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Estimating bear habitat quality in southeastern British Columbia by measuring changes in bear body condition

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ESTIMATING BEAR HABITAT QUALITY IN SOUTHEASTERN BRITISH COLUMBIA BY MEASURING CHANGES IN BEAR BODY CONDITION

By

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ABSTRACT

The energetic changes of bears using different habitats must be known to accurately estimate habitat quality. Recapture collars were used to test the hypothesis that change in weight and fat content of wild black bears, *Ursus americanus,* was positively correlated to the quality and quantity of the food in their habitat. Fat content was measured using bioelectrical impedance analysis (BIA). Food quantity and quality were determined using biomass estimates of six major bear foods, nutritional analysis, digestibility correction factors, and scat composition analysis. Changes in the body condition of black bears was not positively correlated to the measured value of the food in the habitat. Results indicate that black bears may forage more efficiently on berries than on forbs and graminoids. BIA was also used to compare the mean percent body fat of male and female black bears before and during the 1992 berry season. Female bears during the berry season were fatter than female and male bears before the berry season and male bears during the berry season. Female bears may have higher energetic costs and may need to be in better condition prior to denning.

ACKNOWLEDGMENTS

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Mom and Dad, thanks for teaching me how to work hard, set high goals, and always do my best. Tracy, thanks for your love and support, and thank you for taking care of everything at home while I was in the field.

To the black bears and grizzly bears I handled and disturbed in the name of "Science," I sincerely hope all of it will someday make a difference in bear conservation.

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CHAPTER ONE: INTRODUCTION

Knowledge of habitat use by bears is central to bear management; therefore, past studies have documented habitat selection (eg. Kelleyhouse 1977, Zager 1980, Servheen 1983, Grenfell and Brody 1983, and Hammer et al. 1991). Despite these projects, important questions remain unanswered. Servheen (1985) indicated that bear managers require information on carrying capacity, habitat effectiveness, predictability of food production, affects of human activity on movement patterns, nutritional requirements, and food digestibility. Servheen also suggested that more information is needed on the relationship between habitat value and population demographics such as survival, reproductive intervals, dispersal, and home range size. Scientists conducting long term bear research projects using both wild and captive bears are studying some of these topics (e.g., McLellan and Shackleton 1988 and 1989, McLellan 1989, Pritchard and Robbins 1990, Hewitt 1989); however, the relationship between the body condition of wild bears and the value of food in their habitat has not been investigated.

Because of their carnivore digestive system, bears cannot effectively digest low quality vegetation; therefore, they must select highly digestible foods to meet their nutritional requirements (Bunnell and Hamilton 1983). Determining the relationship between food value and the body condition of bears is important because body condition is related to bear growth, reproductive ability (Bunnell and Tait 1981), survival (Eagle and Pelton 1983), and carrying capacity (Servheen 1985).

Most of the remaining bear habitat in the world has been affected by human activities including resource extraction, settlement, and recreation. These activities usually affect habitat effectiveness. Knowing how the value of foods in each habitat is related to the body condition of wild bears will give managers a better understanding of how human activities impact long term bear conservation. With such information, managers will be able to better understand the impacts of actions such as timber harvest, road access, oil exploration, and recreation on bear habitat, and on the physiological condition of bears themselves.

The Cumulative Effects Model (CEM) is designed to quantify how individual and collective land uses affect grizzly bears (Godtel 1987). The CEM is composed of three submodels: the habitat submodel, the displacement submodel, and the mortality submodel (Weaver et al. 1985, Winn and Barber 1985, Godtel 1987). The CEM integrates these submodels to calculate the habitat effectiveness and mortality risks of an area (Weaver et al. 1985).

The habitat submodel quantifies grizzly bear habitat in terms of food, cover, and edge values (Weaver et al. 1985). Food value is rated on the availability of fruits and berries, vegetation, mast, insects, and animal food (Godtel 1987). However, in reality, food value is not solely dependent on quantity. Food value is also dependent on nutritional quality, digestibility, rate of passage through the digestive system, and foraging efficiency. In this study, I calculated food value indices based on quantity, quality, and digestibility and directly determined their relationship to the change in body condition of bears to provide a more accurate measure of food value. Changes in body condition unexplained by these measured food value indices can be explained by rate of passage and foraging efficiency.

In the past, habitat quality was measured by the number of animals of a species using that habitat. However, Van Horne (1983) showed that density by itself may not be an accurate measure of habitat quality. Social interactions may limit the number of animals using the high quality areas and cause higher densities in low quality areas. Habitat quality should be a combination of both density and changes in animal body condition. In habitats with the same quality, the area with the higher density of animals should have animals with decreasing body condition.

The ideal free distribution (IDF) model of habitat selection (Fretwell and Lucas 1969) predicts that individuals in different habitats should have the same energy gains if the population is at carrying capacity. If the energy gains of bears using different habitat is equal, the number of individuals in each habitat type should be a good estimate of habitat quality. However, the IDF model assumes that individuals have perfect knowledge of the area and that no individual will exclude another individual from an area. The second assumption is violated for bears. Therefore, the energetic gains of bears in different habitats must be known to estimate habitat quality. The recapture collars combined with BIA allow the measurement of energetic gains (changes in percent fat and weight) of bears using different habitats.

OBJECTIVES

The objectives of this study were to:

1. Test the hypothesis that change in weight and fat content of wild black bears was positively correlated to an estimate of the quality and quantity of the food in their habitat. Fat content was calculated using BIA, while food value was calculated using biomass estimates of six major bear foods, nutritional analysis, digestibility correction factors, and scat composition analysis.

2. Develop a model relating food biomass, nutritional quality, and digestibility to changes in the body condition of bears. Objective two will only be met if the hypothesis in objective one is accepted.

3. Compare the mean percent body fat of male and female black bears before and during the 1992 berry season.

4. Continue testing the performance of the recapture collars on bears.

STUDY AREA

The study area was located in the North Fork of the Flathead River drainage in southeastern British Colombia (49°N,114°W) and bordered Glacier National Park, USA to the south and Waterton National Park, Canada to the east (Fig. 1). The valley is five to ten kilometers wide with the river running through it at elevations between 1,200 and 1,300 meters. The mountains on both sides rise to elevations above 2,800 meters. The valley bottom contains extensive riparian areas with important bear food.

Lodgepole pine (*Pinus contorta*) is the dominant tree species in the valley. Western larch (*Larix occidentalis*), spruce (*Picea engelmanni* X *P. glauca*), and sub-alpine fir (*Abies lasiocarpa*) are also common in the valley. Higher areas are dominated by a mixture of spruce, sub-alpine fir, and alpine larch (*L. lyallii*). The forest is interspersed with avalanche chutes, alpine meadows, and clear cuts.

Both logging and gas exploration have taken place in the study area. Logging began in the late 1950's and still continues. Gas exploration began in 1980 with extensive seismic work and some well drilling. At the time of this study, the most recent exploratory well was drilled and abandoned in the summer of 1990. Logging and human residences are common in Montana along the western border of Glacier National Park. Recreation in the form of hunting,

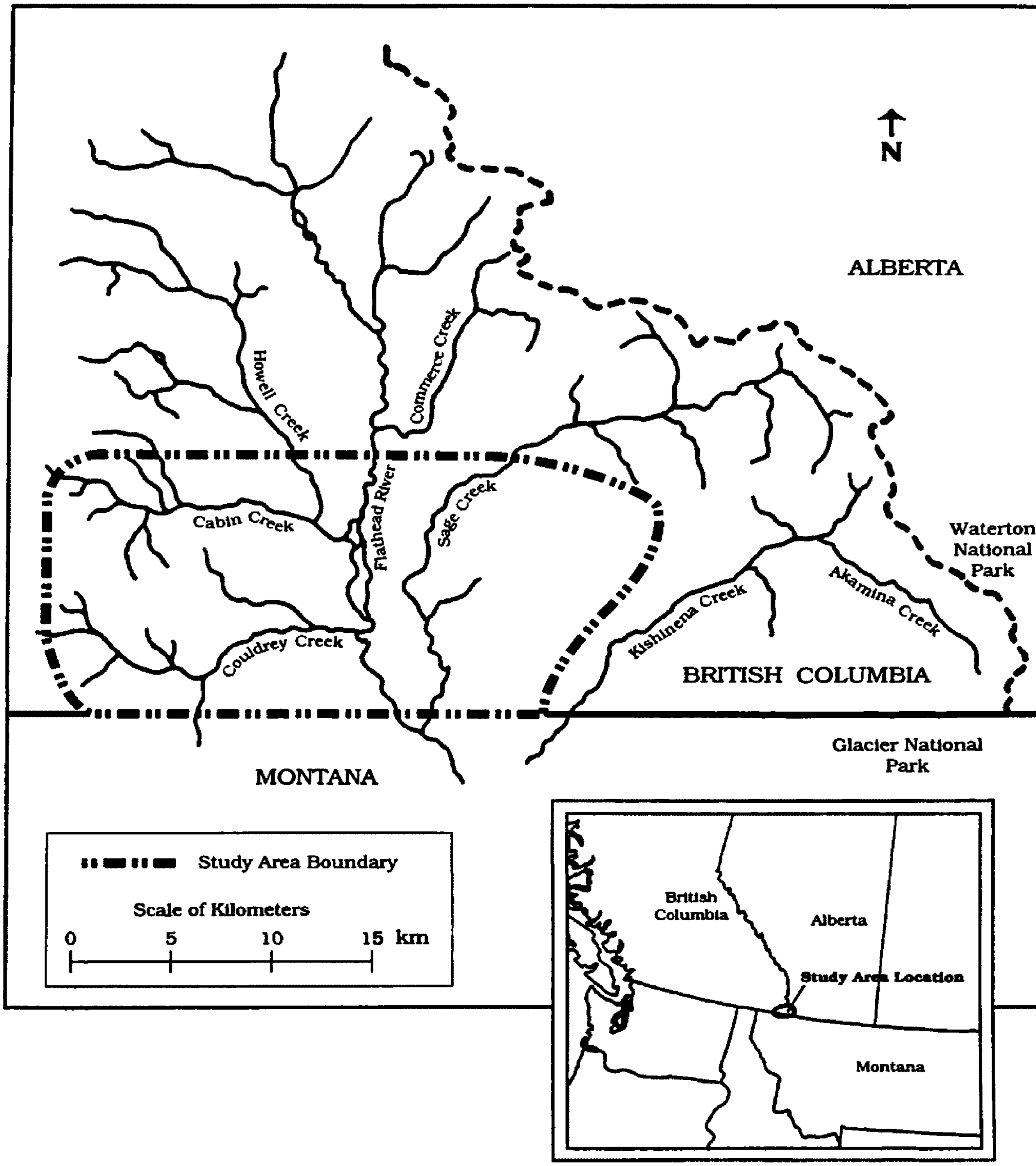

Figure 1. Location of the study area in southeastern British Columbia.

fishing, and camping occurs on both sides of the U.S. - Canadian border.

Large mammals inhabiting the study area include grizzly bears (*Ursus arctos*), black bears, wolves (*Canis lupis*), coyotes (*Canis latrans*), wolverines (*Gulo gulo*), mountain lions (*Felis concolor*), moose (*Alces alces*), elk (*Cervus elaphus*), white-tailed deer (*Odocoileus virginianus*), mule deer (*Odocoileus hemionus*), mountain goats (*Oreamnos americanus*) and bighorn sheep (*Ovis canadensis*).

CHAPTER TWO: BODY CONDITION

INTRODUCTION

The relationship between habitat quality and changes in body condition of wild bears has been poorly documented because repetitive captures of individual bears are required. In the past, repetitive captures have only occurred once or twice throughout the season using conventional trapping techniques (Kingsley et al. 1983), although Rogers and Wilker (1990) obtained more frequent weight measurements on researcher-habituated black bears. Recent technological advances in the form of recapture collars (Wildlink Inc. Brooklyn Park, MN) now allow repetitive captures. These collars combined with BIA (Farley and Robbins 1994) allowed the measurement of body condition changes over time.

METHODS

Captures

Bears were initially trapped and processed using conventional techniques. All captured bears were measured, weighed, and had their body fat measured using the bioelectrical impedance meter (RJL Systems Body Composition Analyzer). Recapture collars were put on when the appropriate bears were captured.

Black bears were used the first year to further field test the recapture collars before placing one on a grizzly bear the second year. Adult females were used when possible because they were not growing and were small enough to be immobilized by a recapture collar's 1.5 ml darts. The smaller home ranges of adult females also facilitated intensive tracking.

Adult females were also used because they are the most important cohort of the population. The condition of females is directly related to reproductive success. Kingsley et al. (1983) found that mature female grizzly bears cycled more weight than adult males. They related these higher fluctuations to the increased reproductive cost of mature females. Because mature females cycle more weight than mature males, mature females should be more sensitive to habitat quality measured in food value. Therefore, mature female body condition should be a more sensitive measure of habitat food value than the body condition of any other cohort.

Two female black bears were fitted with recapture collars during the 1991 field season. One male black bear, two female black bears, and one female grizzly bear were fitted with recapture collars during the 1992 field season. Because of technical problems with the recapture collars, I stopped using the recapture collars during July of 1992. Two female black bears were fitted with recapture collars in a continuation of the study during 1993 by McLellan (pers. comm., B.C. Min. of Forests) (Table 1).

Table 1. Recapture collar bears.

