

Nutritional ecology of grizzly bears across the Northern Continental Divide Ecosystem

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Abstract

The Northern Continental Divide Ecosystem (NCDE) population is currently in the process of moving to eventual consideration for delisting under the Endangered Species Act. Recent estimates of population growth rate (2004–2012) indicate that it is likely increasing. From 2009–2012, we documented apparent population health by investigating food habits and resulting physiological outcomes of ingested foods associated with habitats used. Analysis of carbon and nitrogen stable isotopes provided information on percent terrestrial meat, plant matter, and anthropogenic foods in the diets of captured NCDE bears ($n = 296$). We also estimated body fat content of captured bears ($n = 199$). We found that the use of animal matter differed within the grizzly bear population. Adult females used less meat when compared to subadults and adult males ($P < 0.0001$). Regions on the southwestern, southern, and eastern periphery of the ecosystem used a significantly higher proportion of meat than those in the interior or northwestern periphery ($P < 0.0001$). For example, diets of bears in the Whitefish Mountains and North and South Fork of the Flathead River were, on average, composed of 70% less meat than those on the East Front. Use did not differ by year, indicating minimal fluctuation in this resource among years for the time period monitored, 2009–2012. Body fat content of NCDE grizzly bears differed by sex and age. Adult males had significantly higher den entrance fat contents than adult females and subadults ($P < 0.0001$). However, adult females entered dens at estimated mean fat levels above those thought to be critical for cub production (i.e., $> 20\%$), with confidence limits of female bears reaching below this threshold only in the southern and southwestern periphery and western interior and periphery of the ecosystem. Average body fat

content did not significantly differ across the ecosystem. Thus, we conclude that the widely varying food resources across the NCDE are adequate to meet the needs of reproductively-active adult females. As truly opportunistic omnivores, grizzly bears in the NCDE can likely exploit diverse combinations of food items across the NCDE to arrive at similar, healthy body conditions.

Background

The Northern Continental Divide Ecosystem (NCDE) contains the largest remaining grizzly bear population within the U.S., and targeted efforts towards the conservation and eventual recovery of this population have been in place since the species' listing in 1975. The greater NCDE represents an expansive landscape with a diverse collection of grizzly bear habitats. As such, the types and amounts of foods that support grizzly bears vary widely across the ecosystem, mainly west and east of the Continental Divide. Various studies have assessed food habits at different times and in different locations across the ecosystem (Servheen 1983, Mace and Jonkel 1986, Aune and Kasworm 1989, McClellan and Hovey 1995). Food items are diverse and spatially unique, including roots and corms (e.g., *Hedysarum*, *Lomatium* spp.), fruits (e.g., *Vaccinium* spp., *Shepherdia* spp., *Rhamnus* spp., *Amelanchier* spp., *Sorbus* spp.), Umbelliferous forbs (e.g., *Heracleum lanatum*, *Angelica* spp., *Osmorhiza* spp.), other green vegetation (e.g., *Equisetum* spp., *Carex* spp., graminoids), animal matter, and presumably whitebark pine mast when available, with relative proportions of major food groups and foods within groups varying widely across regions of the ecosystem.

While limited in availability in some regions, animal matter (i.e., meat) is an important food item in portions of the NCDE. Relative to herbaceous foods, meat provides a superior amount of highly-digestible protein and energy that can influence productivity of grizzly bear populations (Hilderbrand et al. 1999). For this reason, we would expect variation in productivity of females across the ecosystem to be influenced by differences in seasonal and regional availability of meat.

Previous research in this and other ecosystems indicates that the nuts of whitebark pine, where available, may be an important food for some grizzly bears (Felicetti et al. 2003, Aune and Kasworm 1989). Due to their high fat content, whitebark pine nuts are a high quality food relative to other plant matter when they are available. Whitebark pine has declined significantly in the NCDE primarily due to white pine blister rust (*Cronartium ribicola*) and fire exclusion (Keane et al. 1994). Nevertheless, Aune and Kasworm (1989) documented limited use of whitebark pine nuts by grizzly bears in high elevations along the Eastern Front of the NCDE. Whitebark pine nuts were reported to be historically used by bears in the Mission Mountains (B. Cheff, pers commun.) but presently are used little (Mace and Jonkel 1986) due to the decline in whitebark pine due to blister rust.

Because of the wide variation in diets of NCDE grizzly bears and the spatial breadth of the ecosystem, it is not feasible to maintain on-the-ground monitoring of availability and use of each major food, especially herbage and fruit-bearing shrubs. With sufficient sample sizes, it is possible to use ratios of stable isotopes in food items to monitor inferred assimilated diets (i.e., that which is digested and metabolically used) of grizzly bears (Robbins et al. 2004). As an

example, ratios of ^{15}N to ^{14}N ($\delta^{15}\text{N}$) become higher with increasing trophic level, allowing distinction between a plant-based, animal-based, or mixed diets.

