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- parametric statistics for the behavioral sciences. Second edition. McGraw-Hill, New York, New York, USA.
- SKOOG, R. O. 1968. Ecology of the caribou (*Rangifer tarandus granti*) in Alaska. Dissertation, University of California, Berkeley, California, USA.
- THOMAS, D. C. 1982. The relationship between fertility and fat reserves of Peary caribou. *Canadian Journal of Zoology* 60:597–602.
- TYLER, N. J. C. 1987. Natural limitation of the abundance of the High Arctic Svalbard reindeer. Dissertation, University of Cambridge, Cambridge, United Kingdom.
- WELLS, J. V., AND M. E. RICHMOND. 1995. Populations, metapopulations, and species populations: What are they and who should care? *Wildlife Society Bulletin* 23:458–462.
- ZAR, J. H. 1984. Biostatistical analysis. Second edition. Prentice-Hall, Englewood Cliffs, New Jersey, USA.

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EFFECT OF HIBERNATION AND REPRODUCTIVE STATUS ON BODY MASS AND CONDITION OF COASTAL BROWN BEARS

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Abstract: We investigated the effect of hibernation and reproductive status on changes in body mass and composition of adult female brown bears (*Ursus arctos*) on the Kenai Peninsula, Alaska. This information is fundamental to understanding nutritional ecology of wild brown bear populations. Six adult females handled in the fall and following spring (paired samples) lost 73 ± 22 kg ($\bar{x} \pm$ SD; $32 \pm 10\%$) of fall body mass over 208 ± 19 days. Of this mass loss, $56 \pm 22\%$ (55 ± 22 kg) was lipid and $44 \pm 22\%$ (43 ± 21 kg) was lean body mass. Catabolism of lipid stores accounted for $88.4 \pm 8.1\%$ of the body energy used to meet maintenance demands. Overwinter differences in body composition of adult females assessed only once in either the fall ($n = 21$) or spring ($n = 32$) were similar to those of paired samples. Relative fatness of bears entering the den was positively related to the contribution of fat (%) to body mass ($P < 0.01$) and body energy ($P < 0.01$) losses during hibernation. Thus, relative fatness at the onset of fasting influences the relative proportion of lipid stores and lean body mass catabolized to meet protein and energy demands during hibernation. In the spring, lone females had greater body and lean masses than females with cubs of the year or yearlings. Lipid content was greatest in lone females in the fall. Studies using body mass and composition as indices of population health should consider season or reproductive class.

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Key words: body composition, body condition, brown bear, hibernation, Kenai Peninsula, reproductive class, *Ursus arctos*.

Knowledge of seasonal changes in body mass and composition provides important insights into the nutritional ecology of bears. Female brown bears fast during hibernation, give birth during this winter dormancy, and lactate for 2 to 3 months before den emergence (Farley and Robbins 1995). Additionally, the cubs may stay

with the mother, who continues to lactate, for up to 3 years. These life-history traits create significant energy demands for the female. Female body mass and body fat content are positively related to reproductive success of individuals and, thus, to parameters of population productivity such as litter size, interval between litters, and age of first reproduction (Rogers 1976, 1987; Bunnell and Tait 1981; Blanchard 1987; Stringham 1990; Noyce and Garshelis 1994; Atkinson and Ramsay 1995; Samson and Huot

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1995; Hilderbrand et al. 1999). Quantification of the impact of hibernation and reproductive class on body mass and composition, specifically lipid stores and lean body mass, is important in understanding population productivity.

The impacts of hibernation and cub production on body mass and composition have been quantified for brown bears in captivity (Watts and Jonkel 1988, Farley and Robbins 1995, Barboza et al. 1997) but not in the wild. Wild polar bears lose lipids and lean body mass while fasting, and the proportional loss of these 2 body components is influenced by the relative fatness of the bear at the onset of the fasting period (Atkinson et al. 1996). Body composition also differs across reproductive classes in wild polar bears (Atkinson and Ramsay 1995). The objectives of this study were to quantify changes in body mass and composition during the period of winter dormancy and assess the effect of reproductive status on seasonal body mass and composition in wild, adult female brown bears.