BEAR	SPECIES	AGE[a]	FIELD SEASON
SAF1[b]	black	3	1991
AF1[c]	black	4	1991
AM1[d]	black	6	1992
AF2	black	14	1992
AF3	black	4	1992
AF4	grizzly	4	1992
AF5	black	6	1993
AF6	black	12	1993

[a] Age when captured and fitted with a recapture collar. Ages were calculated from teeth sections.
[b] SAF - subadult female
[c] AF - adult female
[d] AM - adult male

Body Condition Measurements

Two different measurements of body condition were taken on all bears captured, total body weight and percent body fat. Weight was measured to the nearest pound using a 300-pound spring scale and then converted to kilograms.

Percent body fat was measured using a bioelectrical impedance meter following the techniques described by Farley and Robbins (1994). Snout - tail resistance was measured by attaching the anterior electrodes to the upper lips and the posterior electrodes to either side of the base of the tail. Snout to tip of tail lengths and snout to vent lengths were measured along the dorsal contours. Percent and total body compositions were calculated using equations developed by Farley and Robbins (1994) (see Appendix D).

Change in percent body fat and change in weight were calculated for each recapture interval. Average daily changes in percent body fat and weight were then calculated by dividing by the number of days in the recapture interval.

Percent Body Fat of Black Bears Before and During the 1992 Berry Season

After I stopped using the recapture collars in 1992, general trapping continued to compare the mean percent body fat of adult male and female black bears before and during the 1992 berry season. Because individual bears were caught more than once during the 1992 field season, multiple captures of the same bear were randomly eliminated to maintain independence within and between groups for this analysis. Only one capture per bear was used for the analysis.

I considered female black bears age four or older and male black bears age six or older as adults. Jonkel and Cowan (1971) indicated that female black bears in their study area along the North Fork of the Flathead River could begin reproduction at age four. Hovey (pers. comm., B.C. Min of Forests) estimated that female black bears in the North Fork of the Flathead reach their full size by the time they begin reproduction between age four and five. Hovey also estimated that male black bears in the North Fork of the Flathead stop growing between the ages of six and seven.

Preliminary analysis indicated the data were not normally distributed. A power transformation ($y^{1.87}$) normalized the data. After a 10% trimming fraction was used to remove outliers, a oneway analysis of variance combined with Fisher's least significant difference (LSD) procedure (Koopmans 1987) was used to determine which groups were significantly different.

RESULTS

Body Condition of Recapture Collar Bears.

Figures 2-13 and Tables 2-3 show the changes in body condition (weight and percent body fat) and the changes in body composition (total and percent body water, total and percent body fat, and total and percent body protein) of the six recapture collar bears that had multiple captures. Two bears (AF1 and AF4) that wore the recapture collars but were not recaptured during the same season are excluded.

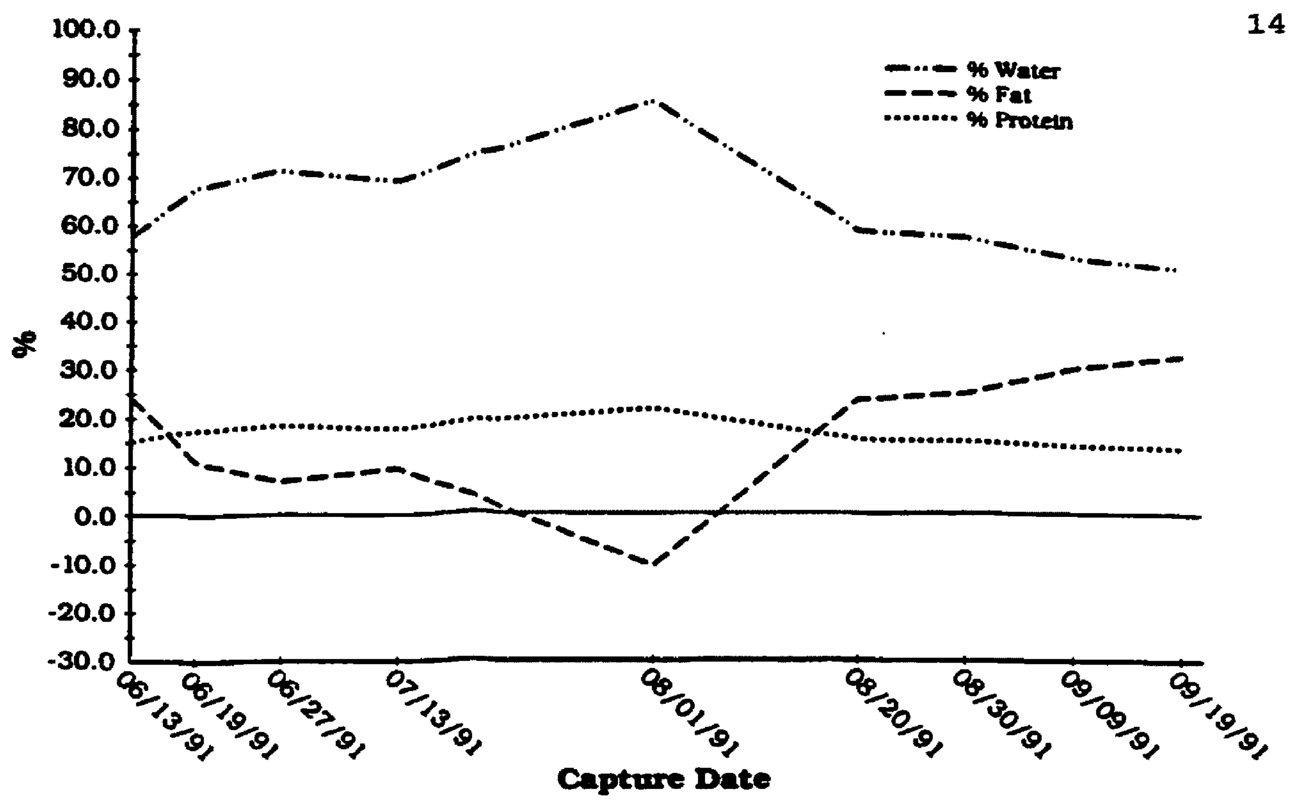

Figure 2. Body composition in percent of bear SAF1, a 3 year old female black bear, 1991.

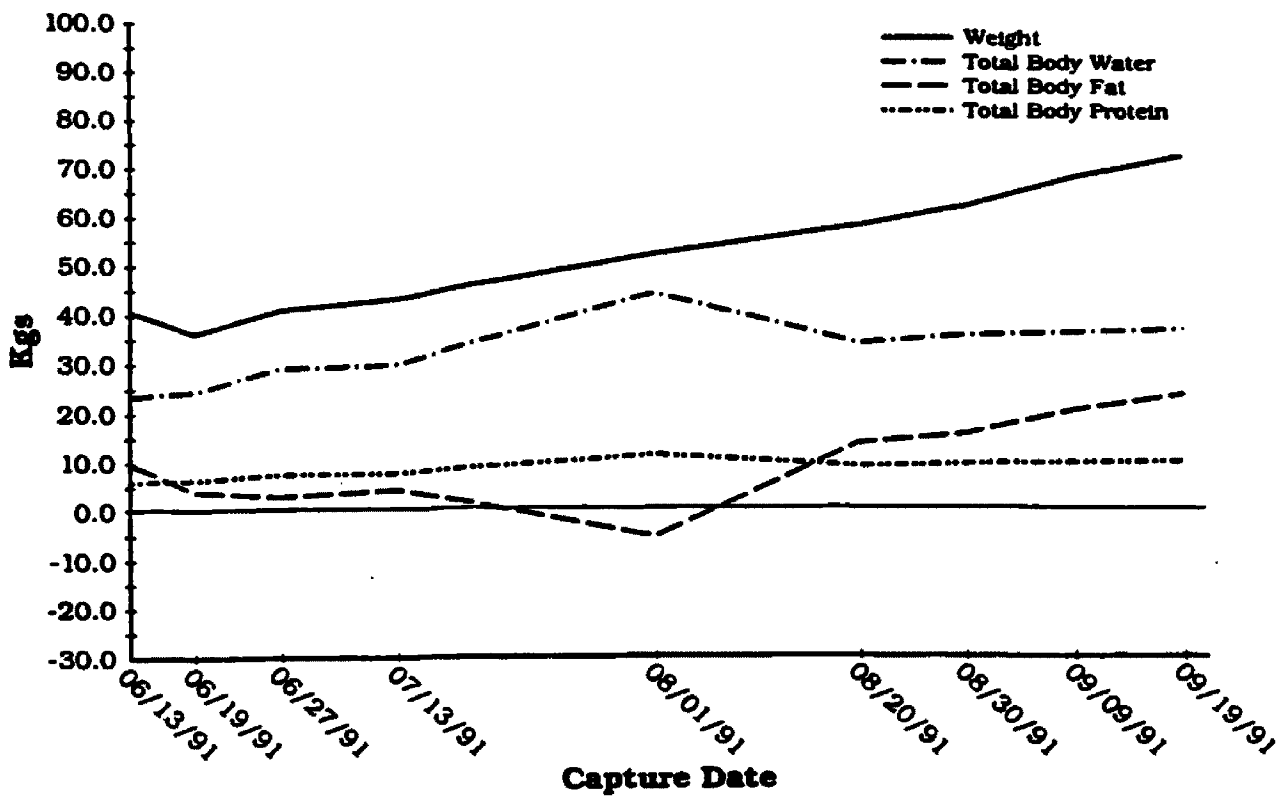

Figure 3. Body composition in kilograms of bear SAF1, a 3 year old female black bear, 1991.

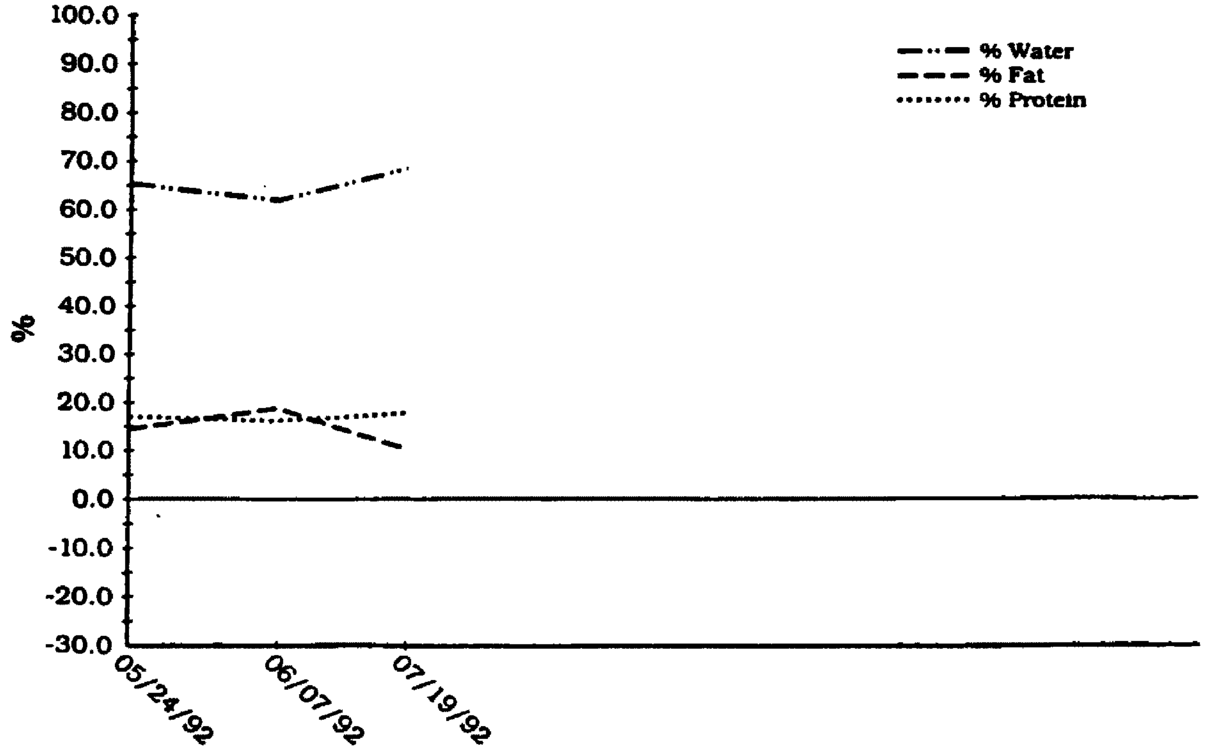

Figure 4. Body composition in percent of bear AM1, a 6 year old male black bear, 1991.