Assessing assimilated diet with stable isotope analysis offers estimates of the relative dietary proportions of food groups incorporated into the animal via digestion and metabolism of energy (Hilderbrand 1996). Various tissues represent assimilated diet of the animal during short (plasma) or long (hair) periods of time, rather than the short window of insight offered by scat analysis (Robbins et al. 2004). Within the animal, metabolically active tissues (hair, blood components, etc.) incorporate material that reflects the isotopic ratio of the animals' diet. Hence, ratios of hair provide a catalogue of the assimilated diet during its growth period (approximately, summer to fall). Further, hairs can be segmented by length to assess changes in ingestion during the time of growth. In comparison, the turnover rate of blood components allows for shorter-term estimates of assimilated diet; ratios from blood plasma reflect the 1–2 weeks of digested diet prior to collection, while red blood cells reflect the recent 2–3 months of diet.

Habitat health and gross availability of high-quality foods can be measured indirectly by assessing the physiological condition of animals. Bioelectrical impedance analysis (BIA) provides an estimate of fat content of captured grizzly bears (Farley and Robbins 1994, Hilderbrand et al. 1998). Because ratios of lean body mass to fat mass vary widely from spring to fall, depending on available foods, these values provide insight into past nutrition and resulting body condition of individual bears. Monitoring fat content and lean body mass to fat ratios in all bears captured allows for a better understanding of how body condition varies by sex and age and location of the bear within seasons. These estimates also provide information on whether females meet physiological requirements (primarily, high body fat content before denning, > 20%) for successful bearing of offspring (Robbins et al. 2012). Body fat content of captured bears offers a measurement of the physiological outcome of assimilated diet and is a potential predictor of reproductive success of females.

Understanding the complex nutritional ecology of grizzly bears, especially in light of current and potential changes in available food items, will support better understanding of habitat and bear conditions and inform and improve conservation decisions for the NCDE population. We collected data on assimilated diet, body condition, and reproductive effort of a representative sample of grizzly bears within the greater NCDE and compared those parameters to management status, sex, and age of the bears. Objectives included establishing baseline data on assimilated diets and body conditions of bears across the ecosystem, assessing whether assimilated diet influences body condition, reproductive success of females, management status, and assumed density of bears across the Ecosystem. This research continues recovery efforts by investigating how assimilated diets of individual grizzly bears 1) vary across the ecosystem and 2) influence population health. Further, we have investigated ecosystem-wide patterns in gross assimilated diet and body condition of grizzly bears over a uniform time period. Analyses are currently underway to assess if it is possible to estimate use of whitebark by grizzly bears in this ecosystem.

Methods

Hair and blood samples were collected from captured animals by federal and state managers and researchers. Grizzly bears were captured via leg-hold snares, culvert traps, or free-range darting. Captured bears were immobilized with combinations of either tiletamine/zolazepam, tiletamine/zolazepam/medetomidine + atipamezole antagonist, or tiletamine/zolazepam/dexmedetomidine + atipamezole. Drug administration and humane handling procedures were the responsibility of agency or tribal team leaders and generally followed those within Kreeger and Arnemo (2007). Hair samples and premolar teeth were collected to establish genotype and age of the bear. Hair samples were collected by shaving the hair at the skin. Lab personnel sorted hair samples by underfur and guard hair. Blood samples were collected from most individuals. Sampled blood was centrifuged into red blood cell (RBC) and plasma portion and stored frozen until isotopic analysis. Some hair samples from known individuals were opportunistically collected throughout the study area.

At time of capture, individuals were given age class, location, and management status designations. Bears less than 5 years old and verified with an adult female at time of capture were classified as dependents. Those less than 5 years old and not accompanied by an adult female (verified or unverified) were classified as subadults. Adults (≥ 5 years of age) were classified as either adult males or adult females. One of 7 distinct ecoregions of the NCDE was assigned to the location of each capture event (Figure 1). We classified bears under management or non-management status according to the following rule set (adapted from Hopkins et al. 2010). Regardless of capture site, only bears implicated as causing a conflict (i.e., a situation of displayed habituation, conditioning, offensive aggression, or predation) immediately before or any time prior to capture were designated as management bears. Bears that were dependent offspring of concurrent conflict females were designated as management bears. Unknown circumstances during natural or human-caused bear mortalities can present difficulty in assigning management status. If circumstance is unknown, prior status may dictate designation at time of death. Dead bears were given conflict status only in circumstances in which there was credible evidence of displayed habituation, conditioning, offensive aggression, predation prior to death. As such, defense of life situations were assessed on a case-by-case basis, with credible information weighing heavily into our designation. Lastly, non-management bears could be relabeled as management bears, but management bears could never transition to non-management status.

