Use of stable isotope analysis to identify food-conditioned grizzly bears on Alaska's North Slope

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Abstract: Managers often must decide whether to use non-lethal intervention (e.g., hazing or relocation) or lethal removal for resolving bear–human conflicts. Bears with a history of anthropogenic food use are less likely to respond favorably to non-lethal intervention. Stable isotope analysis can be a useful tool to determine a bear's history of anthropogenic food use. We analyzed nitrogen (N) and carbon (C) stable isotopes in 51 hair samples collected between 1991 and 2006 from 30 grizzly bears (*Ursus arctos*), and their likely food items, from the oilfield region of Alaska's Arctic Coastal Plain (USA) to evaluate the feasibility of using stable isotopes to identify human food use in bears without direct observation. $\delta^{15}N$ values varied by >4‰, indicating a trophically diverse diet. We found differences in isotopic values between bears that we had observed on a diet of natural foods (NF) only and those on a predominantly anthropogenic diet (food-conditioned [FC]). For 12 FC and 15 NF bears, mean $\delta^{15}N$ values were 6.6‰ (0.26 SE) and 4.8‰ (0.12 SE) and mean $\delta^{13}C$ values were −20.4‰ (0.3 SE) and −23.0‰ (0.14 SE), respectively. We confirmed that 3 putative NF bears whose home ranges overlapped the oilfields were likely NF bears. Isotope analysis confirmed visual observations of bear feeding behavior, and in the absence of extensive field observations could be used to determine whether an individual bear is likely to respond favorably to non-lethal management.

Key words: Alaska, anthropogenic food, aversive conditioning, carbon, diet, grizzly bear, hair, nitrogen, North Slope, stable isotope

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Introduction

Grizzly bears (*Ursus arctos*) inhabiting the Arctic Coastal Plain, which includes the North Slope oilfields, are at the northern limit of their range in Alaska, USA. Natural food resources in this area are seasonally limited and grizzly bear densities are relatively low (Shideler and Hechtel 2000). As part of a continuing investigation of grizzly bear use of the North Slope oilfields, we evaluated the response of bears to the widespread availability of anthropogenic food in the 1990s and the effects of a substantial reduction in the availability of these food sources that began in 1999 (Shideler and Hechtel 2000). Based on direct observations from air and ground of their feeding behavior, we had assigned radiomarked bears to 1 of 2 categories. We had designated bears that fed solely on natural foods as natural food (NF), and those that learned to seek out and obtain anthropogenic food ≥3 times/year as food-conditioned (FC; see Hopkins et al. 2010).

We had conducted management activities to reduce potential conflicts between bears and humans in the oilfields and Deadhorse (R. T. Shideler, unpublished data [2012]) using non-lethal methods such as hazing (Clark et al. 2003, Brabyn et al. 2005, Honeyman 2008, Hopkins et al. 2012) and translocation (Hopkins et al. 2010) and lethal removal of bears that had compromised human safety. Our experience with non-lethal methods suggested that success in preventing conflicts was in part dependent on the degree to which the bears had become food-conditioned. During this study, 20 of 24 food-conditioned adults or independent subadults had been killed by humans in conflict situations even after multiple hazing events that spanned up to 10 years for some individuals (R. Shideler, unpublished data [2009]). Therefore, we concurred with Mazur (2010) and Hopkins et al. (2012) that

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behavior of food-conditioned bears is unlikely to be modified with hazing or translocation, and management resources could be diverted to bears that would be better candidates for success. Assessing a bear's history of exploiting human food or food waste could be a useful tool for prescribing a management technique for a bear involved in a conflict situation.

Analysis of stable isotopes of nitrogen and carbon ($\delta^{15}N$ and $\delta^{13}C$) have proven useful for investigating food habits of bears (Hilderbrand et al. 1996, 1999; Ben-David et al. 2004; Bentzen et al. 2007; Edwards et al. 2011) and for identifying individuals presumed to have fed on agricultural crops or human food or food waste (Mizukami et al. 2005a,b; Greenleaf 2005; Merkle et al. 2011). Because anthropogenic foods are frequently based on C_4 plants such as corn and sugarcane (including corn-fed livestock) rather than the C_3 plant-based food webs naturally available to most bear populations, it is possible to detect the enriched $\delta^{13}C$ values from C_4 plants in bears that consume human foods (Mizukami et al. 2005b). Stable nitrogen ($\delta^{15}N$) isotope values increase by 2–5‰ with each trophic transfer and have been used to estimate the proportion of meat relative to plants in the diets of omnivorous mammals, including grizzly bears (Edwards et al. 2011). This dual-isotope approach has also been used in Yosemite National Park (California, USA) to identify American black bears (*U. americanus*) that consumed human food and to estimate the proportion of human food in the diet of those bears (Hopkins et al. 2012).