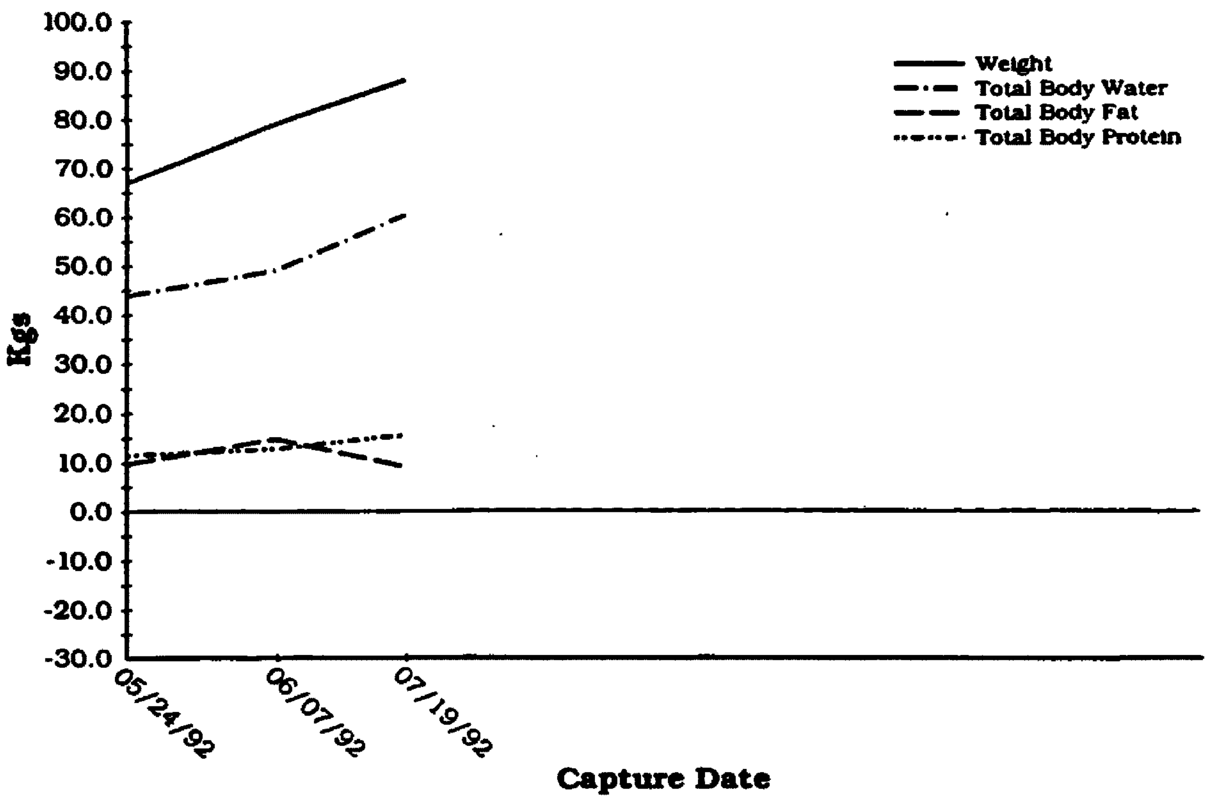

Figure 5. Body composition in kilograms of bear AM1, a 6 year old male black bear, 1991.

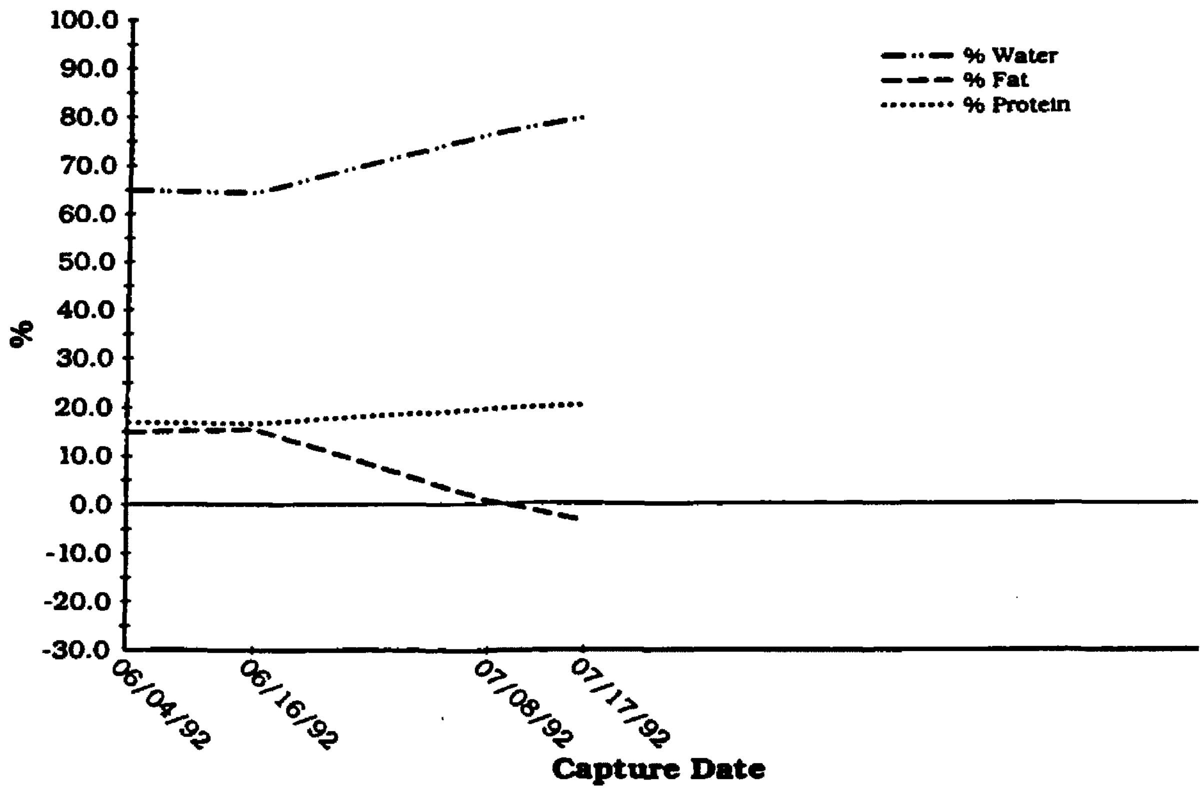

Figure 6. Body composition in percent of bear AF2, a 14 year old female black bear, 1992.

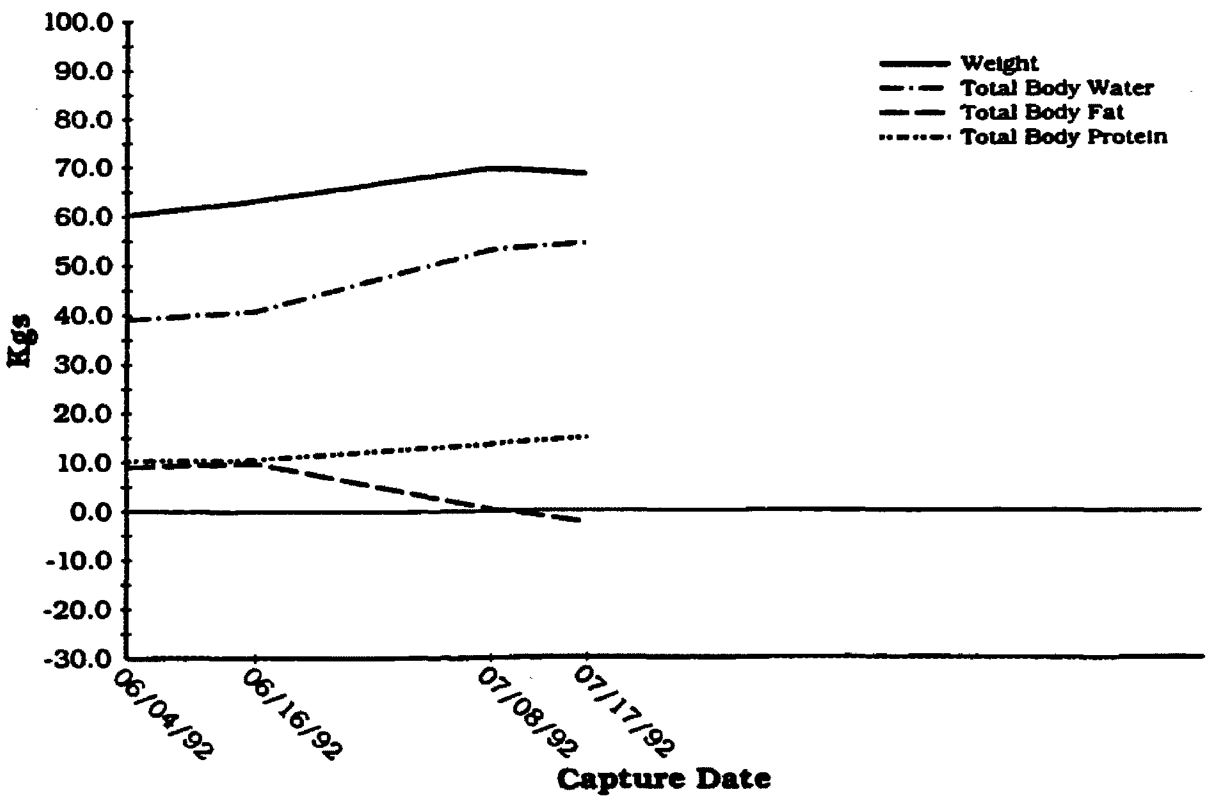

Figure 7. Body composition in kilograms of bear AF2, a 14 year old female black bear, 1992.

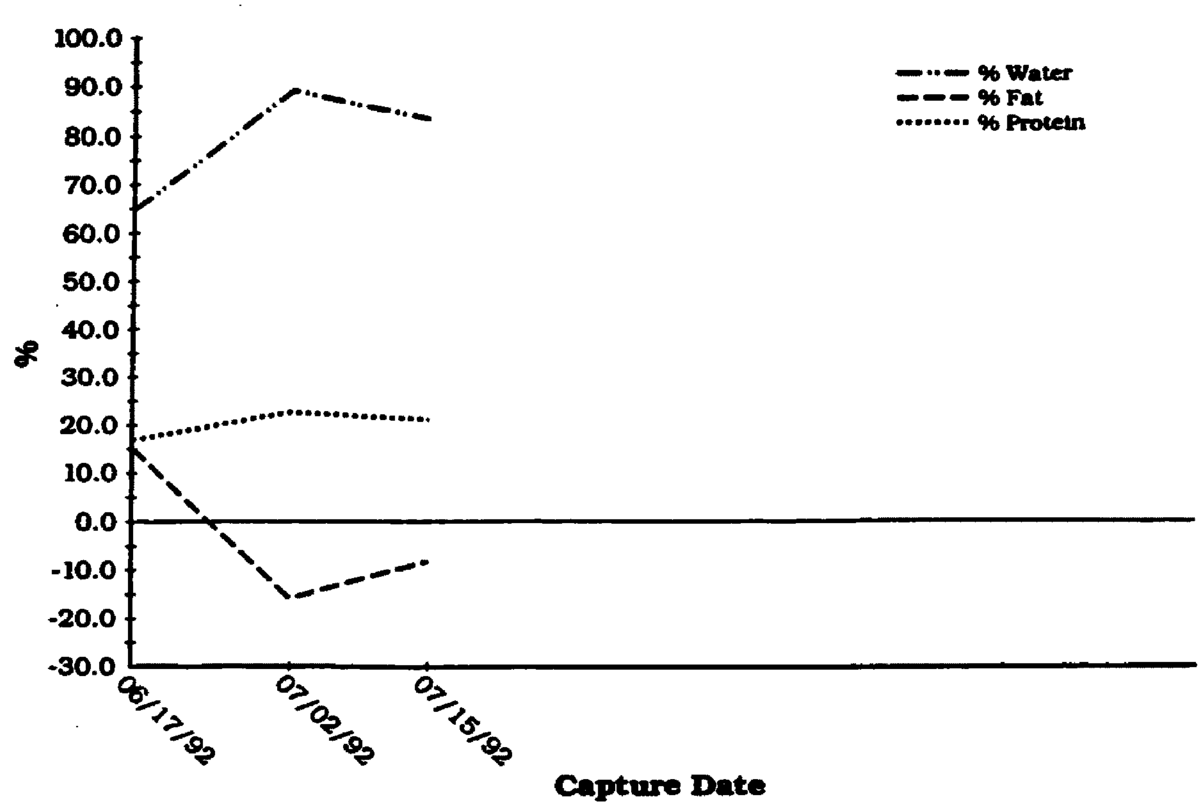

Figure 8. Body composition in percent of bear AF3, a 4 year old female black bear, 1992.

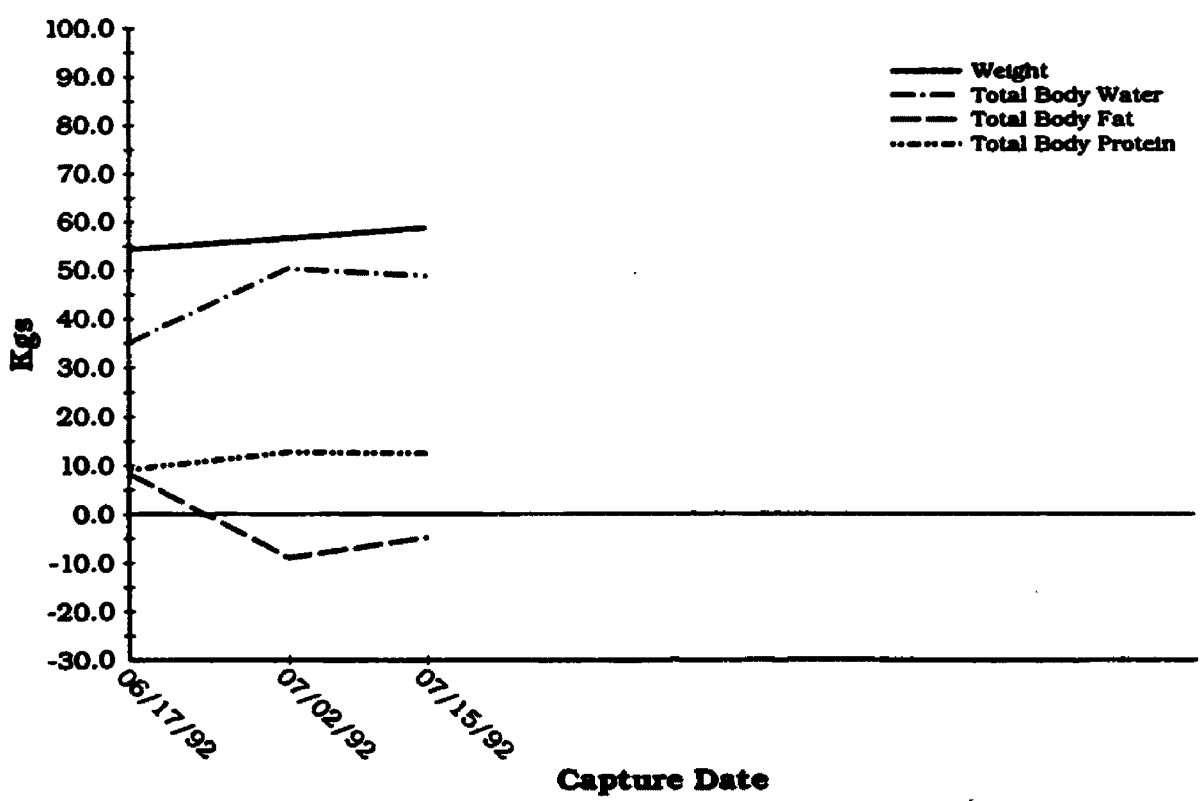

Figure 9. Body composition in kilograms of bear AF3, a 4 year old female black bear, 1992.