Samples were analyzed for stable isotope ratios to estimate the assimilated diet of each bear. Because hair and blood are metabolically active for different time periods, isotope signatures will represent the assimilated diet of the animal for that same time period. In general, blood isotope signatures represent a shorter window in time than hair samples. We used these metabolic differences to our advantage as multiple samples collected from one animal can indicate the diet of that animal over weeks to months. Isotope data were analyzed to determine intake of plant matter and meat and was characterized by month, sex, age, reproductive status, area of capture, and management status. Unless otherwise indicated by the collector, hair collected before August 1 was considered as the previous year's growth; that collected after August 1 was classified as the current year's growth. We also analyzed a representative set of

foods from the NCDE to understand the variation in isotope signatures of foods and establish ecosystem-specific isotopic values for diet sources.

All blood and plasma samples were freeze-dried and ground prior to stable isotope analysis. Food items were also freeze-dried and homogenized. Hair samples were rinsed with a 2:1 chloroform:methanol solution to remove surface contaminants and ground to homogenize the sample. We weighed and sealed ground samples into tin boats for isotopic analysis (Hilderbrand et al. 1996). Isotope ratios of $\delta^{13}\text{C}$, $\delta^{15}\text{N}$, and $\delta^{34}\text{S}$ were assessed by continuous flow methods using an elemental analyzer (ECS 4010, Costech Analytical, Valencia, California) and a mass spectrometer (Delta PlusXP, Thermofinnigan, Bremen, Germany) (Brenna et al. 1997, Qi et al. 2003).

We used SIAR V4, implemented through the R statistical package, for our stable isotopic mixing model calculations (Parnell et al. 2010). While SIAR uses a Bayesian framework, we chose to include no prior information in our models. Program SIAR was particularly attractive because it incorporates variation among source isotopic compositions and fractionations. To provide a higher resolution of assimilated foods, we limited our possible diet sources to the number of isotopes analyzed + 1 (Phillips 2001). We ran both 2-source (animal + plant matter) and 3-source (animal + plant + anthropogenic foods) mixing models. Anthropogenic (i.e., human) foods, those foods consumed by humans, are known to contain high levels of corn, a plant which has an elevated carbon isotope signature. On average, human food also has an elevated nitrogen signature (i.e., a relatively high composition of meat). Consequently, this food source is best represented by human refuse. However, corn-fed livestock, a common food source for some East Front bears, have similar isotopic ratios to human refuse (Bahar et al. 2005; Jahren and Kraft 2008). Thus, we define "human food" consumed by bears as both human refuse and corn-fed livestock consumed by bears. Source isotopic values for human foods were estimated directly from the isotopic analysis of human hair (Hopkins et al. 2012). All other isotopic values of diet sources and all fractionations were taken from the literature (Robbins et al. 2005, Fortin et al. 2007, Hopkins et al. 2012, Fortin et al. 2013, J. E. Teisberg, unpublished data). We assumed equal diet-to-tissue fractionation of all tissue types analyzed (Hilderbrand et al. 1996). Analysis of Variance (ANOVA) and post-hoc Tukey-HSD tests were performed in statistical program R to test for differences in $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ isotope signatures across all factors. Factors included management status, sex, age class, reproductive status, year of capture, month of capture, and ecosystem region. Means are reported \pm standard error (SE).

We relied on field capture teams to collect measurements (body mass, body length, and electrical resistance) to estimate body condition on captured bears, as in Farley and Robbins (1994). These measurements allowed for the estimation of body condition, an important indicator of quality of food resources and a predictor of cub production. All field teams were equally trained to accurately collect these data. Body condition indices (body fat content, lean body mass to fat mass ratios) were measured on all captured bears and were characterized by sex, age class, reproductive status, area of capture, and management status. Time of year can influence body fat measures. We standardized body fat contents among bears by extrapolating values to a projected body fat at den entrance (October 25) using a 2nd order regression upon the entire dataset. ANOVA and post-hoc Tukey-HSD tests were performed to test for differences in

body composition across all factors. Factors included management status, sex, age class, reproductive status, year of capture, month of capture, and ecosystem region.

Location data collected from GPS and VHF collared bears from the NCDE Population Trend Monitoring Study (Mace et al. 2012) allowed us to monitor the reproductive productivity of individual bears. We will use aerial observations to investigate possible associations between female reproductive success and cub recruitment relative to female body condition. We also plan to compare the use of certain foods with reproductive success (primarily, cub production and cub recruitment) between individuals across the NCDE ecosystem.

Results and Discussion

Isotopic content and assimilated diet

Grizzly bear tissue samples from 248 captures were analyzed to determine assimilated diets of NCDE grizzly bears (Fig. 1).