To evaluate the feasibility of using stable isotopes to identify putative FC bears without direct observation, we analyzed $\delta^{15}N$ and $\delta^{13}C$ in grizzly bear hair samples from our study area as a post hoc method to confirm the food habits of individuals that we had designated as FC or NF based on repeated observations of those bears. We also used isotope analysis to confirm the diets of 3 bears whose food habits were unknown (UNK) but had been FC in previous years or were observed near facilities that had anthropogenic food sources during the year of observation. In addition, we analyzed $\delta^{15}N$ and $\delta^{13}C$ of naturally available food items as background for investigating the chemical feeding ecology of NF bears in the study area.

Study area

The study area encompassed approximately 25,000 km^2 in the central Beaufort Sea coast region within the Arctic Coastal Plain physiographic province (Wahrhaftig 1965, Shideler and Hechtel 2000, NRC 2003). We used the term "oilfield" to include the 6 individual oilfields that encompass approximately 2,000 km^2 on the Beaufort Sea coast within the study area (Fig. 1). All but 2 of the individual fields are linked by permanent roads. The oilfield consists of approximately 1,000 km of gravel roads; a network of aboveground pipelines; >350 drill sites, processing facilities, and storage areas on gravel pads; 3 jet airports; several large hotels (i.e., camps) for housing industry personnel; and a 14-ha landfill.

Deadhorse, an industrial support service enclave adjacent to the oilfield, has also become a supply center for tourists and hunters in the area and was accessible by highway and public jet airport. There were 3 commercial hotels and numerous private companies and camps that supported oilfield operations. Although there were 5,000–10,000 people working in Deadhorse and the oilfields, there were no permanent residents.

Because of the transitory nature of the work force and the concentration of human activity, management of food waste in the oilfield was problematic. In 1999, bear-resistant food-waste bins were deployed in part of the oilfields and Deadhorse. By 2001, waste bins were deployed throughout the oilfield and an electric fence was constructed around the 14-ha landfill, and industry had implemented an aggressive training campaign about proper waste storage. These measures greatly reduced, but did not eliminate, availability of food waste.

Natural prey available for grizzly bears in the study area included arctic ground squirrels (*Urocitellus parryii*), barren-ground caribou (*Rangifer tarandus*), muskoxen (*Ovibos moschatus*), several species of microtines, and numerous species of waterbirds. Bearberry (*Arctous rubra*) was the most widespread berry, though it was not abundant. Other berries (e.g., blueberry [*Vaccinium uliginosum*], cranberry [*V. vitis-idaea*], crowberry [*Empetrum nigrum*], and soapberry [*Shepherdia canadensis*]) also occurred in some upland areas. Bears fed extensively on roots of sweet vetch (*Hedysarum alpinum*) in spring and autumn and arctic lupine (*Lupinus arcticus*) in summer; graminoids (e.g., horsetail [*Equisetum* spp.], sedge [*Carex* spp.], and cottongrass [*Eriophorum* spp.]) in early summer; and flowers or leaves of forbs (e.g., boykinia [*Boykinia richardsonii*] and coltsfoot [*Petasites frigidus*]) during mid-summer.