METHODS

During 1996–98, adult female brown bears on the Kenai Peninsula, Alaska (~60°N, 150°W) were located with fixed-winged aircraft and anesthetized (Telazol, Fort Dodge Animal Health, Fort Dodge, Iowa, USA; 5–10 mg/kg body mass; Taylor et al. 1989) by darting from a helicopter in the early spring (24 Apr–1 Jun) just after den emergence, and in the fall (6–27 Oct) just before den entry. The time of capture was typically within a few days of den entry or den exit; however, in 2 cases, bears remained outside the den for 7 to 14 days after capture in the fall. Bears were categorized as lone females, females with cubs of the year, females with yearlings, or females with ≥ 2 -year-old offspring based on the age of the offspring accompanying her at the time of capture or during subsequent aerial surveys.

At each capture, bears were weighed with an electronic load cell (± 0.2 kg) and body composition was determined by bioelectrical impedance analysis (BIA, Model 101A, RJL Systems, Detroit, Michigan, USA) and/or isotopic dilution (Farley and Robbins 1994, Hilderbrand et al. 1998). Both methods estimate body water content, which is inversely proportional to fat content (Farley and Robbins 1994). Thus, measures of water content by BIA and dilution allow accurate estimation of body fat content (Standard error $\leq 3.3\%$; Farley and Robbins

1994, Hilderbrand et al. 1998). The mean of the 2 methods is the most accurate predictor of body composition (Hilderbrand et al. 1998). However, because isotopic dilution requires 1.5 to 2.5 hrs to complete, dilutions were only performed on 15 of the bears in the current study. Bioelectrical impedance analysis was also performed on these 15 bears and the mean of the 2 methods was used in analyses. Bioelectrical impedance analysis measures alone were used for an additional 38 bears. The decision of whether or not to perform a dilution was based on field logistics and not skewed by reproductive class or season. Gut fill may produce erroneous measures using BIA or isotopic dilution (Farley and Robbins 1994). However, the effect of gut fill on body composition estimates has not been quantified. Additionally, the bears in the current study were likely already fasting due to temporal proximity to den entry or exit. The contribution of fat to losses of body energy during the hibernation period was estimated according to Atkinson and Ramsay (1995). Relative fatness was calculated as the proportion of fat to lean body mass in the fall (Atkinson et al. 1996).

Estimates of body fat and lean body mass by BIA and isotopic dilution were compared using paired *t*-tests. Changes in body composition during hibernation, length of time between captures, proportional energy loss due to fat, relative fatness, and seasonal body mass and composition by reproductive status were calculated and reported as means (\pm SD). The relationships between relative fatness in the fall and the proportional contribution of fat to loss of body mass and body energy were assessed by power regression analysis. Data were pooled across years and seasonal body composition was compared across reproductive class using analysis of variance (ANOVA) and Fisher's least significant difference (LSD) analyses (Zar 1984).

RESULTS

Body fat and lean body mass estimates by BIA and isotopic dilution did not differ across methods ($t = 1.23$, $df = 14$, $P = 0.24$). Six adult females that were handled during the fall and following spring lost an average of 73 ± 22 kg ($32 \pm 10\%$) of fall body mass. Mass loss consisted of body fat ($56 \pm 22\%$) and lean body mass ($44 \pm 22\%$). Catabolism of lipid stores accounted for $88.4 \pm 8.1\%$ (range of 77 to 98%) of the body energy used to meet maintenance

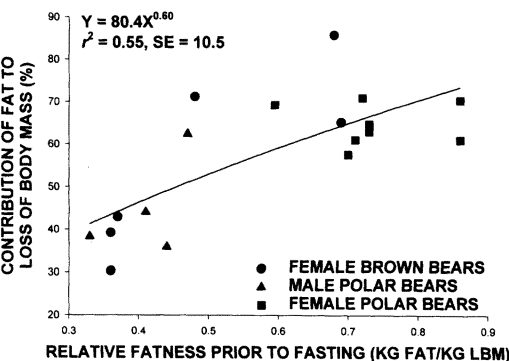


Fig. 1. Relationship between relative fatness in the fall, before den entry, and the contribution of fat to body mass loss during hibernation in polar bears and brown bears (Atkinson and Ramsay 1995, Atkinson *et al.* 1996, current study).