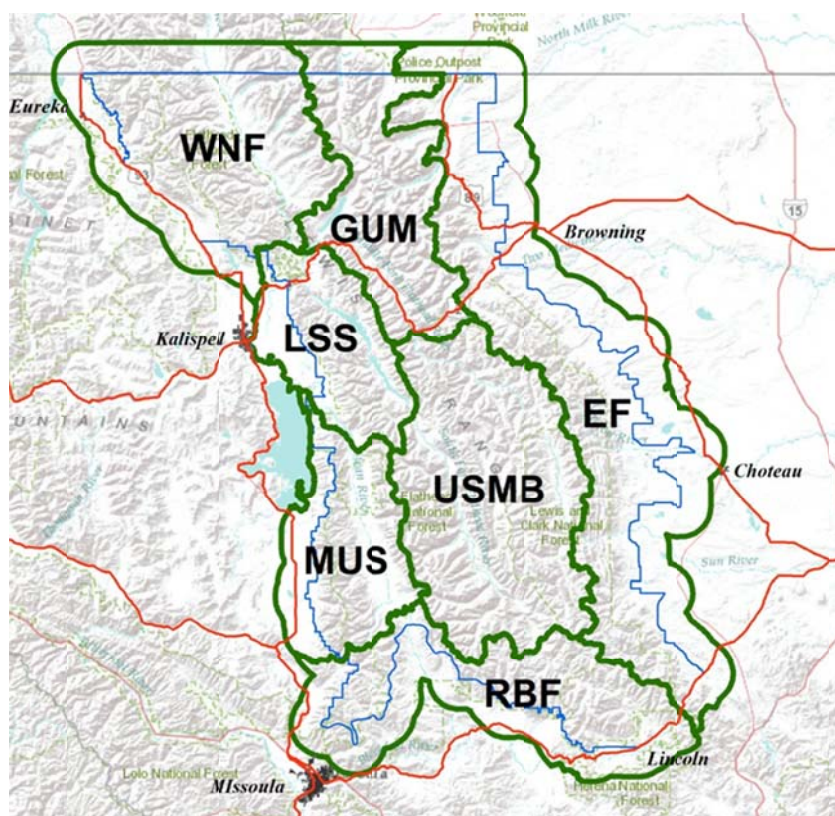


Figure 1. Northern Continental Divide Ecosystem study area and ecoregions used in analysis of body condition and assimilated diet (WNF = Whitefish Range and North Fork Flathead River; GUM = Glacier National Park and Upper Middle Fork Flathead River; LSS = Lower Swan River and Lower South Fork Flathead River; USMB = Upper South and Middle Forks of the Flathead River and Bob Marshall Wilderness; EF = East Front; MUS = Mission Mountains and Upper Swan River; RBF = Rattlesnake Wilderness and Blackfoot River). The NCDE Grizzly Bear Recovery Zone boundary is also displayed (blue outline).

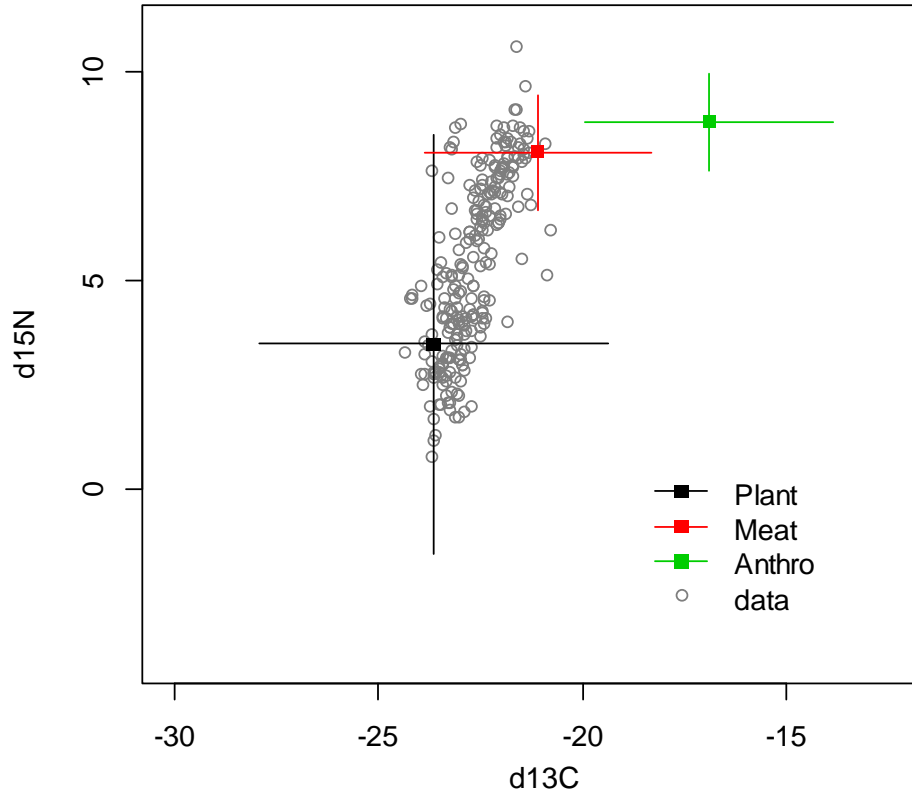


Figure 2. Guard hair isotope signatures of NCDE grizzly bears ($n = 296$) overlaid upon hypothetical values if a bear were to consume each food item as 100% of its diet. Error bars represent variation in 1) isotopic ratios of sources and 2) diet-to-bear isotopic discrimination.