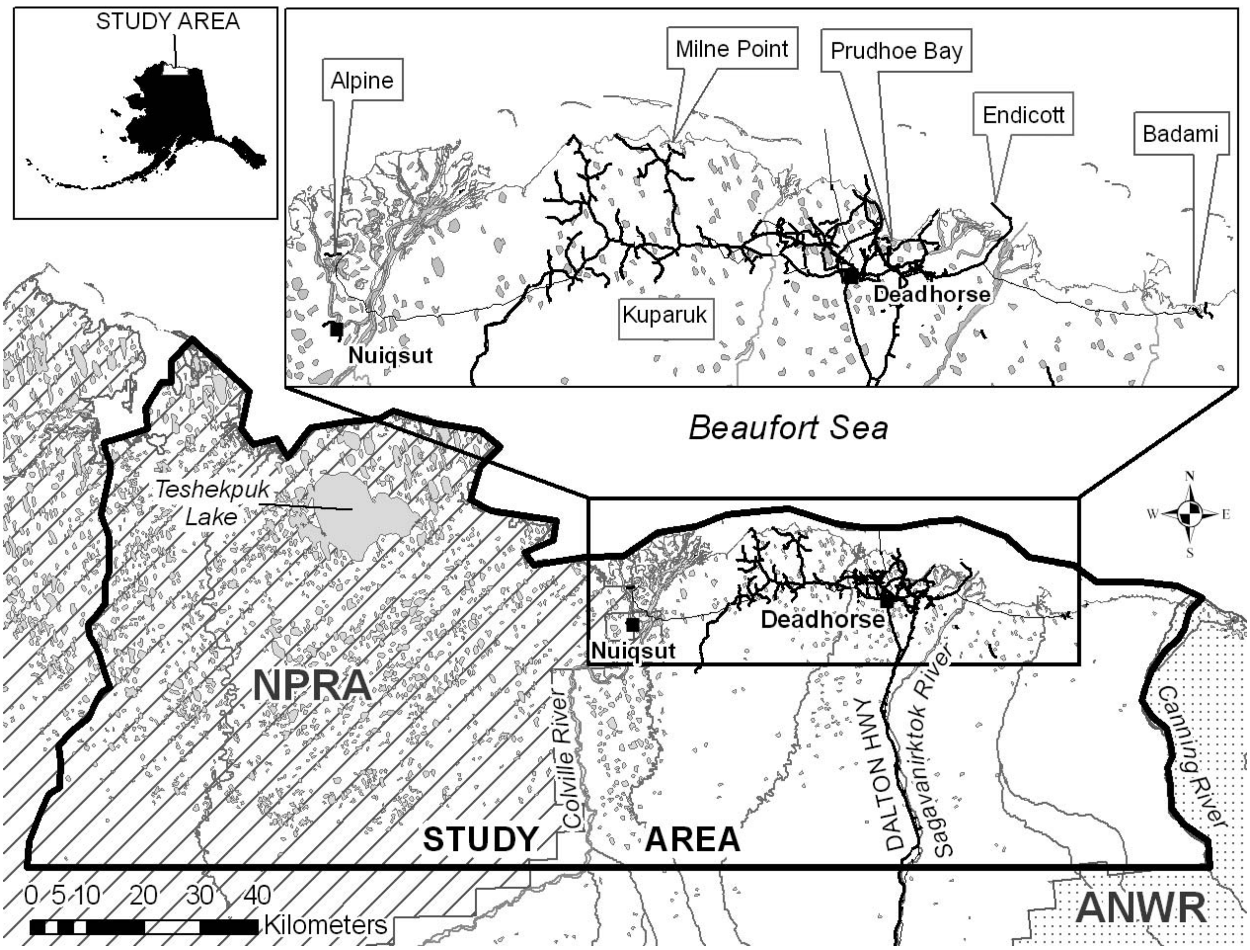

Fig. 1. Study area for the North Slope (Alaska, USA) oilfield grizzly bear project, wherein we analyzed nitrogen and carbon stable isotopes in hair samples collected between 1991 and 2006 from bears and their likely food items. Inset is the current oil and gas production area with individual oilfields identified. ANWR = Arctic National Wildlife Refuge; NPRA = National Petroleum Reserve-Alaska.

Hechtel (1985) and Shideler and Hechtel (2000) further describe grizzly bear food habits in the Brooks Range Foothills and oilfield study areas, respectively.

Methods

Capture and observations

Bears were captured from a helicopter between June and October each year from 1991 through 2006 using an immobilizing dart containing Telazol™ (Fort Dodge, Iowa, USA) fired from a Palmer Cap-Chur ™ projector (Douglasville, Georgia, USA), or with culvert traps when bears were accessible from the oilfield road system. We captured adults (i.e., >5 yr old) and independent subadults (1–5 yr old) but not dependent offspring. We took standard body measurements, collected ear-punch samples for genetic analysis, and extracted a vestigial premolar (Matson et al. 1993) for age estimation by Matson's Laboratory (Milltown, Montana, USA). We fitted bears with very high frequency (VHF) collars (Telonics, Mesa, Arizona, USA) and an individually identifiable combination of colored ear-flags. Capture and handling methods were approved by the Alaska Department of Fish and Game Institutional Animal Care and Use Committee, Protocol 03-0007. We radiotracked bears from the air using fixed-wing aircraft and from roads using vehicles. We attempted to radiotrack bears from aircraft bi-weekly and from the ground more frequently. Although not all bears could be detected from the road, we could identify individuals feeding on anthropogenic foods at facilities. In addition, reliable reports by oilfield security and environmental compliance staff allowed us to identify FC bears (defined as the bears that were observed feeding on anthropogenic food sources >3 days/yr) and compare them with bears in and adjacent to the oilfield that were observed feeding solely on natural foods (NF bears).