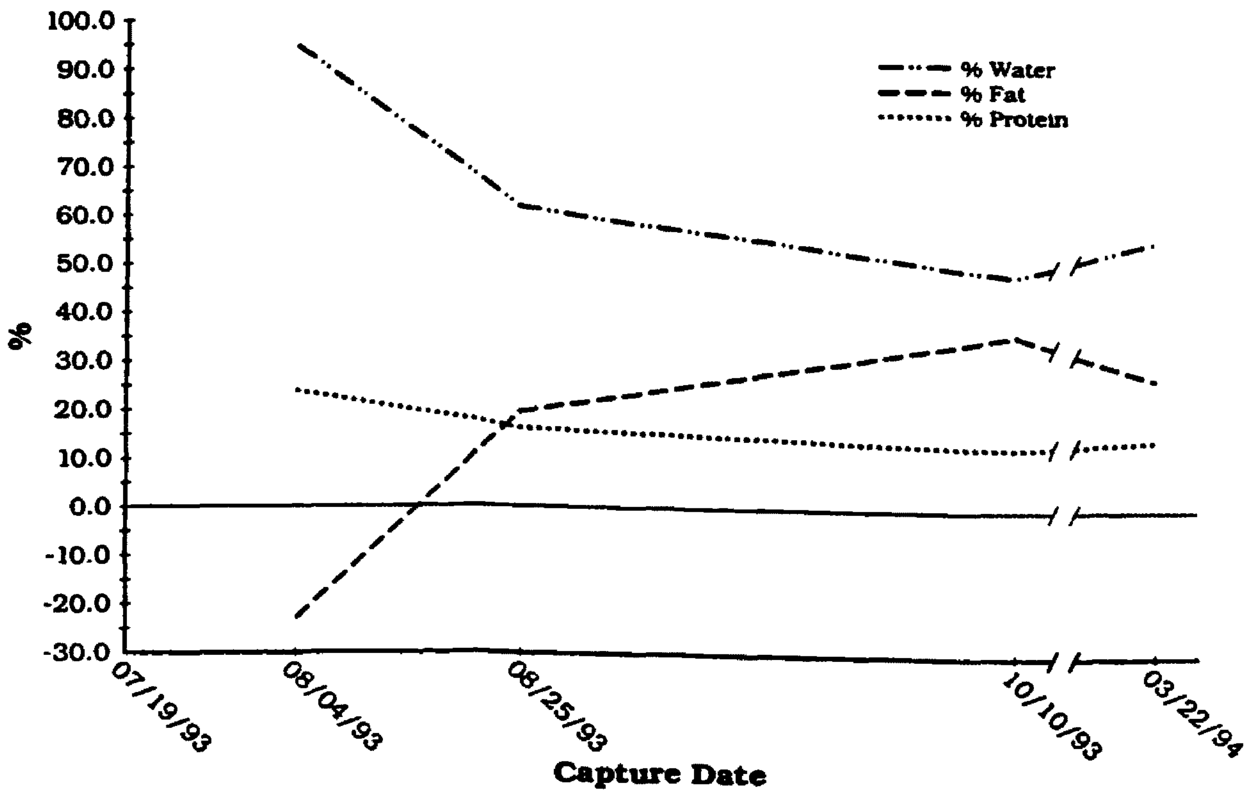

Figure 10. Body composition in percent of bear AF5, a 6 year old female black bear, 1993, 1994.

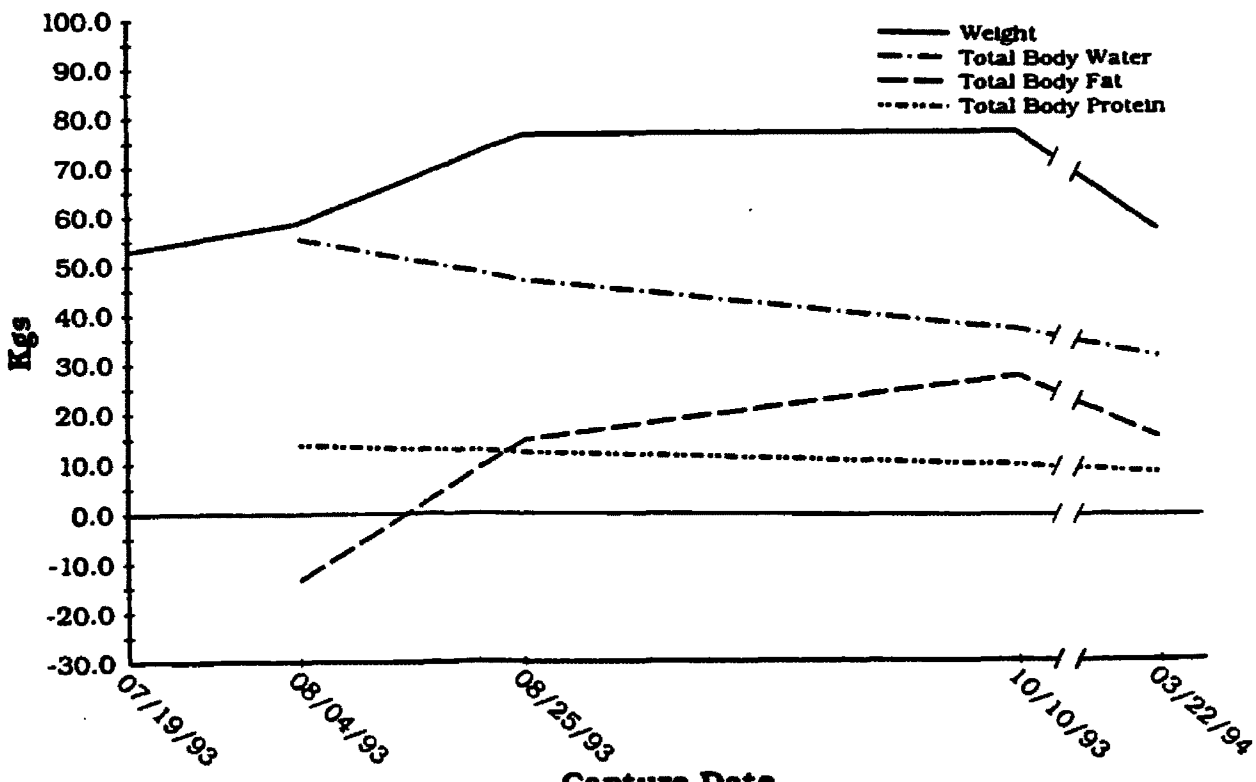

Figure 11. Body composition in kilograms of bear AF5, a 6 year old female black bear, 1993, 1994.

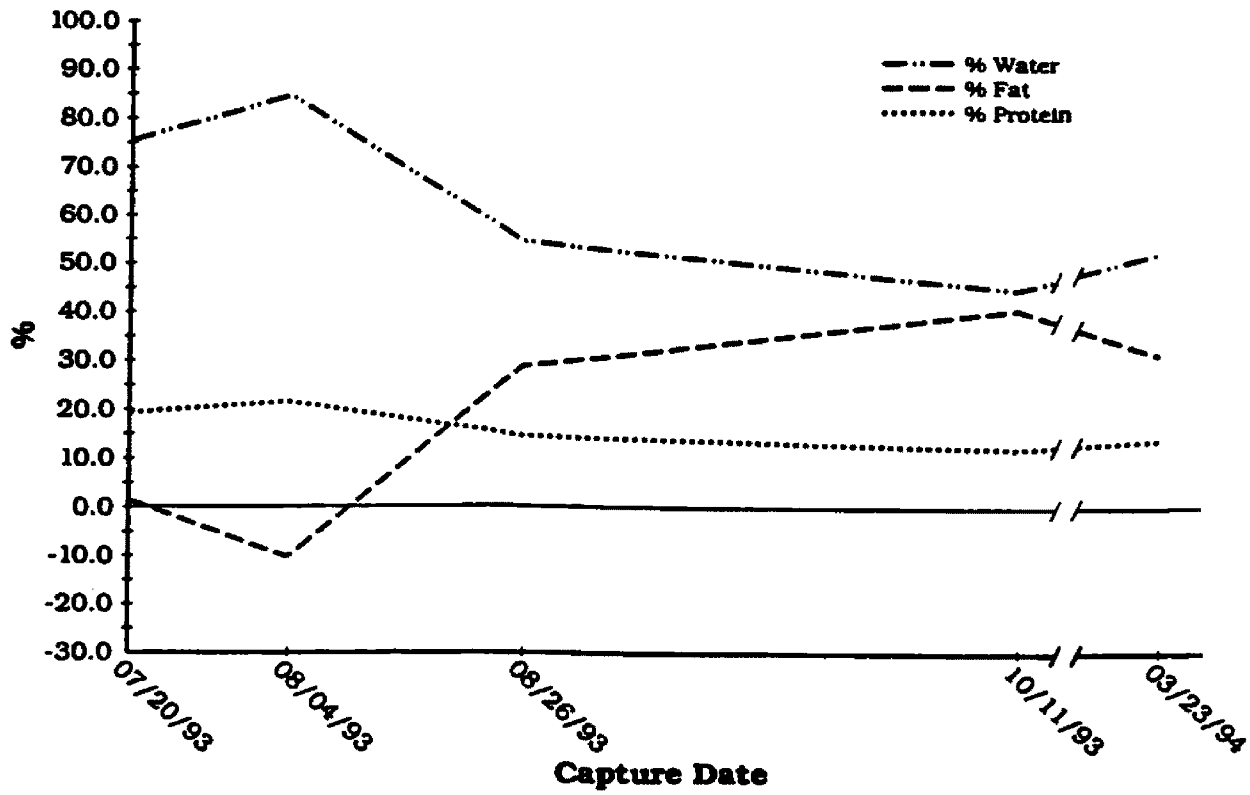

Figure 12. Body composition in percent of bear AF6, a 12 year old female black bear, 1993, 1994.

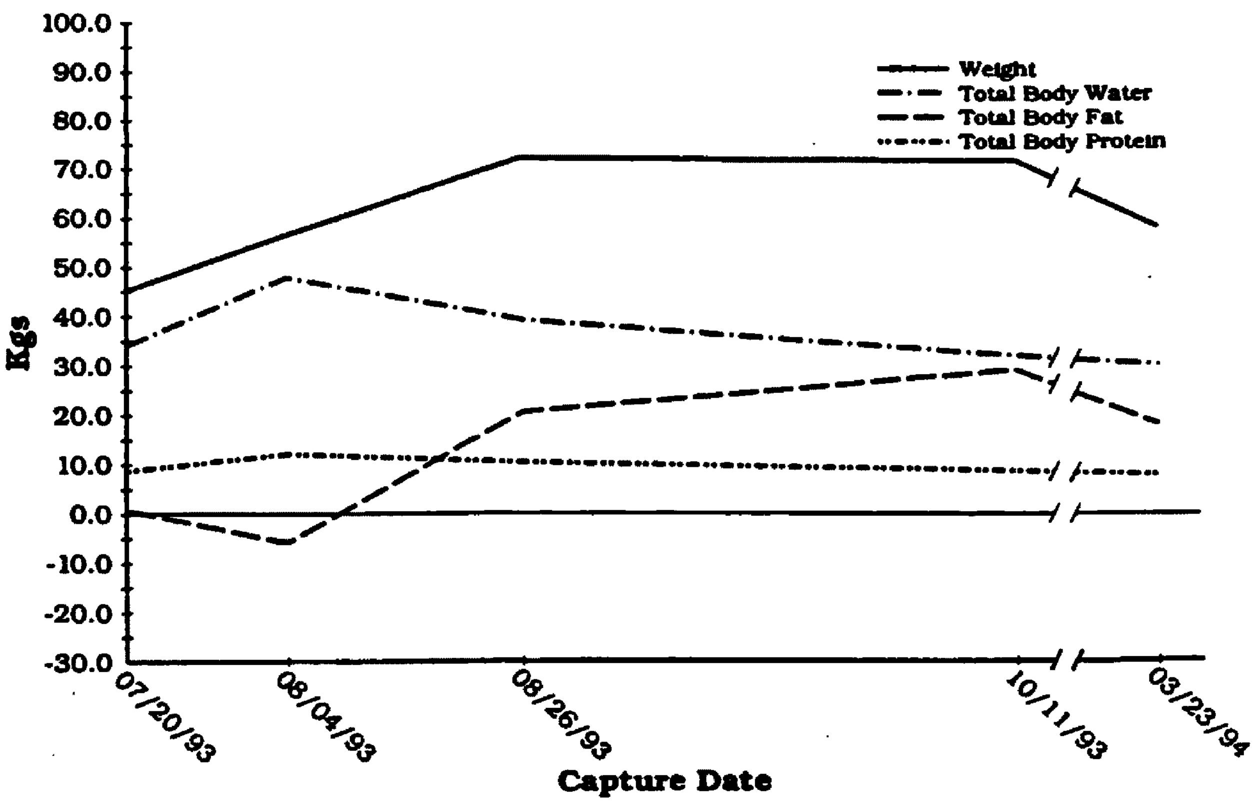

Figure 13. Body composition in kilograms of bear AF6, a 12 year old female black bear, 1993, 1994.