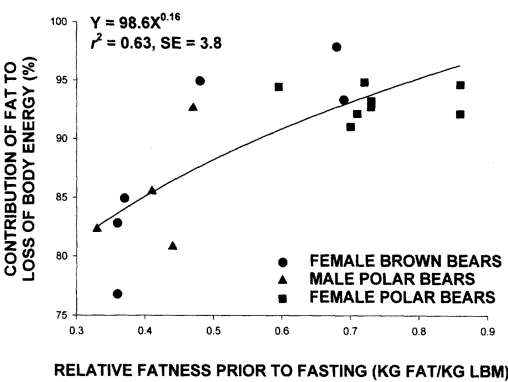


Fig. 2. Relationship between relative fatness in the fall, before den entry, and the contribution of fat to body energy loss during hibernation in polar bears and brown bears (Atkinson and Ramsay 1995, Atkinson *et al.* 1996, current study).

demands. Relative fatness of bears entering the den was 0.49 ± 0.15 kg of fat/kg of lean mass and was positively related to the contribution of fat to body mass ($P < 0.01$; Fig. 1) and body energy ($P < 0.01$; Fig. 2) losses during hibernation. Daily mass loss was 352 ± 136 g/day and the length of time between fall and spring captures was 208 ± 19 days. Two of the 6 individuals entered the den alone and produced 2 cubs in the den, 2 entered the den with 2 cubs of the year, 1 entered the den with 3 cubs of the year, and 1 entered the den with a yearling. Mass differences (84 kg) between randomly captured individuals in the fall ($n = 21$) and spring ($n = 32$) were similar to those of paired samples. Differences in body fat (52 kg) and lean body mass (32 kg) were also similar to those of paired samples.

Lone females had greater body mass, fat content, and lean body mass than females with cubs in the spring (Table 1). In spring, lone females weighed more ($P < 0.05$) than females with cubs of the year or yearlings due mainly to greater ($P < 0.05$) amounts of lean body mass

(Table 1). Females with cubs of the year and females with yearlings had virtually identical body masses. Fat content was greater in females with cubs of the year than in females with yearlings, and lean mass was greater in females with yearlings than in females with cubs of the year. However, neither of these differences were significant (Table 1). Females with 2-year-old cubs had body masses and fat contents that overlapped all other groups, but their lean body mass was similar to that of lone females and greater than that of females with cubs of the year (Table 1).

In the fall, lone females had greater ($P < 0.05$) lipid content than females with cubs of the year or yearlings (Table 1). Body mass and fat content were similar between females with cubs of the year and yearlings, and lean mass was similar across reproductive class in the fall (Table 1).

DISCUSSION

Daily mass loss during hibernation by adult female, coastal brown bears in this study was

Table 1. Body composition of adult female brown bears on the Kenai Peninsula, Alaska, by season and reproductive class, 1996–98.

Season	Reproductive class	Body mass (kg)			Fat mass (kg)			Lean mass (kg)		
		\bar{x}	SD	n	\bar{x}	SD	n	\bar{x}	SD	n
Spring	Alone	176.9 ^{A1}	26.2	5	40.0 ^A	9.8	5	136.9 ^A	18.5	5
	With cubs of the year	152.6 ^B	16.3	12	35.7 ^A	8.5	12	116.8 ^B	12.0	12
	With yearlings	152.0 ^B	22.1	23	28.8 ^A	11.6	23	124.1 ^{AB}	19.9	23
	With 2-year-olds	169.0 ^{AB}	28.8	5	33.1 ^A	18.3	5	135.9 ^A	13.4	5
Fall	Alone	248.0 ^A	29.7	16	90.7 ^A	18.7	16	157.2 ^A	18.9	16
	With cubs of the year	230.3 ^A	28.8	7	71.8 ^B	15.0	7	158.5 ^A	21.2	7
	With yearlings	225.3 ^A	29.5	10	70.9 ^B	20.7	10	154.4 ^A	18.8	10