Sample collection and analysis

We collected full-length hairs from each captured bear by clipping near the skin or plucking loose hair along the dorsal midline between the scapular and lumbar region, and stored samples in re-sealable plastic bags. We also analyzed samples of known grizzly bear foods for $\delta^{15}N$ and $\delta^{13}C$. These included freeze-dried muscle samples from arctic ground squirrels, lemmings (*Lemmus sibiricus* and *Dicrostonyx groenlandicus*), voles (*Microtus* spp.), caribou, and various plants and berries known to be eaten by bears and collected opportunistically throughout the study area (Table S1). We analyzed full-length caribou hair collected in June 2004 from the Teshekpuk Lake Herd and Central Arctic Herd, whose distributions overlapped the study area. Two human hair samples from the investigators (TWB and RTS) were also analyzed to compare the stable isotope signature of humans within the study area to published values for humans elsewhere and to examine isotopic overlap between humans, grizzly bears, and their naturally available foods.

Tissue samples were prepared for analyses at the University of Alaska-Fairbanks Wildlife Toxicology Laboratory, and $\delta^{15}N$ and $\delta^{13}C$ analyses were conducted at the Alaska Stable Isotope Facility as described by Bentzen et al. (2007). We measured 0.2–0.4 mg of hair into a tin capsule and analyzed for stable nitrogen and carbon isotope values using a Carlo Erba NC 2500 (New York, New York, USA) elemental analyzer coupled to a continuous-flow isotope-ratio mass spectrometer. Stable isotope compositions were reported using standard δ notation and were referenced to air for nitrogen and Vienna PeeDee Belemnite for carbon. Analysis of a peptone standard (Sigma Chemical Co., Highland, Illinois, USA) during the sample run for both $\delta^{15}N$ and $\delta^{13}C$ suggested analytical precision of ±0.2‰ and ±0.1‰, respectively.

We used generalized linear models to examine relationships between $\delta^{15}N$ and $\delta^{13}C$ values and bear age (years), sex, capture year, and diet designation (either FC or NF). We only included the first year a bear was sampled to ensure independence of samples. First, we examined the effects of bear age, capture year, and sex on the $\delta^{15}N$ and $\delta^{13}C$ isotope values of all bear hair samples irrespective of diet status with a multiple-regression model. Second, we examined multicollinearity among all covariates and used analysis of covariance to determine the effects of food status (FC vs. NF) and capture month on $\delta^{15}N$ and $\delta^{13}C$ isotope values when controlling for sex, age, and capture year. All residuals were examined for normality (Shapiro–Wilk test, $P > 0.05$), outliers, influential observations, and homoscedasticity.

In some years, we observed bears near facilities where anthropogenic food was available, but we never observed them feeding there. Because we could not confirm their food habits by direct observation, we designated these bears as unknown (UNK) and compared their isotopic signatures with those of FC and NF bears. All analyses were conducted using SAS® version 8.0 (1990; SAS Institute Inc., Cary, North Carolina, USA), with α set at 0.05.

Results

We collected 51 hair samples from 30 individual bears between 1991 and 2006 (Table S2). These included 18 hair samples from 12 bears known to be FC in the first year sampled, 25 samples from 15 NF bears, and 8 samples from 3 UNK bears. Overall, $\delta^{15}N$ values ranged from 3.3‰ to 8.2‰ (5.3‰ ± 0.16‰, mean ± SE), and $\delta^{13}C$ values ranged from −24.6‰ to −18.8‰ (−22.2‰ ± 0.20‰). The mean $\delta^{15}N$ and $\delta^{13}C$ values of the samples from FC bears were 6.3‰ ± 0.26‰ and −20.8‰ ± 0.30‰ (SE) compared with 4.8‰ ± 0.12‰ and −23.2‰ ± 0.14‰ for the samples from NF bears (Table S2). The range in $\delta^{15}N$ values from the samples from the UNK bears was 3.3‰ to 6.1‰ (4.6‰ ± 0.40‰), and $\delta^{13}C$ ranged from −23.6‰ to −21.4‰ (−22.6‰ ± 0.22‰; Table S2).

The $\delta^{15}N$ and $\delta^{13}C$ values for humans did not overlap any of the individual diet items and did not fall within 95% confidence intervals of any naturally available food category (Table S1).

