Further analysis should combine zooarchaeological data and stable isotope analysis at Uyak with other sites on Kodiak and elsewhere in the North Pacific to expand on this regional perspective.

Acknowledgments

Our gratitude goes first to the Alutiiq Museum and Archaeological Repository of Kodiak, Alaska for encouraging and supporting work with the Uyak Site collections. Thanks to the Smithsonian Office of Fellowships, the National Museum of Natural History Archaeobiology Program, the Smithsonian Museum Conservation Institute, and Torben Rick, R. Jeff Speakman, and Melinda Zeder for the opportunity and funding to perform this research. Thanks to the National Ocean Sciences Accelerator Mass Spectrometry (NOSAMS) facility at the Woods Hole Oceanographic Institute for providing the AMS analysis, and to the three anonymous reviewers for their comments.

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