¹ Means within the same column and season having the same superscript are not different ($P > 0.05$) using Fisher's LSD analysis.

similar to that reported in previous studies of captive nonlactating (335 g/day) and lactating (490 g/day) brown bears of similar mass (Farley and Robbins 1995). While virtually all of the mass lost during hibernation by nonlactating, captive females was lipid (Farley and Robbins 1995), the demands of lactation can increase both energy and protein catabolism during hibernation (Farley and Robbins 1995, Barboza *et al.* 1997, Tinker *et al.* 1998). Two bears used to assess the costs of hibernation in the current study gave birth in the den, and therefore, lactated during part of the dormancy. As expected, these bears utilized lean body mass during hibernation (11.6 and 35.0 kg, 14.3 and 34.9% of mass loss, respectively). However, each of the 4 remaining bears in the current study that did not give birth during hibernation also lost lean body mass (19.0 to 54.6 kg, 28.8 to 69.7% of mass loss) and lipid stores. Thus, lean body mass was catabolized by hibernating adult female brown bears in this study in the absence of lactation demands. Potential causes of lean body mass losses by bears in the current study include catabolism during hibernation, catabolism during the brief period bears spent outside the den after fall captures and before spring captures, and water losses due to dehydration (Farley and Robbins 1994).

Atkinson *et al.* (1996) reported that 74 to 99% of the energy used by polar bears to meet maintenance costs during fasting was derived from lipid stores. We report a similar range (77 to 98%) in this study. Relative fatness also influenced the proportion of body lipids and lean body mass used to meet maintenance costs (Atkinson *et al.* 1996). Our findings support this argument in brown bears (Fig. 2). Atkinson and Ramsay (1995) suggested that increases in lean body mass in polar bears before the reproductive fast serve 2 major roles: (1) to support the protein and mineral demands of cub production and lactation, and (2) to provide the musculature necessary to support the large fat stores. A role in supporting cub production has been documented in captive studies quantifying the energy and protein demands of cub production and lactation (Farley and Robbins 1995). In the current study, lone (pregnant) females entered the den with a lean body mass virtually identical to other reproductive classes. However, females exiting the den with cubs of the year had the lowest lean body mass of any reproductive class (Table 1). The second major role above is evi-

denced by the increase in lean body mass that occurs between spring and fall, regardless of reproductive class (Table 1). Furthermore, fasting male polar bears lose a greater proportion of lean body mass than fasting females faced with the additional protein demands of cub production and lactation (Atkinson and Ramsay 1995, Atkinson *et al.* 1996). While increased protein stores accumulated before fasting can be mobilized to meet these 2 roles, "normal" protein stores are likely conserved (Atkinson and Ramsay 1995). A general maintenance of smooth and skeletal muscle function and integrity during winter dormancy occurs in bears despite catabolism of protein during hibernation (Barboza *et al.* 1997, Tinker *et al.* 1998).

Relative fatness at the onset of fasting is likely a critical factor impacting the relative proportion of lipid stores and lean body mass used to meet protein and energy demands in both male and female bears. Thus, studies of fat and protein metabolism in captive, hibernating bears (Lundberg *et al.* 1976, Farley and Robbins 1995, Barboza *et al.* 1997) that have concluded that weight loss is due almost entirely to fat catabolism are likely skewed by the obesity of captive bears relative to wild bears.

The reduced body mass and lean body mass of females with cubs, particularly cubs of the year and yearlings, reflects the combined costs of cub production, lactation, and increased food acquisition. Atkinson and Ramsay (1995) reported differences similar to those in the current study across reproductive classes in adult female polar bears. Females with cubs of the year accumulate lean body mass during the active period and, by fall, have lean body mass contents virtually identical to those of lone females (Table 1). However, the presence of cubs may force females to feed in less productive habitats or at less productive times to avoid cub predation by more dominant bears, particularly males (Schoen and Beier 1990, McLellan 1994, Mattson and Reinhardt 1995), in turn leading to reduced fat depots relative to lone females. The lean body mass of females with yearlings the following spring is intermediate to that of lone females and females with cubs of the year (Table 1). This result suggests that the continued nursing of cubs 9–15 months of age during hibernation increases protein and/or energy demands relative to lone bears. The similar body composition of females with 2-year-old cubs and lone females suggests a decreased energy

and protein demand as the cubs are weaned. Unfortunately, studies of body composition of mothers and offspring and mass transfer between the 2 have not been conducted with cubs >9 months of age.