Overall, $\delta^{13}C$ values decreased with bear age ($F_{3,23} = 5.78$, $P = 0.002$). The mean age of FC bears (3.7 yr) was younger than NF bears (18.3 yr; $F_{1,25} = 5.55$, $P = 0.03$). $\delta^{13}C$ values varied between NF and FC bears (Fig. 2) when controlling for age, year, and sex ($F_{1,\ 22} = 47.53$, $P < 0.001$). Mean $\delta^{13}C$ values were lower for NF bears (−23.05‰ ± 0.77, $n = 15$)

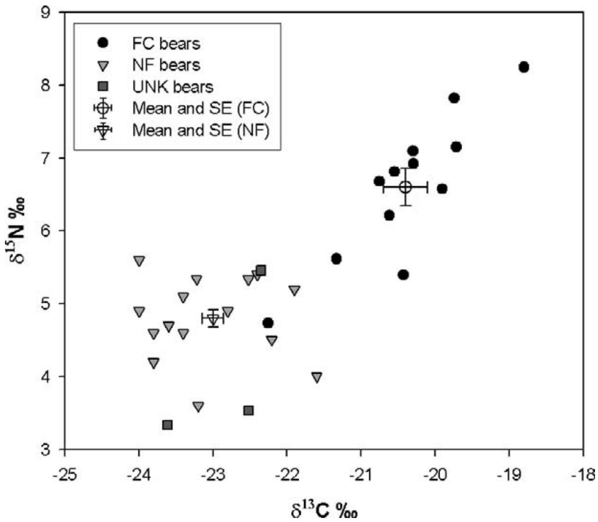

Fig. 2. Diet type and individual $\delta^{15}N$ and $\delta^{13}C$ stable isotope values of hair samples collected from 30 grizzly bears between 1991 and 2006 in the North Slope oilfield region, Alaska, USA. Mean (±SE) values are shown for bears categorized as human-food-conditioned (FC) and bears categorized as feeding predominately on natural foods (NF). UNK indicates bears whose diet source was unknown.

than for FC bears (−20.39‰ ± 0.87, $n = 12$). $\delta^{13}C$ values of the UNK bears were lower than the FC but not the NF bears ($F_{2,27} = 37.69$, $P < 0.001$). $\delta^{13}C$ did not vary with sample month ($F_{3,22} = 1.63$, $P = -0.22$).

Overall, $\delta^{15}N$ values also decreased with bear age ($F_{3,23} = 2.94$, $P = 0.05$). $\delta^{15}N$ values varied between NF and FC bears (Fig. 2) when controlling for age, year, and sex ($F_{1,\ 22} = 22.35$, $P < 0.001$). Mean $\delta^{15}N$ values were lower for NF bears (4.79‰ ± 0.56, $n = 15$) than for FC bears (6.6‰ ± 1.00, $n = 12$). $\delta^{15}N$ values of the UNK bears were lower than the FC but not the NF bears ($F_{2,27} = 20.50$, $P < 0.0001$). $\delta^{15}N$ did not vary with sample month ($F_{3,22} = 1.27$, $P = 0.3$).

We compared $\delta^{15}N$ and $\delta^{13}C$ values for 3 bears for whom we had multi-year samples (Table 1) and whose designated diet status varied among years (Fig. 3). Bear 005, a male sampled from ages 3 to 11 years, switched from a predominantly FC diet to NF diet. Isotope values from bear 006, a female sampled from ages 4 to 18 years, indicated that she was FC in 2005, but NF in 1992, 1994, and 1999. Isotope values from bear 023, a female sampled from ages 2 to 14 years, were consistent with her switching from NF to FC as she had cubs, then converting to NF as anthropogenic food management improved after 2001.

Discussion

Isotope signatures of major food items of North Slope bears and comparisons of NF with FC bears have not been reported previously. The $\delta^{15}N$ values of NF bears varied by more than one trophic level (3.3–8.2‰), indicating a highly variable diet among bears sampled (Table S2). Because of this diverse diet, specific food sources would be difficult to distinguish using only $\delta^{15}N$ and $\delta^{13}C$ values because of the large isotopic overlap among most prey categories (Table S1). The $\delta^{15}N$ values of most NF bears were similar to caribou, muskoxen, microtines,

Table 1. Changes in diet status for 2 female and 1 male grizzly bear(s) between 1991 and 2006 in the North Slope oilfield region, Alaska, USA. FC = food-conditioned (bears observed feeding on anthropogenic food sources >3 days/yr); NF = natural food (bears in and adjacent to the oilfields observed feeding solely on natural foods); UNK = diet source was unknown.

Bear ID	Sex	Sample date	Hair growth year[a]	Diet source from isotopes	Diet source from field observation
005	M	26 Jul 1991	1990	FC	FC
		21 Jul 1992	1991	NF	FC
		28 Jun 1993	1992	NF	UNK
		10 Aug 1999	1999	NF	NF
006	F	16 Oct 1992	1992	NF	NF
		4 Sep 1994	1994	NF	FC
		23 Jun 1999	1998	NF	FC
		19 Aug 2005	2005	FC	FC
023	F	8 Jul 1996	1995	NF	NF
		26 Jun 2001	2000	FC	FC
		7 Aug 2004	2004	NF	NF
		6 Sep 2006	2006	NF	NF

[a]Yr in which most hair growth likely occurred.