Isotopic values occurred within the predicted space (i.e., between values of the major foods included in the analysis; Fig. 2). Adult females had significantly lower nitrogen isotope values (4.3 ± 0.24) when compared to subadults and adult males (4.5 ± 0.22 and 6.0 ± 0.31 , respectively) ($P < 0.0001$). Nitrogen signatures did not differ by year, indicating minimal fluctuation in the meat resource among the years sampled. The assimilated diet of adult males averaged $56 \pm 11\%$ terrestrial meat while adult female diets consisted of $34 \pm 9\%$ meat. On average, adult male meat % values in the NCDE are higher than those of male grizzly bears in the interior of the Yellowstone Ecosystem (Yellowstone males = 45%); however, NCDE adult female values are lower than their Yellowstone counterparts (Yellowstone females = 38%) (Fortin et al. 2013).

On an ecosystem level, we might presume these differences are a matter of access to meat. Use of meat differed widely among ecoregions of the NCDE (Fig. 3). Bears within regions on the southwestern, southern, and eastern periphery of the ecosystem had significantly higher nitrogen isotope signatures than those in the interior or northwestern periphery of the ecosystem ($P < 0.0001$) (Fig. 4). Estimated meat proportions of bear diets ranged from $71 \pm 15\%$ on the East Front to only $6 \pm 5\%$ in the lower Swan River and the lower South Fork of the Flathead. Female grizzly bear nitrogen signatures also differed by area (Fig. 5). Hence, economies (and diets) of bears, are extremely diverse across ecoregions of the NCDE.

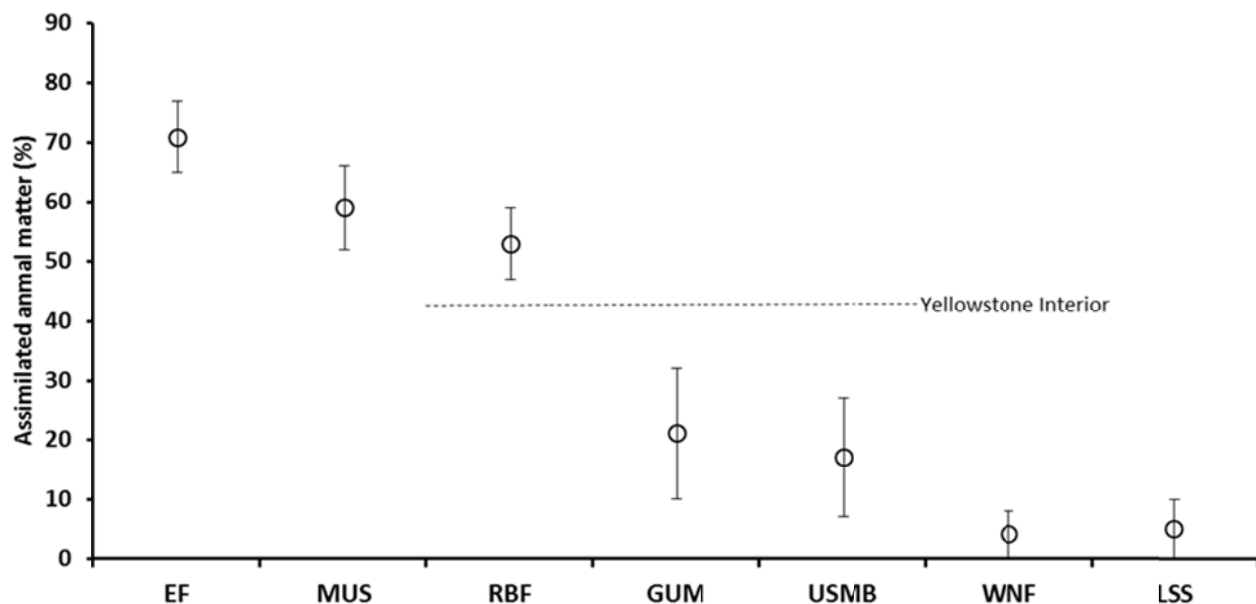


Figure 3. Percent assimilated diet composed of animal matter for all NCDE grizzly bears for each ecoregion (\pm SE). Values were calculated from a 2-source model (plant and animal matter). Area denotations are as in Fig. 1.