Female brown bears throughout their geographic range face similar energetic demands of hibernation and reproduction, despite varied nutritional resources (McLellan 1994, Hilderbrand et al. 1999). In some populations, the costs of hibernation and reproduction may limit reproductive effort and population productivity as reproductive success is positively related to body mass and fat content. Studies that use body mass and/or composition as indices of population health should ensure that the sample is representative of the population and not skewed by season or reproductive class.

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LITERATURE CITED

- ATKINSON, S. N., R. A. NELSON, AND M. A. RAMSAY. 1996. Changes in the body composition of fasting polar bears (*Ursus maritimus*): the effect of relative fatness on protein conservation. *Physiological Zoology* 69:304–316.
- , AND M. A. RAMSAY. 1995. The effect of prolonged fasting on the body composition and reproductive success of female polar bears (*Ursus maritimus*). *Functional Ecology* 9:559–567.
- BARBOZA, P. S., S. D. FARLEY, AND C. T. ROBBINS. 1997. Whole-body urea cycling and protein turnover during hyperphagia and dormancy in growing bears (*Ursus americanus* and *U. arctos*). *Canadian Journal of Zoology* 75:2129–2136.
- BLANCHARD, B. M. 1987. Size and growth patterns of the Yellowstone grizzly bear. *International Conference on Bear Research and Management* 7:99–107.
- BUNNELL, F. L., AND D. E. N. TAIT. 1981. Population dynamics of bears—implications. Pages 75–98 in C. W. Fowler and T. D. Smith, editors. *Dynamics of large mammal populations*. John Wiley & Sons, New York, New York, USA.
- 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.
- , AND ———. 1995. Lactation, hibernation, and mass dynamics of American black bears and grizzly bears. *Canadian Journal of Zoology* 73:2216–2222.
- HILDERBRAND, G. V., S. D. FARLEY, AND C. T. ROBBINS. 1998. Predicting body condition of bears via two field methods. *Journal of Wildlife Management* 62:406–409.
- , C. C. SCHWARTZ, C. T. ROBBINS, M. E. JACOBY, T. A. HANLEY, S. M. ARTHUR, AND C. SERVEEN. 1999. Importance of dietary meat, particularly salmon, to body size, population productivity, and conservation of North American brown bears. *Canadian Journal of Zoology* 77:132–138.
- LUNDBERG, D. A., R. A. NELSON, H. W. WAHNER, AND J. D. JONES. 1976. Protein metabolism in the black bear during hibernation. *Mayo Clinic Proceedings* 51:716–722.
- MATTSON, D. J., AND D. P. REINHART. 1995. Influence of cutthroat trout (*Oncorhynchus clarki*) on behavior and reproduction of Yellowstone grizzly bears (*Ursus arctos*), 1975–1989. *Canadian Journal of Zoology* 73:2072–2079.
- MCLELLAN, B. N. 1994. Density-dependent population regulation of brown bears. *International Conference on Bear Research and Management Monographs Series* 3:15–37.
- NOYCE, K. V., AND D. L. GARSHELIS. 1994. Body size and blood characteristics as indicators of condition and reproductive performance in black bears. *International Conference on Bear Research Management* 9:481–496.
- ROGERS, L. 1976. Effects of mast and berry crop failures on survival, growth, and reproductive success of black bears. *Transactions of the North American Wildlife and Natural Resource Conference* 41:431–438.
- . 1987. Effects of food supply and kinship on social behavior, movements, and population growth of black bears in northeastern Minnesota. *Wildlife Monographs* 97.
- SAMSON, C., AND J. HUOT. 1995. Reproductive biology of female black bears in relation to body size in early winter. *Journal of Mammalogy* 76:68–77.
- SCHOEN, J., AND L. BEIER. 1990. Brown bear habitat preferences and brown bear logging and mining relationships in southeast Alaska. *Alaska Department of Fish and Game, Federal Aid in Wildlife Restoration Study* 4.17.
- STRINGHAM, S. F. 1990. Grizzly bear reproductive rate relative to body size. *International Conference on Bear Research and Management* 8:433–443.
- TAYLOR, W. P., H. V. REYNOLDS, III, AND W. B. BALLARD. 1989. Immobilization of grizzly bears with