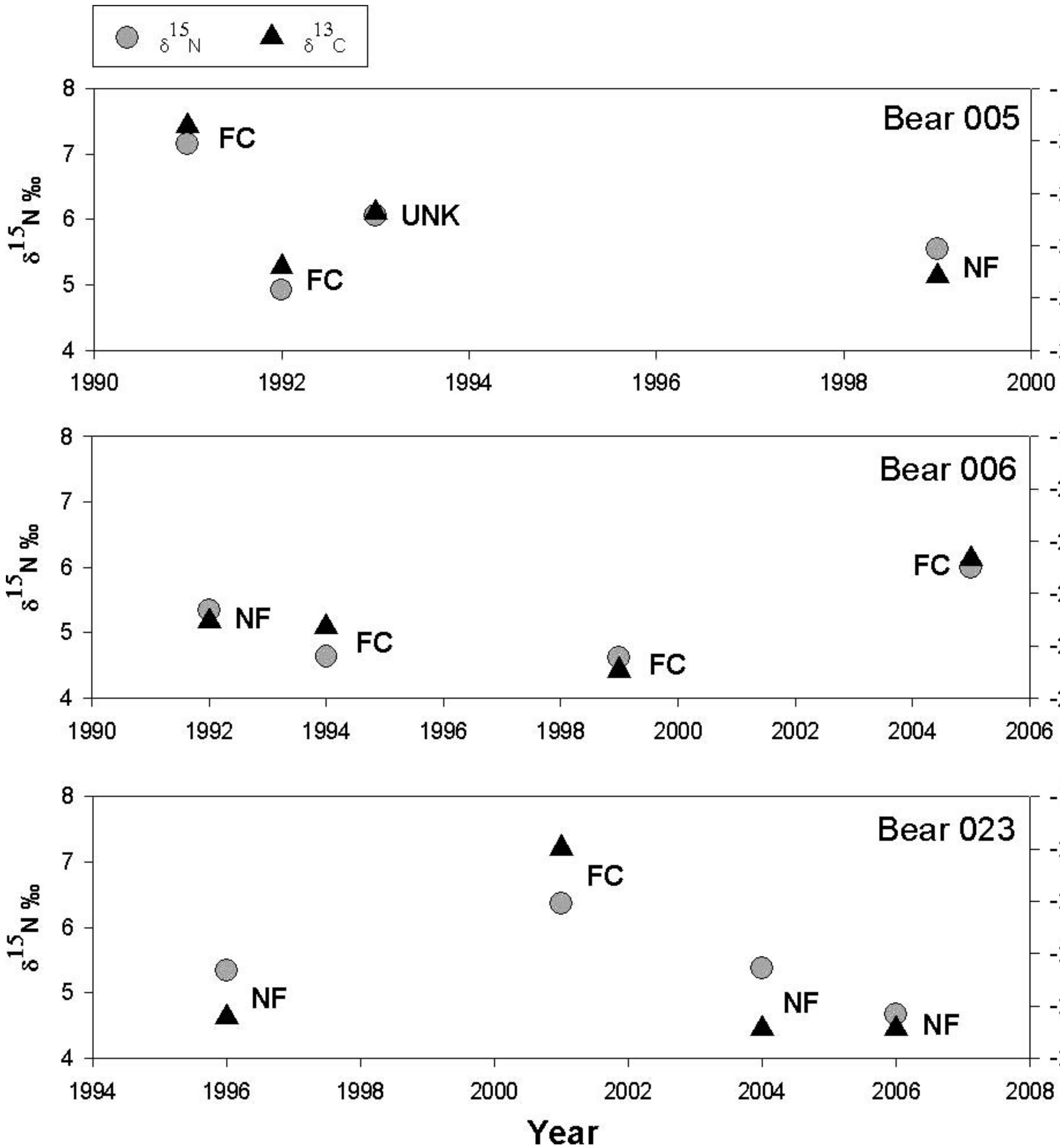

Fig. 3. $\delta^{15}N$ and $\delta^{13}C$ stable isotope values of 3 North Slope (Alaska, USA) grizzly bears that changed assigned diet status based on field observations between feeding on natural food (NF) only and feeding on anthropogenic foods (FC) between 1991 and 2006. Diet status labels are based on field observations. UNK = year in which diet status not confirmed.