Table 2. Body condition and composition of six bears wearing the recapture collars. (Numbers in parenthesis are calculated total body values in kgs.).

BEAR	CAPTURE DATE	WEIGHT (KGS)	% BODY WATER	% BODY FAT	% BODY PROTEIN
SAF1	06/13/91	40.7	57.7 (23.5)	24.2 (9.8)	15.1 (6.1)
SAF1	06/19/91	36.2	67.8 (24.5)	11.2 (4.1)	17.5 (6.4)
SAF1	06/27/91	40.7	71.2 (29.0)	6.9 (2.8)	18.3 (7.4)
SAF1	07/13/91	43.0	69.0 (29.7)	9.7 (4.2)	17.8 (7.6)
SAF1	08/01/91	52.0	84.8 (44.1)	-10.5 (-5.5)	21.5 (11.2)
SAF1	08/20/91	57.9	58.3 (33.8)	23.4 (13.5)	15.3 (8.8)
SAF1	08/30/91	62.0	57.2 (35.5)	24.8 (15.4)	15.0 (9.3)
SAF1	09/09/91	67.9	53.1 (36.1)	30.0 (20.3)	14.1 (9.6)
SAF1	09/19/91	72.4	51.0 (36.9)	32.7 (23.7)	13.6 (9.9)
AM1	05/24/92	67.0	65.4 (43.8)	14.3 (9.6)	17.0 (11.4)
AM1	06/07/92	79.2	62.0 (49.1)	18.7 (14.8)	16.1 (12.8)
AM1	07/19/92	88.2	68.5 (60.4)	10.3 (9.1)	17.7 (15.6)
AF2	06/04/92	60.2	64.9 (39.1)	14.9 (9.0)	16.9 (10.2)
AF2	06/16/92	63.3	64.4 (40.8)	15.6 (9.9)	16.7 (10.6)
AF2	07/08/92	70.1	76.0 (53.3)	0.7 (0.5)	19.5 (13.7)
AF2	07/17/92	68.8	79.4 (54.6)	- 3.6 (-2.5)	20.2 (13.9)
AF3	06/17/92	54.3	64.7 (35.1)	15.2 (8.3)	16.8 (9.1)
AF3	07/02/92	56.6	89.0 (50.4)	-15.9 (-9.0)	22.5 (12.7)
AF3	07/15/92	58.9	83.0 (48.9)	- 8.2 (-4.8)	21.0 (12.4)
AF5	07/19/93	52.9	missing	missing	missing
AF5	08/04/93	58.8	94.5 (55.6)	-23.0 (-13.4)	23.8 (13.8)
AF5	08/25/93	76.9	61.5 (47.3)	19.3 (14.8)	16.0 (12.3)
AF5	10/10/93	79.2	48.4 (38.3)	36.1 (28.6)	12.9 (10.2)
AF5	03/22/94	58.8	55.4 (32.6)	27.1 (15.9)	14.6 (8.6)
AF6	07/20/93	45.2	75.4 (34.1)	1.5 (0.7)	19.3 (8.7)
AF6	08/04/93	56.6	84.6 (47.9)	-10.3 (-5.8)	21.5 (12.1)
AF6	08/26/93	72.4	54.3 (39.3)	28.5 (20.6)	14.4 (10.4)
AF6	10/11/93	72.4	44.8 (32.4)	40.7 (29.5)	12.1 (8.8)
AF6	03/23/94	58.8	52.2 (30.7)	31.2 (18.4)	13.8 (8.1)

Table 3. Change in body condition of six bears wearing recapture collars. Daily weight change and daily fat change are calculated average values between recaptures. Digestible calories/m² is a food value index calculated from plant biomass measurements. Digestible calories/g is a food value index calculated from scat analysis.

BEAR	RECAPTURE INTERVAL	DAILY WEIGHT CHANGE (kgs)	DAILY WEIGHT CHANGE (%)	DAILY FAT CHANGE (%)	DIGESTIBLE CALORIES/m²	DIGESTIBLE CALORIES/g
SAF1	1: 06/13/91 to 06/19/91	-0.8	-2.0	-2.20	missing	missing
SAF1	2: 06/19/91 to 06/27/91	0.6	1.7	-0.54	missing	152,061
SAF1	3: 06/27/91 to 07/13/91	0.1	0.2	0.18	8,836	139,411
SAF1	4: 07/13/91 to 08/01/91	0.5	1.9	-1.06	8,035	190,445
SAF1	5: 08/01/91 to 08/20/91	0.3	0.6	1.82	3,792	330,750
SAF1	6: 08/20/91 to 08/30/91	0.5	0.9	0.14	4,843	330,429
SAF1	7: 08/30/91 to 09/09/91	0.6	1.0	0.55	4,070	330,459
SAF1	8: 09/09/31 to 09/19/91	0.4	0.6	0.28	4,564	280,114
AM1	9: 05/24/92 to 06/07/92	0.9	1.3	0.34	12,735	112,705
AM1	10: 06/07/92 to 07/19/92	0.2	0.2	-0.19	missing	missing
AF2	11: 06/04/92 to 06/16/92	0.3	0.5	0.05	11,051	296,723
AF2	12: 06/16/92 to 07/08/92	0.3	0.5	-0.68	61,877	174,663
AF2	13: 07/08/92 to 07/17/92	-0.1	-0.1	-0.50	missing	missing
AF3	14: 06/17/92 to 07/02/92	0.1	0.2	-2.10	15,423	203,768
AF3	15: 07/02/92 to 07/15/92	0.2	0.3	0.61	4,015	160,163
AF5	16: 07/19/93 to 08/04/93	0.4	0.8	missing	3,765	missing
AF5	17: 08/04/93 to 08/25/93	0.9	1.5	2.05	6,758	missing
AF5	18: 08/25/93 to 10/10/93	0.1	0.1	0.37	missing	missing
AF5	19: 10/10/93 to 03/22/94	-0.1	-0.1	-0.05	missing	missing
AF6	20: 07/20/93 to 08/04/92	0.8	1.8	-0.78	5,986	missing
AF6	21: 08/04/93 to 08/26/93	0.7	1.2	1.80	5,709	missing
AF6	22: 08/26/93 to 10/11/93	0.0	0.0	0.27	missing	missing
AF6	23: 10/11/93 to 03/23/94	-0.1	-0.1	-0.06	missing	missing

Percent Body Fat of Black Bears Before and During the 1992 Berry Season

Mean percent body fat of adult male and female black bears before and during the 1992 berry season were compared. A one way analysis of variance indicated that the mean percent body fat of the four groups of bears was not equal ($P < 0.001$) (Table 4). Fisher's LSD procedure ($P = 0.05$) indicated that female black bears during the berry season had more body fat than both females and males before the berry season. The LSD procedure also showed that females during the berry season had more body fat than males during the berry season. Mean male percent body fat during the berry season was not different from male or female body fat before the berry season.

Table 4. Summary of statistical data and ANOVA for the comparison of mean percent body fat of adult male and female black bears before and during the 1992 berry season.

ORIGINAL DATA

	Before Berry Season		During Berry Season	
Statistics	female	male	female	male
n	3	6	7	4
mean	9.3	11.1	21.5	13.6
sd	7.6	10.5	4.2	1.3

POWER TRANSFORMED ($Y^{1.87}$) AND TRIMMED DATA

	Before Berry Season		During Berry Season	
Statistics	female	male	female	male
n	3	4	7	4
mean	89.0	66.9	319.6	132.9
sd	81.9	78.0	108.0	23.1

ANOVA FOR THE TRANSFORMED AND TRIMMED DATA

Source of variation	SS	df	MS	F
Between groups	220598.5	3	73532.8	10.0
Within groups	103252.1	14	7375.2	

DISCUSSION

Body Condition of Recapture Collar Bears

Percent Body Fat

The interpretation of percent body fat results is complicated by negative percent body fat measurements, a physiological impossibility. A certain amount of error exists in the measurement of percent body fat using bioelectrical impedance analysis. Error is associated with each regression used in the analysis (Farley and Robbins 1994). Because of this error, bioelectrical impedance analysis may result in negative measurements when used on bears with actual percent body fat close to zero (Farley, pers. comm., Washington State Univ.).

Factors such as water, limb position, electrode position, wounds, ingesta volume, and hydration status can affect BIA measurements (Farley and Robbins 1994). Ingesta volume and hydration status cannot readily be determined in the field. Farley and Robbins used BIA successfully on wet bears by placing bears on a sheet of plastic. The plastic prevented current from being conducted to the ground by the water. I followed this procedure when either the bear or the ground was wet. Although some negative percent body fat measurements were taken on rainy days, not all were.

Different limb positions and electrode placements also affect BIA measurements; however, because limb positions and electrode positions were standardized following Farley and

Robbins (1994) it is unlikely the negative percent body fat measurements are due to these factors.

Damaged tissue directly in the current path may also affect BIA measurements. There was slightly damaged tissue directly in the current path on every bear recaptured using the capture collars because the collars darted the bears in the back of the neck. However, damaged tissue cannot adequately explain all the occurrences of negative percent body fat. BIA indicated negative percent body fat in some conventionally caught bears without tissue damage directly in the current path.

Percent body fat of the recapture collar bears generally decreased during the pre-berry season and increased during the berry season (Figs. 2,4,6,8,10 & 12). The mean change in percent body fat before the berry season was - 0.43% per day (n = 7, s = 0.86%) and 0.32% per day (n = 5, s = 0.15%) during the berry season. The difference in means was not statistically tested because of small sample sizes, annual variation, and a lack of independence in the samples.

Because percent body fat and percent body water are inversely related, percent body water increased as percent body fat decreased during the pre-berry season. Likewise, percent body water decreased as percent body fat increased during the berry season. Percent protein generally increased before the berry season and decreased during the berry season.

Because percent body fat generally decreased while weight increased during the pre-berry season and because ash remains constant, the gain in weight has to be attributed to either a gain in body water, a gain in body protein, or a gain in both. Both percent body water and percent body protein generally increase before the berry season. However, this fact by itself does not mean that both total body water and total body protein increase during this season. The increase in percent body water and percent body protein depends on the relationship between the rate of change of total body water, total body protein, and total body fat. The graphs of body composition show that total body protein increases whenever total body water increases and that total body protein decreases whenever total body water decreases (Figs. 3,5,7,9,11 & 13). Changes in total body water are greater than corresponding changes in total body protein. This fact suggests that although some pre-berry weight gain is due to an increase in total body protein, a large portion of it is due to a gain in total body water. Other body composition studies have documented changes in the body water of humans and other animals; however, their findings do not explain the pre-berry season increase in total body water and associated weight gain in bears (Shizgal 1985, Elwyn et al. 1975, Pace and Rathburn 1945, Twyman and Liedtke 1987).

The increase in both total body protein and percent protein during the pre-berry season suggests that the bears were growing and/or rebuilding muscle tissue. Little of this increase in protein was probably for growth because most of the bears sampled, especially the females, were mature bears. Bears emerging from hibernation may need to replace muscle protein catabolized for energy during the winter. Nelson et al. (1983) found that protein was continuously broken down during denning; however, the protein was immediately replaced by recycling nitrogen from the urea. Maxwell et al. (1988) suggest that if not enough fat reserves are available, denning bears catabolize additional protein to meet their energy requirements. This catabolized protein exceeds the bear's ability to recycle nitrogen from the urea and the bear urinates. Urination causes the bear to lose both water and protein. The protein is lost because the nitrogen in the urea is not recycled.

Only three of the recapture collar bears (SAF1, AF5, and AF6) were recaptured during the berry season. The percent body fat of these three bears increased during the berry season. Correspondingly, percent body water and percent body protein decreased during this period. Although total body fat generally increased for these three bears during the berry season, there were differences in the changes in total body water and total body protein for these three bears during the berry season. Total body water and total body protein, after initial decreases, increased slightly in bear SAF1. Percent body water and percent protein decreased in bear SAF1 during this period because total body water and total body protein initially decreased and then increased at a slower rate than total body fat. Weight gain by bear SAF1 during the berry season was primarily, but not completely, due to an increase in total body fat. Total body water and total body protein decreased in bears AF5 and AF6 during the berry season. The weight gain of these two bears during the berry season was completely due to a gain in total body fat.

The pre-berry season gain in protein may be caused by the composition of pre-berry season foods. Pre-berry season foods are higher in digestible protein than are berry season foods. In fact, huckleberries (*Vaccinium* species) have negligible digestible protein. Pre-berry season plant foods are also higher in digestible protein earlier in the season than later in the season (McLellan and Hovey 1995).

Brody and Pelton (1988) suggest another explanation for the gain in pre-berry season protein and gain in berry season fat. They suggest that a systemically mediated decrease in protein assimilation and an increase in fat assimilation may occur during the berry season.