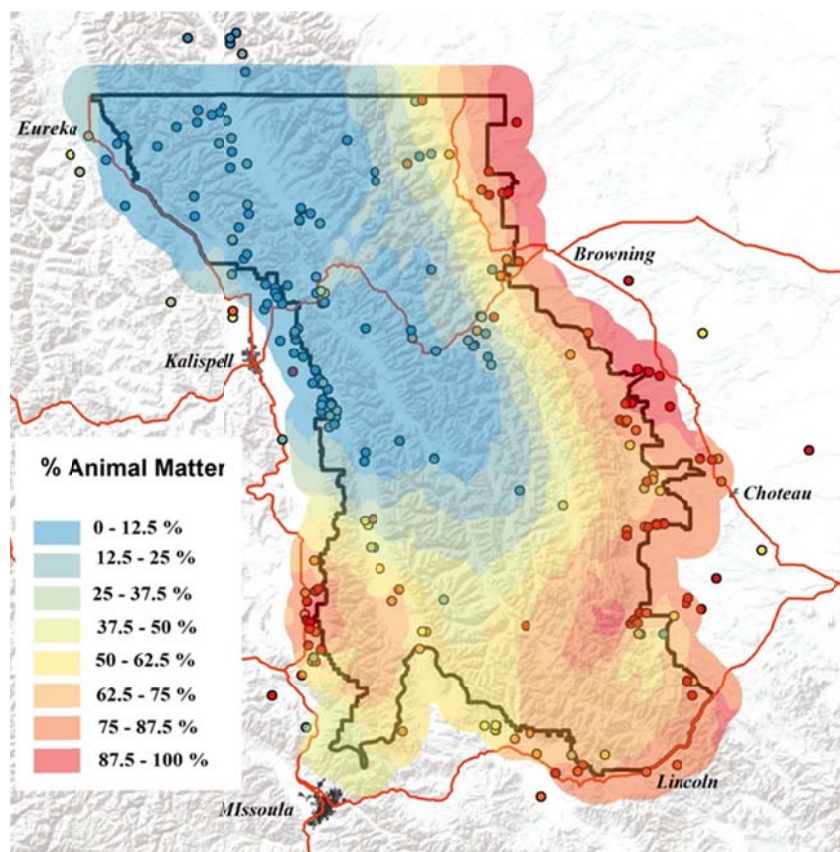


Figure 4. Kriged surface of isotope values ($\delta^{15}\text{N}$) of guard hair from all captured grizzly bears across the Northern Continental Divide Ecosystem, 2009–2012. Higher values (hotter colors) indicate greater amount of animal matter in diets of bears. Lower values (cooler colors) indicate a greater amount of plant matter in bear diets. Sampling locations are also plotted.

Very few grizzly bears in the NCDE have high proportions of human foods (i.e., food from human refuse or corn-fed livestock) in their diet. A few bears did show acute signatures indicative of higher percentage of corn-based diet from blood samples. One bear in particular caught in the northwest NCDE had 26% of its previous 1-2 week diet coming from anthropogenic sources. A few other bears on the East Front showed longer-term signatures (29% and 33% of diet from human foods). Compared to northwestern NCDE bears, we estimate that East Front bears on average had 8–9% more of their diet coming from human sources.