- tiletamine hydrochloride and zolazepam hydrochloride. *Journal of Wildlife Management* 53: 978–981.
- TINKER, D. B., H. J. HARLOW, AND T. D. BECK. 1998. Protein use and muscle fiber changes in free-ranging, hibernating black bears. *Physiological Zoology* 71:414–424.
- WATTS, P. D., AND C. JONKEL. 1988. Energetic costs of winter dormancy in grizzly bear. *Journal of Wildlife Management* 52:654–656.
- ZAR, J. H. 1984. *Biostatistical analysis*. Prentice Hall, Englewood Cliffs, New Jersey, USA.
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ESTIMATING POPULATION SIZE OF GRIZZLY BEARS USING HAIR CAPTURE, DNA PROFILING, AND MARK-RECAPTURE ANALYSIS

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Abstract: We used DNA analysis to estimate grizzly bear (*Ursus arctos*) population size in a 9,866-km² area in southeast British Columbia and a 5,030-km² area in southwest Alberta. We sampled bears by removing hair at bait sites surrounded by a single strand of barbed wire. DNA profiling with microsatellites of the root portion of the hair was used to identify individuals. We collected hair from 109 different bears and had 25 recaptures in 5 10-day trapping sessions in British Columbia. In Alberta we collected hair from 37 bears and had 9 recaptures in 4 14-day sessions. A model in program CAPTURE (M_h) that accommodates heterogeneity in individual capture probabilities estimated the population size in British Columbia as 262 (95% CI = 224–313) and in Alberta as 74 (60–100). We believe that hair capture combined with DNA profiling is a promising technique for estimating distribution and abundance of bears and potentially many other species. This approach is of special interest to management biologists because it can be applied at the scale conservation and management decisions are made.

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Key words: Alberta, British Columbia, Canada, density, DNA profiling, grizzly bears, hair removal, mark-recapture, microsatellite analysis, population size, *Ursus arctos*.

Estimating carnivore abundance is central to their conservation, however, options for estimating carnivore population size are few and often require specific circumstances or assumptions that are difficult to meet. Estimating bear population size is difficult and only has been achieved in conjunction with intensive effort (McLellan 1989, Garshelis 1992, Stirling et al. 1997). Recent efforts to develop bear inventory methods have involved the use of mark-recapture modeling. Researchers have used live capture to mark bears and then recaptured bears using camera stations (Mace et al. 1994), aerial survey (Larsen and Markel 1989, Stirling et al. 1997), and hair removal and DNA fingerprinting analysis (Proctor 1995). Most recently, hair removal and DNA fingerprinting have been used to mark and recapture grizzly bears (Woods et al. 1996, 1999). This latter method has several benefits as live capture of bears is unnecessary, individuals can be identified with

a small risk of error, and hair removal sites are faster to set and are checked less often than live-capture sites. Simpler logistics allow a study design that comes closer to meeting the assumptions and sample size requirements of current mark-recapture models.

There are several important assumptions involved with mark-recapture analysis to estimate population size. The most important may be the assumption of population closure, which White et al. (1982) separate into demographic and geographic closure. Demographic closure assumes there are no births or deaths or permanent immigration or emigration during the study. Errors due to demographic changes in population size are likely to be small for bears, especially if the duration of study is restricted to 6–10 weeks. Geographic closure is violated if individuals move on and off the study area between trapping sessions. A positive bias results when animals have home ranges that span the