Although percent body fat and percent body water are inversely related, total body fat and total body water are not. Total body fat, total body water, and total body protein all decreased while bears AF5 and AF6 were denned. Because total body fat decreased faster than total body water and total body protein, percent body water and percent body protein increased while percent body fat decreased. Weight loss over the winter was primarily due to the decrease in total body fat; however, the fact that total body protein also decreased during this interval supports the idea that bears emerging in the spring need to rebuild body protein. Koebel et al. (1991) and Maxwell et al. (1988) also found that most of the weight lost by their denned bears was due to fat metabolism; likewise, their denned bears also lost some protein and water.

__Weight__

Weight changes of the recapture collar bears follow a general pattern. As expected, all the bears weighed more at their last fall capture then they did at their first spring capture. Although the weights of the two female bears caught in their dens were decreasing, they still weighed more in March 1994 than they did in July 1993 (Table 2). Bear AF5 lost 0.16% of her body weight per day from October 10, 1993 to March 22, 1994 while bear AF6 only lost 0.12% of her body weight per day for the same period; however, these two bears were not weighed when they emerged in 1994. This rate of loss is less than that for three captive male black bears in Watts' (1989) study. His three male black bears lost 0.26%/day, 0.19%/day, and 0.18%/day over winter.

Bears may continue to lose weight in the early spring from nutritional stress (Eagle and Pelton 1983). This post emergence period may lack the food necessary for weight gain. Bear SAF1 was the only recapture collar bear that lost weight early in the field season. She lost 4.5 kgs between her first two captures during the middle of June. Although it is possible this weight loss may coincide with this post emergence period, it could also be due to another unknown factor. The 1991 emergence date of bear SAF1 is unknown; however, several studies in northwestern Montana found that black bears emerge sometime between mid April and mid May (Jonkel and Cowan 1971, Kasworm and Manley 1988). Recapture collar bears caught during the middle of June in 1992 did not lose weight.

Overall, rate of weight gain was higher during the berry season than before the berry season. However, the rate of weight gain during any recapture interval in the berry season may have been smaller than the rate of weight gain in any interval during the pre-berry season. Mean pre-berry weight gain for the recapture bears was 0.1 kgs/day ($n = 8$, $s = 0.4$ kgs/day) while mean weight gain during the berry season was 0.5 kgs/day ($n = 11$, $s = 0.28$ kgs/day). The difference in means was not tested statistically because of small sample sizes, annual variation, and a lack of independence in the samples.

Male black bear AM1 had a lower rate of weight gain during his second recapture interval than during his first. Both female black bears AF5 and AF6 did not gain as much weight between the end of August and the middle of October as they did during the previous intervals. Late season berries may be less abundant and less nutritious than early season berries.

Percent Body Fat of Black Bears Before and During the 1992 Berry Season

The results indicate that female black bears during the berry season had proportionally more body fat than any other group tested. Female bears expend energy giving birth and supporting cubs while they are denned; therefore females may require higher fat reserves than males. Males may also need less stored energy for maintenance during the winter because they spend less time hibernating than females. In northwestern Montana, Kasworm and Manley (1988) found that male black bears generally denned later and emerged earlier than female black bears.

Despite the poor berry season in 1992 (Appendix B), female bears during the berry season had more body fat than females before the berry season. Bears during the berry season should have more body fat than bears before the berry season. Huckleberries and buffaloberries (*Shepherdia* *canadensis*), the two most commonly eaten berry species in the study area, have more digestible energy than any of the forbs eaten during the pre-berry season (McLellan and Hovey 1995). Bears may also assimilate fat more readily during the berry season than during the pre-berry season (Brody and Pelton 1988).

The results indicated that male black bears were not fatter during the berry season than before the berry season. This lack of difference might be caused by the loss of sensitivity associated with non-parametric analyses. Sample sizes were small resulting in the necessary use of non-parametric analyses that are robust but not as sensitive as parametric techniques. Because sample sizes were small, these results may not hold true for a more representative sample of the population.

CONCLUSION

BIA provides the ability to obtain quick and accurate body condition measurements in the field. Combined with the recapture collars, BIA provides the ability to track the body condition of individual free ranging bears through measurements taken at frequent recaptures. Neither BIA nor the recapture collars are without problems; however, these problems can be overcome by using techniques that will mitigate the effects of the problems if they occur.

The use of BIA on conventionally captured bears during 1992 showed that female black bears during the berry season had more body fat than any of the other three groups tested. The use of BIA on the recapture collar bears showed that percent body fat decreased in the pre-berry season and increased in the post berry season although weight generally increased from spring to fall. BIA also suggested that pre-berry season weight gain was primarily due to a gain in total body water and secondarily due to a gain in total body protein. Although the results obtained using BIA and the recapture collars are inconclusive because of small sample sizes, this is the first time that body condition has been tracked to this extent in free ranging bears.

CHAPTER THREE: HABITAT QUALITY

INTRODUCTION

A major factor affecting the body condition of animals is the quantity and quality of the food in the habitat that the animals use. Because body condition affects reproduction and survival, the relationship between body condition and the food in the animal's habitat is important. Although many bear habitat studies have been done, none have tried to specifically link food quantity and quality to the body condition of individual free ranging bears. If the quality and quantity of foods can be specifically linked to the body condition of bears, habitat management could potentially be used to produce bear foods that correspond to improvements in bear body condition. This in turn could increase the survival and reproduction of bears providing other factors that affect bear mortality and reproduction are also managed for the same goal.

METHODS

Habitat Quality

Bears wearing recapture collars were monitored closely using radio telemetry conducted at least once daily from the ground and approximately once a week from the air. Bear locations were recorded on aerial photographs and topographic maps. These locations were investigated on the ground after the bear had left the immediate area.

Vegetative plots were conducted at radio location sites when visible evidence of the right age (either scats, feeding sign, or beds) indicated bear use. Ten meter radius all species vegetative plots measuring coverage class, size class, elevation, and aspect were conducted to determine habitat type. Plots were centered at the location of specific bear sign.

Because bears were sometimes located more than once a day and because all radio locations were investigated, it was possible to have several vegetative plots from locations on the same day. To maintain independence and make sure that any one day during a recapture interval was not weighted more than any other day, I only used plots separated by at least twelve hours in my analysis. However, it is important to understand that true independence could not be met because bears can learn and remember. Very likely, bears' feeding habits are based on experiences and therefore are never truly independent.

Biomass of six major bear foods was estimated during their season of use following techniques developed by Vandehey (1991). The biomass plots were centered on bear sign. The direction of biomass plots on the ground was randomly chosen. This direction was the same for all the biomass plots conducted at one site.

Graminoides were clipped in five randomly selected 1m x 1m microplots within a 10m X 10m macroplot. *Equisetum* was clipped within a 1m x 10m plot while *Angelica* was clipped within a 5m x 10m plot. Wet weight was obtained in the field for all clipped vegetation. All clipped vegetation was air dried for several days and then oven dried at 40° C for twenty-four to thirty-six hours to obtain dry weights.

Cover and basal area of *Heracleum lanatum* plants in a 5m x 10m plot were measured and biomass was estimated using a regression developed by Vandehey (1991).

During 1991, *Shepherdia* biomass was estimated within a 10m radius plot following Vandehey (1991). *Shepherdia* berries were non existent in 1992. In 1993, *Shepherdia* biomass was estimated within a 5.64m radius (0.01 ha) plot, a standard plot size used by the B.C. Forest Service (Bruce McLellan, pers. comm., B.C. Min. of Forests). All berry producing stems within the plot were placed in three size classes (0.375 in, 0.5 in, and 0.625 in). Berries from at least thirty branches of each size class were counted and weighed so regression analysis could be used to estimate biomass. For 1991 *Shepherdia* biomass data, I used biomass per stem class data collect by Fred Hovey (unpubl. data, B.C. Min. of Forests). Biomass per stem class data in 1993 were collected by Bruce McLellan (unpubl. data, B.C. Min. of Forests).

The biomass of *Vaccinium* species was estimated by counting berries in nine 1 x 1.5 m plots located 10 meters apart. A subsample of berries was picked to obtain the average wet and dry weight of the huckleberries. I did not differentiate between huckleberry species because of hybridization (Vandehey 1991).

Other foods such as ants, wasps, and ungulate remains were noted; however, they were not used in the biomass calculations because it was impossible to estimate their biomass efficiently.

Statistical Analysis

I standardized the biomass of each of the six bear foods by converting the dry biomass for each food into average dry biomass per m^2 for each recapture interval. Then for each food, the dry biomass per m^2 was multiplied by the digestible energy of each bear food measured (calories/g) to obtain average digestible calories per m^2 for each recapture interval (Table 3). The digestible energy values used were obtained from the analysis of plants collected seasonally from the study area (McLellan and Hovey 1995). The average digestible calories per m^2 were then linearly regressed with the average daily change in body condition for a recapture interval. Average daily change in percent body fat and average daily percent change in weight were used as measures of body condition. Average daily percent change in weight was used to standardize between bears of different weights because body weight affects metabolism (Kleiber 1961), and metabolism affects body condition.

Percent Body Fat

The hypothesis that change in percent body fat of wild black bears was positively correlated to the value of six major foods (digestible cal/m^2) in their habitat was tested with a linear regression. Recapture intervals with negative percent body fat measurements were excluded from the analysis because they are unrealistic and indicate error. Preliminary analysis suggested that variance was not constant and that the dependent data were not normally distributed for each value of the independent variable. The unequal variance and the lack of a normal distribution were largely due to the values of recapture interval 12; however, a review of the original data showed that the change in percent body fat and the food value for this interval were accurate. A transformation of food value by (- 1/X) normalized the data and equalized the variance.

Weight

The hypothesis that percent change in body weight of wild black bears was positively correlated to the value of six major foods (digestible cal/m^2) in their habitat was tested with a linear regression. Preliminary analysis suggested that variance was not constant. The unequal variance was largely due to the values of recapture interval 12; however, a review of the original data showed that the percent change in weight and the food value for this interval were accurate. A transformation of food value by (- 1/X) equalized the variance.

RESULTS

Relationship Between Food Value and Percent Body Fat

The hypothesis that change in percent body fat of wild black bears was positively correlated to the value of 6 major foods in their habitat was not accepted (Figs. 14 & 15). The transformed values of change in percent body fat were negatively correlated to food value ($r^2 = 0.54$) although the correlation was not significant ($p > 0.05$) (Fig. 15).

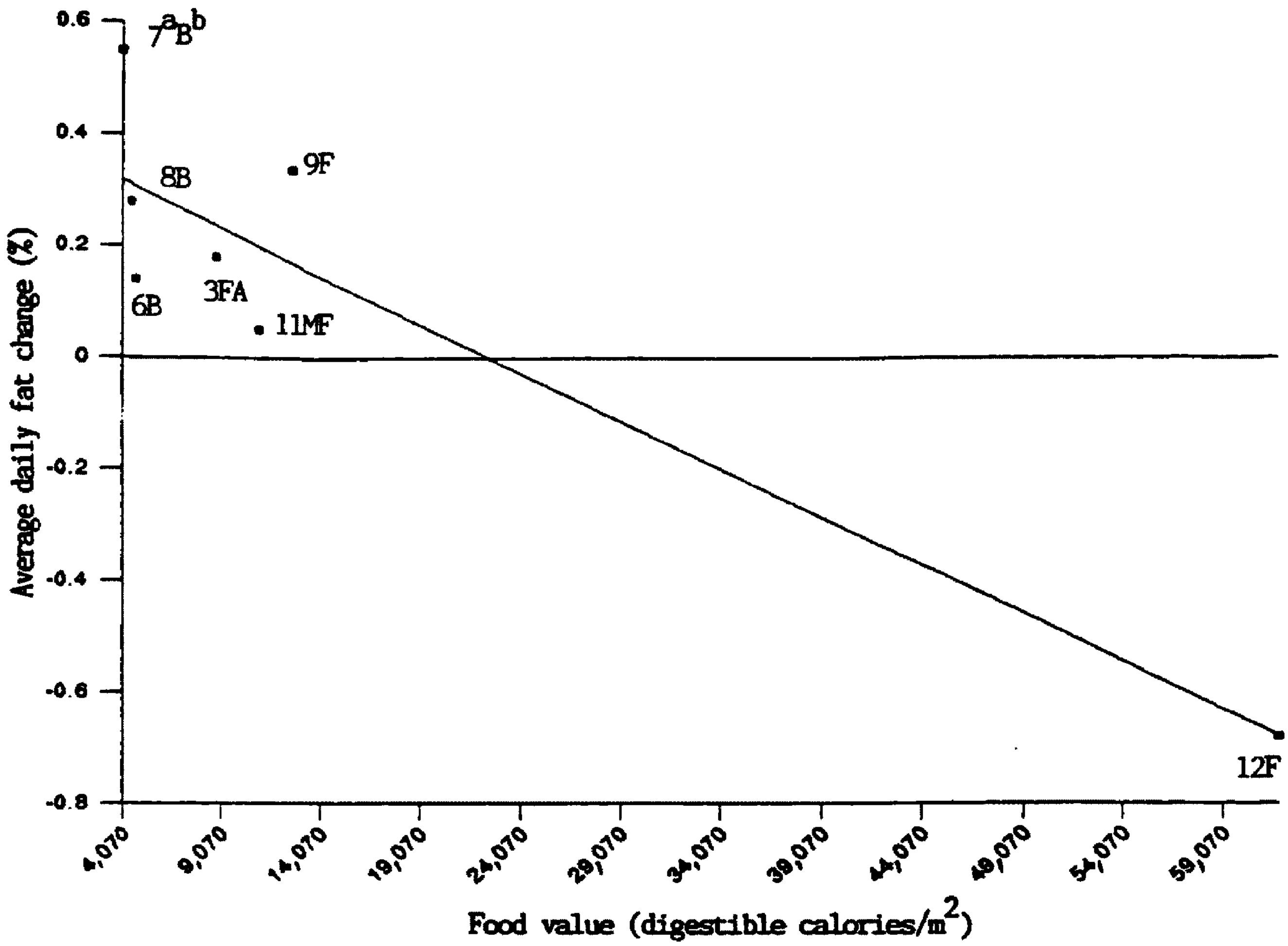

Figure 14. Linear regression of percent body fat versus digestible calories per m². $Y = 0.39 + (-1.73E-05)(X)$, $r^2 = 0.85$, SEE = 0.16, n = 7, $F_{(1,5)} = 28.35$, $p = 0.003$.