and Arctic ground squirrels, indicating a diet composed mainly of vegetation. This result agrees with qualitative scat analysis and non-systematic observations of bear food habits in the oilfield region (Shideler and Hechtel 2000), Brooks Range Foothills (Hechtel 1985), adjacent Yukon Territory (MacHutchon and Wellwood 2003), and the Mackenzie River delta (Edwards et al. 2011). Although grizzly bears in this region are less carnivorous than those in other populations (Mowat and Heard 2006, Edwards et al. 2011), arctic ground squirrels and microtines are important seasonal diet items for some individuals (Shideler and Hechtel 2000). Although a large portion of meat in the diet may have elevated $\delta^{15}N$ values of some individuals, it is unlikely to account for the large range we observed in $\delta^{13}C$ values among all bears. Local variability in $\delta^{13}C$ values of plants and animal prey likely caused some variation among individual bears, but the high $\delta^{13}C$ values we observed for FC bears exceeded that of most grizzly bear prey and suggested a food source not available to most other North Slope bears.

Alternative food sources that could have accounted for the higher $\delta^{13}C$ in FC bears included marine mammals (Hoekstra et al. 2002), anadromous fish (Kline et al. 1998), or anthropogenic food (Darr and Hewitt 2008). Ringed seals (*Pusa hispida*) and bearded seals (*Erignathus barbatus*), both abundant in the Beaufort Sea, are potentially available to grizzly bears along the coast. One NF male (bear 083 in 2002; Table S2) successfully hunted for ringed seal pups on land-fast ice for a few weeks in spring 2002 and 2007, but we did not observe other bears hunting seals. Furthermore, $\delta^{15}N$ values for seals are approximately 16–17‰ (Hoekstra et al. 2002), well above the values for the FC bears, further indicating that seals were not responsible for the high $\delta^{13}C$ values of FC bears. In addition, during hundreds of hours of aerial surveys, radiotracking flights, and ground observations, we observed grizzly bears scavenging on marine mammal carcasses only once. Within the study area, shallow coastal waters and barrier islands along the Beaufort Sea coast probably intercepted most drifting carcasses and prevented them from reaching shore; therefore, their availability to grizzly bears was likely minimal. The relatively few carcasses that may have reached shore or nearby barrier islands were likely scavenged by polar bears (*U. maritimus*) before grizzly bears found them. Grizzly bears were occasionally observed fishing, but anadromous fish were an unlikely source for the elevated $\delta^{13}C$ values of FC bears. There have been isolated occurrences of Pacific salmon (*Oncorhynchus* spp.) in the study area (ADFG 2012), but there were no major salmon runs and few areas of suitable fishing habitat where bears could catch them. Dolly Varden trout (*Salvelinus malma*) occurred in several rivers, and their $\delta^{13}C$ values were in the same range as those of FC bears. However, Dolly Varden $\delta^{15}N$ values ranged from 10‰ to 12‰, which was considerably higher than those of FC bears. The most parsimonious explanation for the higher $\delta^{13}C$ values of FC bears was that their diets included substantial portions of anthropogenic foods derived from a C_4-based food web.

Both $\delta^{15}N$ and $\delta^{13}C$ decreased with bear age, suggesting that older bears became more proficient at foraging for natural foods and were less likely to consume anthropogenic foods. Alternatively, this relationship may reflect the small number of FC bears among the older age cohorts. Many FC bears were killed in conflict situations during this study as the availability of anthropogenic foods decreased.

Food-conditioned bears generally had higher $\delta^{13}C$ values than did NF bears or other mammals in the region, likely due to the high $\delta^{13}C$ values of corn or sugarcane in anthropogenic foods. Food-conditioned bears with the highest $\delta^{15}N$ and $\delta^{13}C$ signatures in their hair showed values similar to those in human hair collected from the oilfield area; Missouri, USA (Hopkins et al. 2012); and the United States as a whole (Bowen et al. 2009); as well as England, Germany, and Japan (O'Connell and Hedges 1999, Mizukami et al. 2005a, Petzke et al. 2005). This suggests that the recent diets of these bears were composed almost entirely of human foods.

The differences we observed in $\delta^{13}C$ values between NF and FC bears contrasted with the lack of difference in $\delta^{13}C$ values in hair between NF and FC black bears within Yosemite National Park, California (Hopkins et al. 2012) and between NF and FC Asiatic black bears (*U. thibetanus*) in rural agricultural areas of Nagano Prefecture, Japan (Mizukami et al. 2005b). The differences we measured in $\delta^{15}N$ and $\delta^{13}C$ values between NF and FC bears were likely due to the greater amount and consistent availability of human foods to FC bears in the North Slope oilfields, especially before 2001. Both Greenleaf et al. (2009) and Hopkins et al. (2012) estimated relatively small proportions of human foods in the diets of FC black bears in Yosemite based on scat and stable isotope analysis, respectively. Furthermore, food items from Alaska's Arctic Coastal Plain are depleted in $\delta^{13}C$ relative to the Yosemite ecosystem (Greenleaf 2005), which together with more consistently available human food in the North Slope oilfield likely contributed to the greater difference in $\delta^{13}C$ we observed between FC and NF grizzly bears.