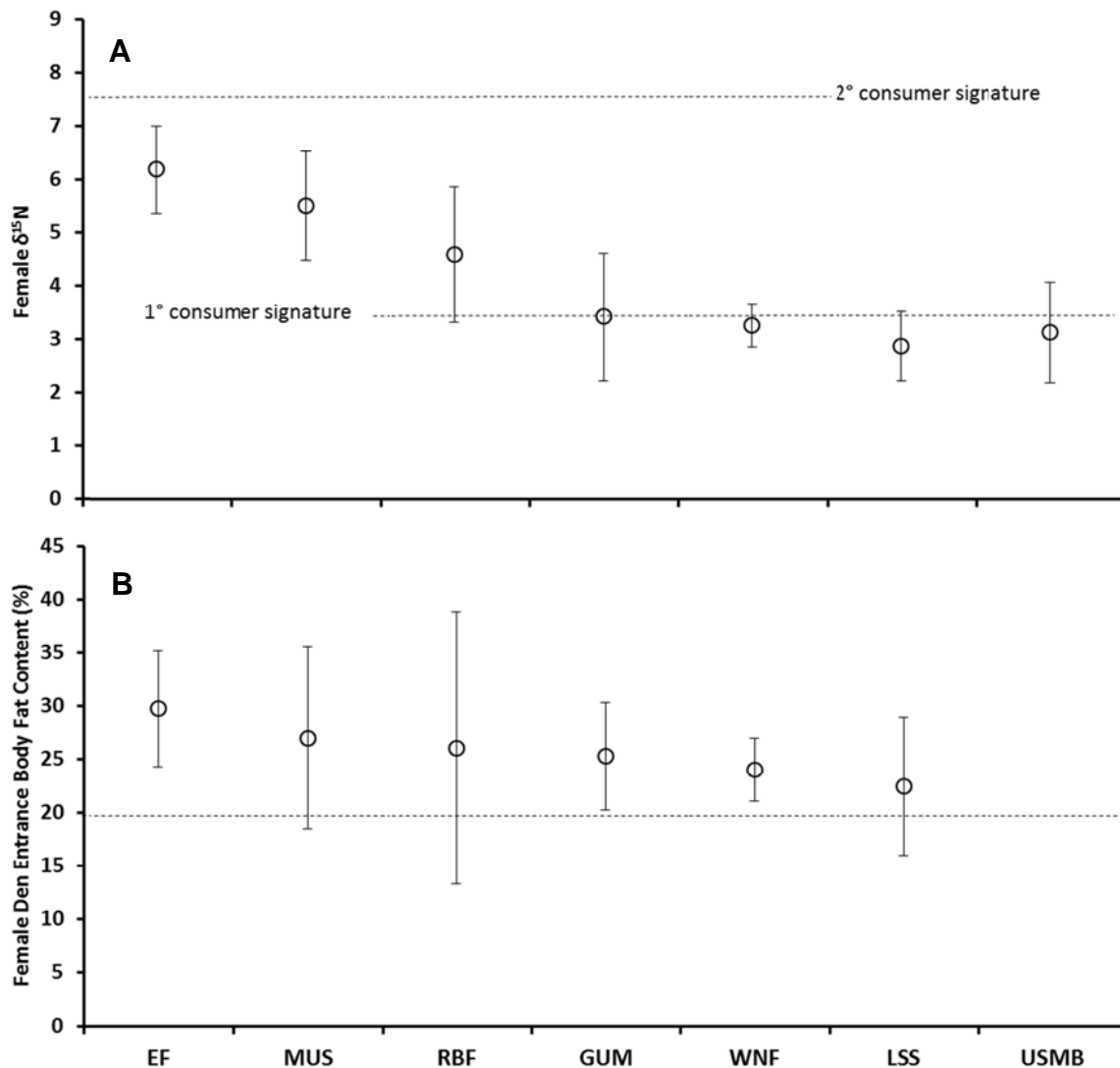


Figure 5. (A) $\delta^{15}\text{N}$ signatures (2009–2011) of female grizzly bears across regions of the NCDE, \pm SE (A). Dotted lines indicate expected isotope ratios at primary and secondary consumer trophic levels. (B) Body fat content at fictional and standardized date of den entry (Oct. 25) of female grizzly bears (\pm SE) across regions of the NCDE, 2009–2011. The dotted line indicates the threshold value at den entrance for cub production, as in Robbins et al. 2012. Area denotations are as in Fig. 1.

Body condition

We estimated body fat content of 199 captured bears. We found no significant differences in mean fat content at den entrance between age classes upon den entrance (adult males [$31.3 \pm 1.5\%$], adult females [$29.0 \pm 0.9\%$], and subadults [$27.7 \pm 0.7\%$]; $P = 0.089$). Adult females entered dens at mean fat levels above those thought to be critical for cub production (i.e., $> 20\%$), with confidence limits of female bears reaching below this threshold only in the southern and southwestern periphery and western interior/periphery of the ecosystem (Robbins et al. 2012; Fig. 5). Unlike meat use, body fat contents significantly differed between only a few regions of the NCDE (Fig. 6). Bears within the lower South Fork Flathead and lower Swan River region had significantly lower body fat contents than East Front grizzly bears. We observed no significant association between trophic level and body fat content. Given diverse use of plant and animal matter across ecoregions of the NCDE, we cannot conclude that mixing proportions of protein and carbohydrates influence body fat content of bears.

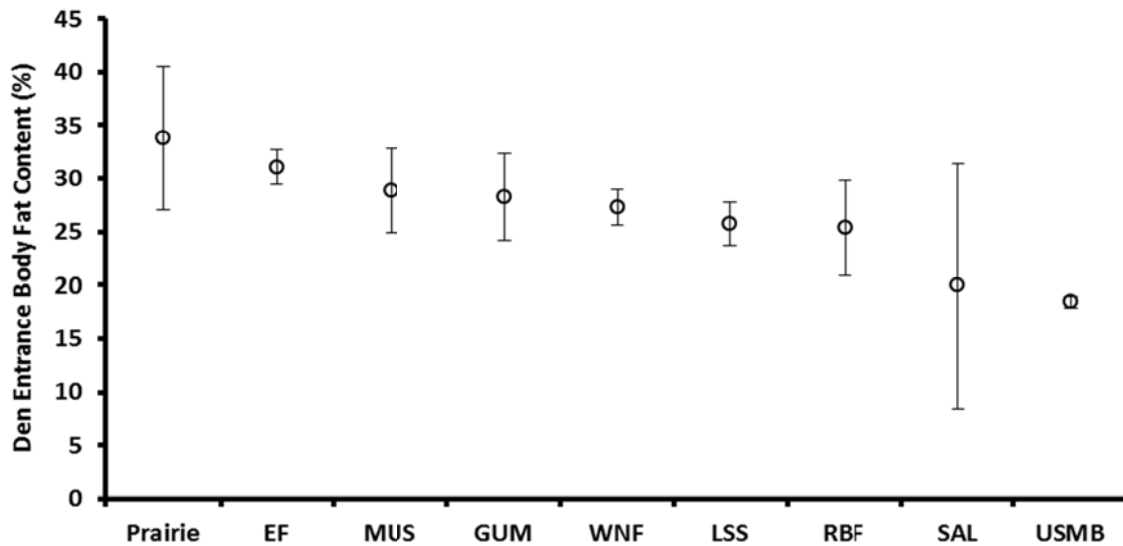


Figure 6. Average body fat content (at standardized date of den entrance, Oct. 25), \pm 95% confidence interval, for all grizzly bears within each NCDE ecoregion. Area denotations are as in Fig. 1.