[a] Numbers at data points are recapture intervals (Table 3).

[b] Food the bear was eating during the recapture interval. Determined from observation and scat analysis (Table 7). F = forbs and grass, A = ants, B = berries, M = meat.

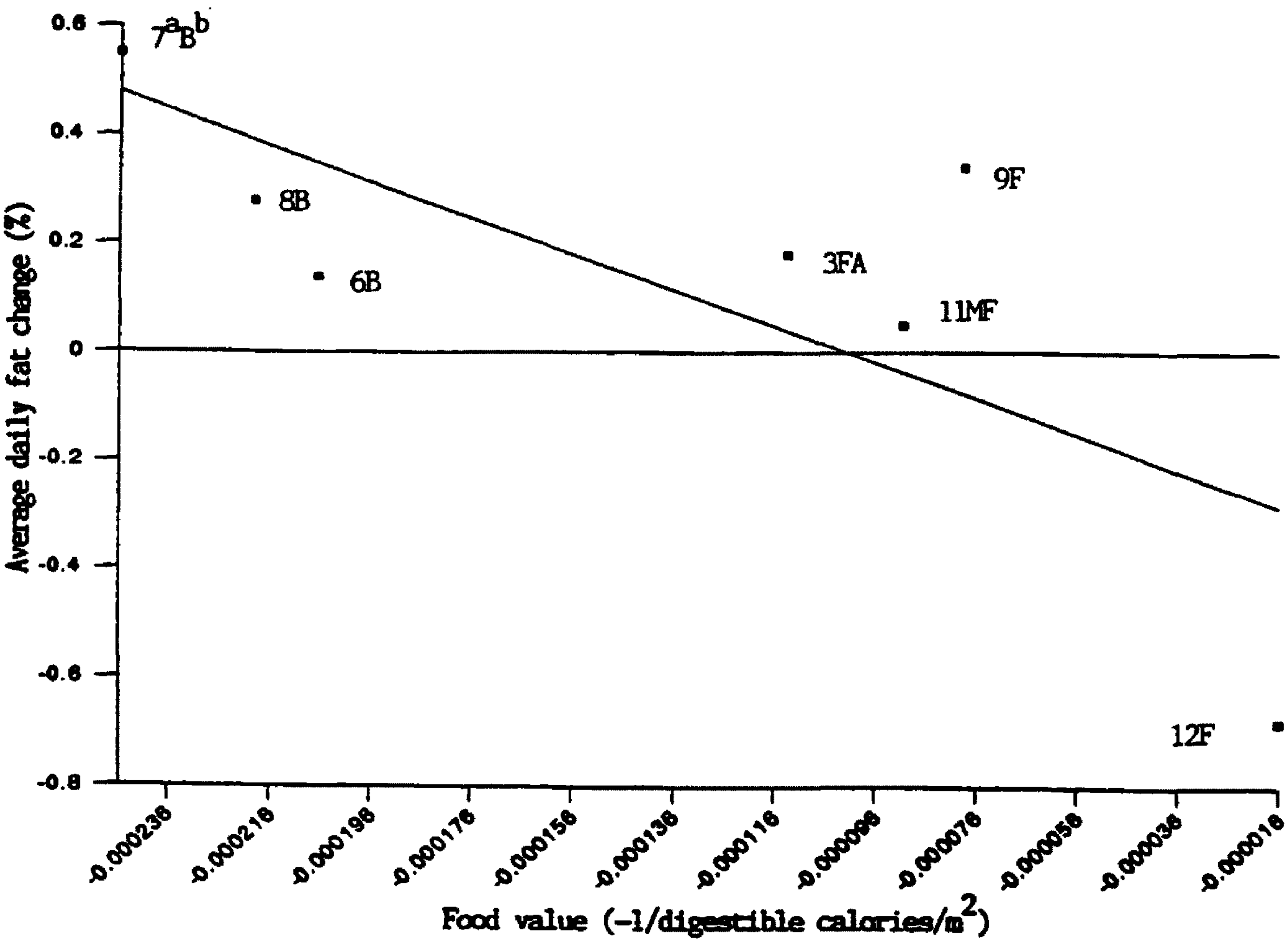

Figure 15. Linear regression results of percent body fat versus transformed values of digestible calories per m^2. Transformation = -1/X. $Y = -0.34 + (-3328.77)(X)$, $r^2 = 0.54$, SEE = 0.29, n = 7, $F_{(1,5)} = 5.8$, $p = 0.06$.

[a] Numbers at data points are recapture intervals (Table 3).

[b] Food the bear was eating during the recapture interval. Determined from observation and scat analysis (Table 7). F = forbs and grass, A = ants, B = berries, M = meat.

Relationship Between Food Value and Weight

The hypothesis that percent change in weight of black bears was positively correlated to the value of six major foods (digestible cal/m^2) in their habitat was not accepted (Figs. 16 & 17). Percent change in weight was not correlated to the transformed food values ($r^2 = 0.00$, $p = 0.92$) (Fig. 17).

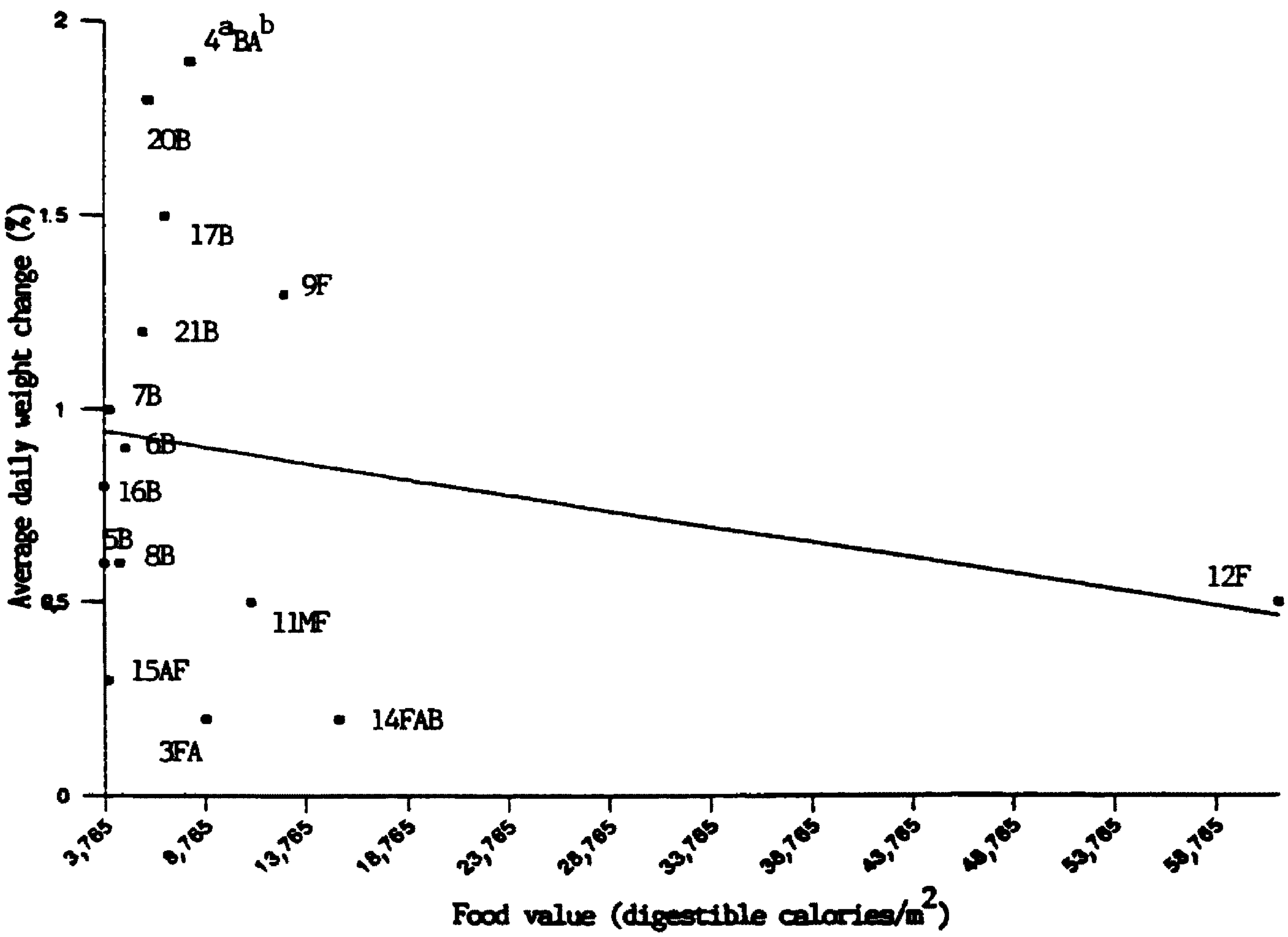

Figure 16. Linear regression results of percent change in weight versus digestible calories per m^2. $Y = 0.98 + (-8.23E-06)(X)$, $r^2 = 0.05$, $SEE = 0.56$, $n = 15$, $F_{(1,13)} = 0.65$, $p = 0.43$.

[a] Numbers at data points are recapture intervals (Table 3).

[b] Food the bear was eating during the recapture interval. Determined from observation and scat analysis (Table 7). F = forbs and grass, A = ants, B = berries, M = meat

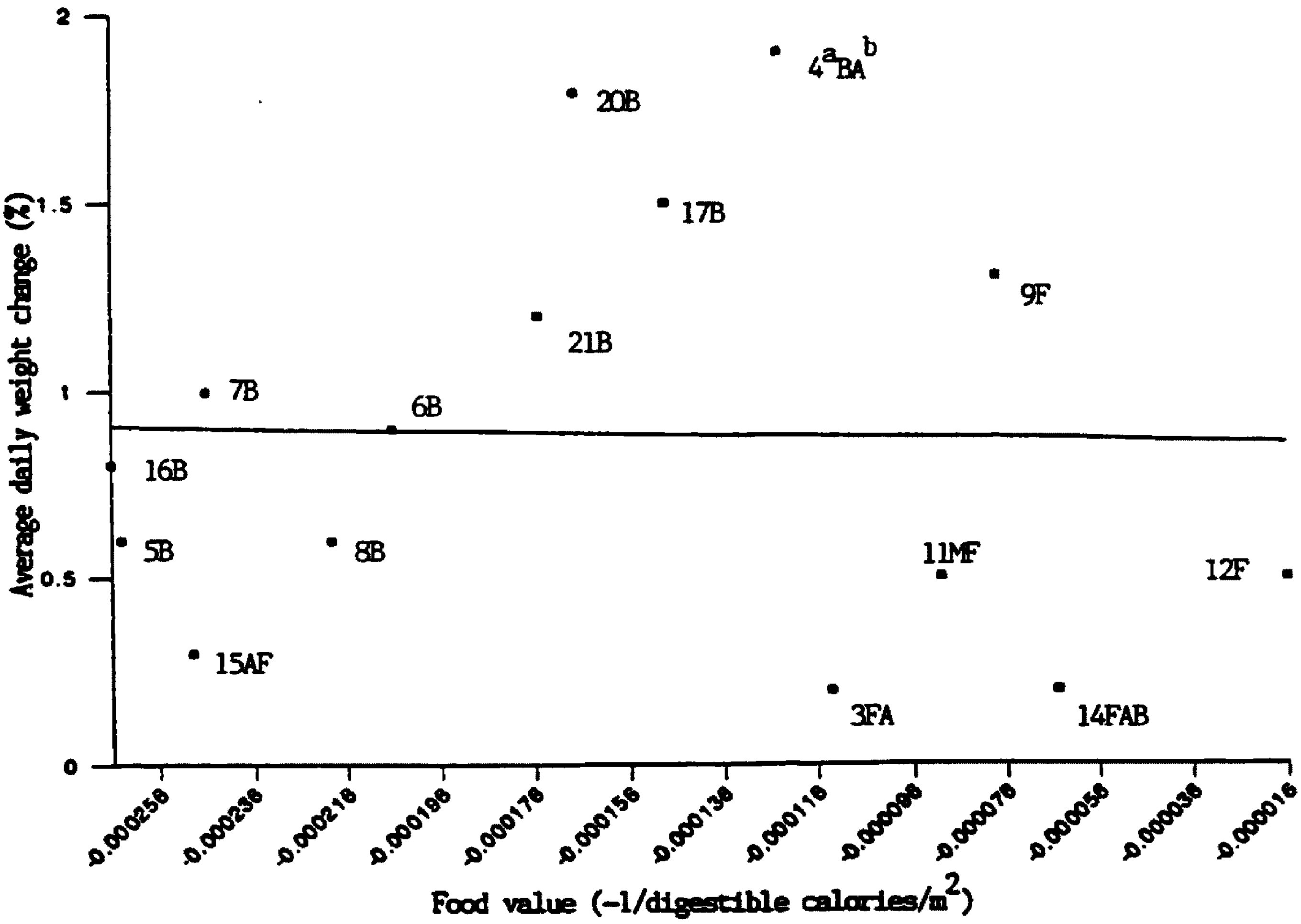

Figure 17. Linear regression results of percent change in weight versus transformed values of digestible calories per m^2. Transformation = -1/X. Y = 0.86 = (-186.27)(X), r^2 = 0.00, SEE = 0.57, n = 15, $F_{(1,13)}$ = 0.01, p = 0.92.