Isotope values of the 5 bears designated as UNK fell within the range of NF bears. All of these individuals had foraged within a few hundred meters of facilities but had not been observed to seek out anthropogenic food in spite of ample opportunities to do so. Confirmation that they were likely not strongly food-conditioned suggested that, all other conditions being equal, they would be suitable candidates for non-lethal management should they begin to engage in conflict activity.

To examine how changes in stable isotopes signatures can be used to predict changes in diet category, we compared observed diet history of 3 bears with changes in their $\delta^{15}N$ and $\delta^{13}C$ values (Fig. 3; Table 1). Bear 005 was initially FC but changed to NF as he matured. Although in 1992 he met our strict criteria for FC, his isotopic signature fell within the NF range, likely because the hair was sampled early in the year and reflected his previous summer's diet. Bear 006 also met our criteria for FC but usually fed on anthropogenic sources during early spring and autumn. Her isotopic signatures and the time of sampling did not always match her diet designation. Although she was designated FC 3 of 4 years, her isotopic signatures were within the NF range for 2 of those years. This discrepancy can also be explained by the timing of her hair sample. For example, 006 spent the latter part of 2004 feeding on anthropogenic food (FC) but spent much of 2005 as NF (feeding on natural foods). When sampled in late summer with a yearling at heel, her signature remained FC, likely because she was still shedding hair from 2004 when sampled. Bear 023 started as NF, became FC as she had her first litter but returned to NF as local garbage management improved, and perhaps due to management actions that included active hazing. These examples demonstrated that interpretation of stable isotope values from hair, while broadly reflective of food habits, should be interpreted cautiously unless augmented with knowledge of regional patterns of hair growth and seasonal use of food resources.

Although we analyzed intact hair, which represented diet assimilation during the period of hair growth, samples of feces, serum or whole blood could provide assessment of the bear's diet from the most recent day to several weeks, respectively (Hilderbrand et al. 1996, Kurle and Worthy 2002, Crait and Ben-David 2007). However, sampling of blood requires capture and immobilization of the target animal, which is not always feasible. If sampling were limited to hair collected opportunistically, analysis of hair segments could provide an estimate of feeding history (Mizukami et al. 2005a) if regional patterns of hair growth are known (Jones et al. 2006).

We caution that our results pertain to a bear population that does not inhabit areas with access to abundant anadromous fish or marine mammals or that are not deliberately fed C_4 plants such as corn or oats for diversionary feeding or baiting for harvest or tourism. Elevated $\delta^{15}N$ and $\delta^{13}C$ values from diets rich in these sources could mask the signatures of anthropogenic foods. In these situations, analysis of stable isotopes of other elements such as sulfur or mercury (e.g., Fellicetti et al. 2004) may provide additional insight into local bear diets.

Management implications

Management agencies rarely have sufficient resources to engage in intensive efforts to rehabilitate food-conditioned bears. Non-lethal management techniques such as hazing, relocation, or translocation are labor-intensive and have variable success (Brabyn et al. 2005, Honeyman 2008, Mazur 2010, Hopkins et al. 2012). Bears with a history of anthropogenic food use are less likely to respond favorably to non-lethal intervention. In bear conflict situations, agencies must identify a management prescription and implement it rapidly. When deciding on mitigating measures, managers should consider a bear's reactivity to humans, activity periods (e.g., night vs. day; Clark et al. 2002), and conflict setting (e.g., urban vs. wildland), along with the bear's history of anthropogenic food use. In bear populations where the degree of human food use is sufficient for FC bears to be isotopically distinct from NF bears, stable isotope values could be used to assist in making appropriate management decisions when field observations are inadequate.

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Supplemental material

Table S1. Isotope data ($\delta^{15}N$ and $\delta^{13}C$) of plant and terrestrial mammal food items of grizzly bears, collected from 1991 to 2006 in the North Slope oilfield region, Alaska, USA. TLH = Teshekpuk Lake Herd caribou; CAH = Central Arctic Herd caribou. Muskoxen data from Barboza and Reynolds (2004).

Table S2. Isotope data ($\delta^{15}N$ and $\delta^{13}C$) of hair samples of 30 individual grizzly bears feeding on natural foods (NF), anthropogenic foods (FC [food-conditioned]), and unknown food sources (UNK), collected from 1991 to 2006 in the North Slope oilfield region, Alaska, USA.