Literature Cited

- Aune, K. E., and W. F. Kasworm. 1989. Final Report – East Front grizzly studies. Montana Fish, Wildlife, and Parks. Helena. 332pp.
- Bahar, B., F. J. Monahan, A. P. Moloney, P. O’Kiely, C. M. Scrimgeour, and O. Schmidt. 2005. Rapid Communications in Mass Spectrometry 19:1937–1942.
- Brenna, J. T., T.N. Corso, H.J. Tobias and R.J. Caimi. 1997. High-precision continuous-flow isotope ratio mass spectrometry. Mass Spectrometry Reviews. 16:227–258.
- Farley, S.D., and C.T. Robbins. 1994. Development of two methods to estimate body composition of bears. Canadian Journal of Zoology 72:220–226.
- Felicetti, L. A., C. C. Schwartz, R. O. Rye, M. A. Haroldson, K. A. Gunther, and C. T. Robbins. 2003. Use of sulfur and nitrogen stable isotopes to determine the importance of whitebark pine nuts to Yellowstone grizzly bears. Canadian Journal of Zoology 81:763–770.
- Fortin, J. K., C. C. Schwartz, K. A. Gunther, J. E. Teisberg, M. A. Haroldson, M. A. Evans, and C. T. Robbins. 2013. Dietary adjustability of grizzly bears and American black bears in Yellowstone National Park. Journal of Wildlife Management 77:270–281.
- Hilderbrand, G.V., S.D. Farley, C.T. Robbins, T.A. Hanley, K. Titus, and C. Servheen. 1996. Use of stable isotopes to determine the diets of living and extinct bears. Canadian Journal of Zoology 74:2080–2088.
- Hilderbrand, G. V., S. G. Jenkins, C. C. Schwartz, T. A. Hanley, and C. T. Robbins. 1999. Effect of seasonal differences in dietary meat intake on changes in body mass and composition in wild and captive brown bears. Canadian Journal of Zoology 77:1623–1630.
- Hopkins, J. B., S. Herrero, R. T. Shideler, K. A. Gunther, C. C. Schwartz, and S. T. Kalinowski. 2010. A proposed lexicon of terms and concepts for human-bear management in North America. Ursus 21:154–168.
- Jahren, A. H., and R. A. Kraft. 2008. Carbon and nitrogen stable isotopes in fast food: Signatures of corn and confinement. Proceedings of the National Academy of Sciences 105:17855–17860.
- Keane, R. E., P. Morgan, and J. P. Menakis. 1994. Landscape assessment of the decline in whitebark pine (*Pinus albicaulis*) in the Bob Marshall Wilderness complex, Montana, USA. Northwest Science 68:213–239.
- Kreeger, T. J., and J. M. Arnemo. 2007. Handbook of wildlife chemical immobilization. Third edition. Laramie, Wyoming. 418 pp.

- Mace, R. D., and C. J. Jonkel. 1986. Local food habits of the grizzly bear in Montana. *Ursus* 6:105–110.
- McClellan, B. N., and F. W. Hovey. 1995. The diet of grizzly bears in the Flathead River drainage in southeastern British Columbia. *Canadian Journal of Zoology* 73:704–712.
- Parnell, A., Inger, R., Bearhop, S. & Jackson, A. L. 2010. Source partitioning using stable isotopes: coping with too much variation. *PlosOne* 5: e9672
- Phillips, D. L. 2001. Mixing models in analyses of diet using multiple stable isotopes: a critique. *Oecologia* 127:166–170.
- Qi, H., Coplen, T.B., Geilmann, H., Brand, W.A. and Böhlke, J.K. 2003. Two new organic reference materials for $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ measurements and a new value for the $\delta^{13}\text{C}$ of NBS 22 oil. *Rapid Communications in Mass Spectrometry*. 17:2483–2487.
- Robbins, C.T. 2004. Nutritional ecology of ursids: a review of newer methods and management implications. *Ursus* 15:161–171.
- Robbins, C. T., M. Ben-David, J. K. Fortin, and O. L. Nelson. 2012. Maternal condition determines birth date and growth of newborn bear cubs. *Journal of Mammalogy* 93:540–546.
- Servheen, C. 1983. Grizzly bear movements, food habits, and habitat use in the Mission Mountains, Montana. *Journal of Wildlife Management* 47:1026–1035.