[a] Numbers at data points are recapture intervals (Table 3).

[b] Food the bear was eating during the recapture interval. Determined from observation and scat analysis (Table 7). F = forbs and grass, A = ants, B = berries, M = meat.

DISCUSSION

The rejection of the hypothesis for both the change in percent body fat - food value relationship and the percent change in weight - food value relationship based on the data I collected suggests that more than just quantity and quality of food is important to the body condition of bears.

Optimal foraging theory assumes that fitness is an increasing function of net energy gain; therefore, animals should maximize their energy intake when choosing what foods to eat (Charnov 1974, Pulliam 1974, and Pyke et al. 1977). My estimate of food value (digestible calories/m^2) only includes a quality and quantity estimate. However, the distribution of the food and how efficiently it can be handled (Pulliam 1974), and how fast it passes through the digestive system also affect net energy intake.

Berries have less digestible calories/m^2 than forbs and graminoids (Figs. 14-17); however, Figures 2-13 indicate that bears gain weight and fat more rapidly in the fall when they are eating berries. This higher gain while bears are eating berries suggests that bears may forage more efficiently on berries than on forbs and graminoids.

Foraging efficiency in berries could be higher for several reasons. Berries may be assimilated more quickly than forbs and graminoids allowing bears to eat more berries than forbs and graminoids over the same amount of time.

Animals may also forage more efficiently when search and handling times are reduced (Pyke et al. 1977). During the berry season lower search and handling times for berries could offset their lower digestible calories/m^2.

Although the results suggest that bears may forage more efficiently on berries, these results are preliminary. The number of bears used in the analysis was small due to the expense of the recapture collars. Additionally, the number of biomass plots for each recapture interval was small.

The number of plots for each interval was small partly because some plots were eliminated to maintain independence and partly because the average number of days between captures was low. The number of plots was also low because each bear radio location did not result in a biomass plot. Plots were only done when bear sign was present and bear sign was not found at each bear location. The small sample sizes increase the possibility that the samples were not representative of the population as a whole.

Biomass plots were based on bear radio location sites; however, these sites were not necessarily foraging areas. Locations of bears may also have been taken while bears were either resting or traveling. Plots were done when either scats, foraging evidence, or beds were present; however, all three were not always present. Because foraging evidence was not always present at a biomass plot site, some biomass plots may not represent bear foraging areas.

Because bears are omnivorous, trying to measure all the different types of foods they eat would be extremely time consuming; therefore, only the foods shown to be important to the population as a whole were sampled. Scat analysis showed that some of these major bear foods were not important to certain individuals, while other foods that were not sampled were important. The biomass of certain types of bear foods such as carrion and ants was difficult to estimate, so although they are important bear foods, they were ignored in the biomass analysis.

The higher weight and percent body fat gains while the bears were eating berries may also partially be due to a systemically mediated increase in fat and carbohydrate metabolism that occurs in the fall (Brody and Pelton 1987).

CONCLUSION

The results suggest that bears may forage more efficiently on berries than on forbs and graminoids; however, the results are only preliminary because of small sample sizes and differences between what the bears ate and what was sampled.

CHAPTER FOUR: SCAT COMPOSITION

INTRODUCTION

Scats were analyzed to determine if the plants measured in the biomass plots accurately represented what the individual recapture collar bears were eating. Foods measured in the vegetative plots did not necessarily reflect what individual bears ate during an interval. These foods were measured because previous studies in the area determined these were some of the most important foods to the bear population as a whole.

Scats were also analyzed to determine if a body condition - diet model more accurately represented the relationship between changes in body condition and food value than a body condition - plant biomass model. Corrected scat compositions closely approximate what the bears actually ingest; however, because of individual variation in what bears eat and yearly variations in food, this may or may not be similar to what foods are important to a bear population over several years. Depending on how representative the foods measured in the vegetative plots are of the foods the bears really ate, the body condition - diet model may be a more accurate model.

Because corrected scat composition closely approximates what bears ate, it indicates the foraging choices the bears made. Therefore, if bears forage optimally, the corrected scat composition includes a measure of foraging efficiency.

METHODS

Scat Analysis

When scats were present at investigated telemetry locations, they were collected if they were the right age and size expected for the bear being tracked. After the scats were collected, they were air dried for approximately one week. Once dry, they were bagged in paper sacks and stored until they were analyzed at the end of the field season. The composition of the scats was analyzed following the procedures outlined by Mattson et al. (1991). The analysis was completed by the Montana Department of Fish, Wildlife, and Parks lab at Montana State University, Bozeman, Montana.

Because bears were sometimes located more than once a day and because all radio locations were investigated, scats could be collected from the same bear at different locations during one day. Because bears often spend hours in the same location, several scats from the same bear could also be collected at one location. To maintain independence and make sure that any one day during a recapture interval was not weighted more than any other day, I randomly selected one scat per location to use in the analysis. Also, locations were separated by at least twelve hours.

Percent scat composition for recapture intervals was calculated by summing the percent compositions of individual scats collected during the interval and then converting these totals back to percent. Because the composition of scats does not equal the composition of food ingested, the scat compositions were corrected using correction factors for digestibility (Hewitt 1989). Corrected scat composition approximates the composition of food ingested.

The corrected percentage of each food during a recapture interval was multiplied by the value of that food item (digestible calories/g). Then individual food values in each interval were added to give a corrected index of food value (digestible calories/g) for the entire interval. These corrected food value indices were regressed with the average daily change in percent body fat and the average daily percent change in weight of the bear for the recapture interval. As in the plant biomass analysis, negative percent body fat measurements were not used in the analysis.

Statistical Analysis

Percent Body Fat

The hypothesis that change in percent body fat of black bears was positively correlated to the value of the food (digestible calories/g) the bears ate was tested with a linear regression. Recapture intervals with negative percent body fat measurements were excluded from the analysis because they are unrealistic and indicate error. A preliminary plot of the data suggested that there might be a stronger positive linear correlation between changes in body condition and food value if only the data from the 1991 recapture intervals of bear SAF1 were used; therefore, a linear regression was also done using only these data. Using only the data from the 1991 recaptures of bear SAF1 eliminates annual variation and variation between bears.

Weight

The hypothesis that the percent change in weight of black bears was positively correlated to the value of the food (digestible calories/g) the bears ate was tested with a linear regression. Preliminary analysis suggested that variance was not constant. A transformation of food value by (- 1/X) equalized the variance.

RESULTS

Scat Composition

The food habits of the recapture collar bears as a group are similar to what has been reported in other studies (Table 5) (e.g. Tisch 1961, Carriles 1990, Holcroft and Herrero 1991, Eagle and Pelton 1983, Beeman and Pelton 1977, Graber and White 1983). After the scat composition data were corrected for digestibility using scat correction factors the most important foods were ants, angelica, horsetail species, gramminoids, sweet pea (*Lathyrus* sp.), mountain sweet cicely (*Osmorhiza chilensis*), thistles (*Cirsium* sp.) clover (*Trifolium* sp.), buffaloberries, and huckleberries (Tables 6 & 7).

Table 5. Scat contents by percent volume for recapture collar bears during the 1991 and 1992 field seasons.

Bear	Amal	Amar	Ants	Bait	Camb	Ceel	Cisp	Cost	Debr	Epan	Eqsp	Gram	Hela	Lasp	Lica	Lysp	Odvi	Osch	Risp	Shca	Sosi	Taof	Trsp	Vagl	Vasc	Vesp
SAF1	1.0	2.4	3.4	0.0	2.4	0.0	1.3	1.4	9.0	4.4	4.6	6.7	0.0	2.0	2.4	0.4	0.0	0.3	0.0	25.7	1.0	0.1	3.0	18.0	10.3	0.2
AM1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	45.0	43.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	11.3	0.0	0.0	0.0	0.0
AF2	0.0	1.8	0.8	14.0	0.0	0.0	0.0	0.0	0.8	0.0	11.3	12.6	6.0	12.5	6.5	0.0	0.0	26.2	0.0	0.0	0.0	0.0	7.5	0.0	0.0	0.0
AF3	0.0	9.7	17.0	0.0	0.0	0.5	9.7	0.0	22.7	0.0	1.0	1.0	0.0	14.4	0.0	0.0	4.0	11.5	4.0	0.0	0.0	4.5	0.0	0.0	0.0	0.0

See appendix C for description of abbreviations.

Table 6. Estimated dietary content (% of dry matter) for recapture collar bears during the 1991 and 1992 field seasons. Calculated using scat correction factors.

Bear	Amal	Amar	Ants	Bait	Camb	Ceel	Cisp	Cost	Debr	Epan	Eqsp	Gram	Hela	Lasp	Lica	Lysp	Odvi	Osch	Risp	Shca	Sosi	Taof	Trsp	Vagl	Vasc	Vesp
SAF1	0.6	2.6	4.6	0.0	1.5	0.0	1.0	0.9	12.6	2.1	2.9	4.7	0.0	1.1	2.6	0.1	0.0	0.1	0.0	43.2	0.6	0.1	3.8	9.5	5.2	0.1
AM1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	38.5	49.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	12.3	0.0	0.0	0.0	0.0
AF2	0.0	1.7	1.3	40.4	0.0	0.0	0.0	0.0	1.4	0.0	3.2	7.4	6.9	3.4	6.1	0.0	0.0	18.6	0.0	0.0	0.0	0.0	9.6	0.0	0.0	0.0
AF3	0.0	3.2	27.1	0.0	0.0	1.8	4.9	0.0	33.8	0.0	0.2	0.2	0.0	6.3	0.0	0.0	13.7	3.7	3.6	0.0	0.0	1.5	0.0	0.0	0.0	0.0

See appendix C for description of abbreviations.

Table 7. Estimated dietary content (% of dry matter) by recapture interval. Calculated using scat correction factors.

I	Amal	Anar	Ants	Bait	Camb	Ceel	Cisp	Cost	Debr	Epan	Eqsp	Gram	Hela	Lasp	Lica	Lysp	Odvi	Osch	Risp	Shca	Sosi	Taof	Trsp	Vagl	Vasc	Vesp
2	0.0	18.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	18.6	19.0	0.0	5.7	18.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	20.3	0.0	0.0	0.0
3	0.0	0.0	13.2	0.0	10.5	0.0	6.8	0.0	37.5	10.5	1.8	13.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	6.0	0.0	0.0	0.0
4	0.0	0.0	10.8	0.0	0.0	0.0	0.0	0.0	33.2	3.9	0.2	1.0	0.0	1.4	0.0	0.6	0.0	0.4	0.0	41.1	0.0	0.0	0.0	3.3	4.1	0.0
5	0.0	0.0	1.9	0.0	0.0	0.0	0.0	0.0	3.1	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	78.4	0.0	0.0	0.0	7.6	8.0	0.8
6	1.3	0.0	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.9	0.0	0.0	0.0	0.0	0.0	72.8	1.3	0.0	0.0	17.0	5.8	0.0
7	3.2	0.0	0.0	0.0	0.0	0.0	0.0	6.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	68.1	3.2	0.0	0.0	11.1	8.1	0.0
8	0.0	0.0	5.7	0.0	0.0	0.0	0.0	0.0	14.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	41.7	0.0	0.0	0.0	27.5	10.4	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	38.5	49.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	12.3	0.0	0.0	0.0	0.0
11	0.0	0.0	1.3	80.8	0.0	0.0	0.0	0.0	1.3	0.0	2.9	1.9	0.0	6.8	0.0	0.0	0.0	5.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12	0.0	3.4	1.2	0.0	0.0	0.0	0.0	0.0	1.5	0.0	3.4	13.0	13.8	0.0	12.3	0.0	0.0	32.2	0.0	0.0	0.0	0.0	19.2	0.0	0.0	0.0
14	0.0	6.3	15.2	0.0	0.0	3.5	0.0	0.0	32.0	0.0	0.4	0.5	0.0	0.0	0.0	0.0	27.5	7.4	7.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
15	0.0	0.0	39.0	0.0	0.0	0.0	9.9	0.0	35.5	0.0	0.0	0.0	0.0	12.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.1	0.0	0.0	0.0	0.0

I = recapture interval. See appendix C for description of abbreviations. See Table 3 for recapture interval bears and dates.

Bear AF2 must have learned how to beat traps because bait was an important part of her diet while she was being followed. Debris was present in the diet of three bears and increased with the amount of ants in their diets.

While they were being followed, the diets of the recapture collar bears consisted of the same foods in different percentages. However, the overall diets of individual bears cannot be directly compared because the bears were not followed during the same seasons and for the same amount of time.

Relationship Between Food Value and Body Condition

Percent Body Fat

The hypothesis that change in percent body fat of black bears was positively correlated to the value of the food (digestible calories/g) the bears ate was not accepted. Percent body fat was not correlated to food value (r^2 = 0.06, p = 0.56) (Fig. 18).

When only the data from bear SAF1 were used, change in percent body fat had a higher positive correlation to food value (r^2 = 0.34) than when data from all the recapture bears were used. However, the correlation was still not significant at the 95 percent confidence level (p = 0.30) (Fig. 19).

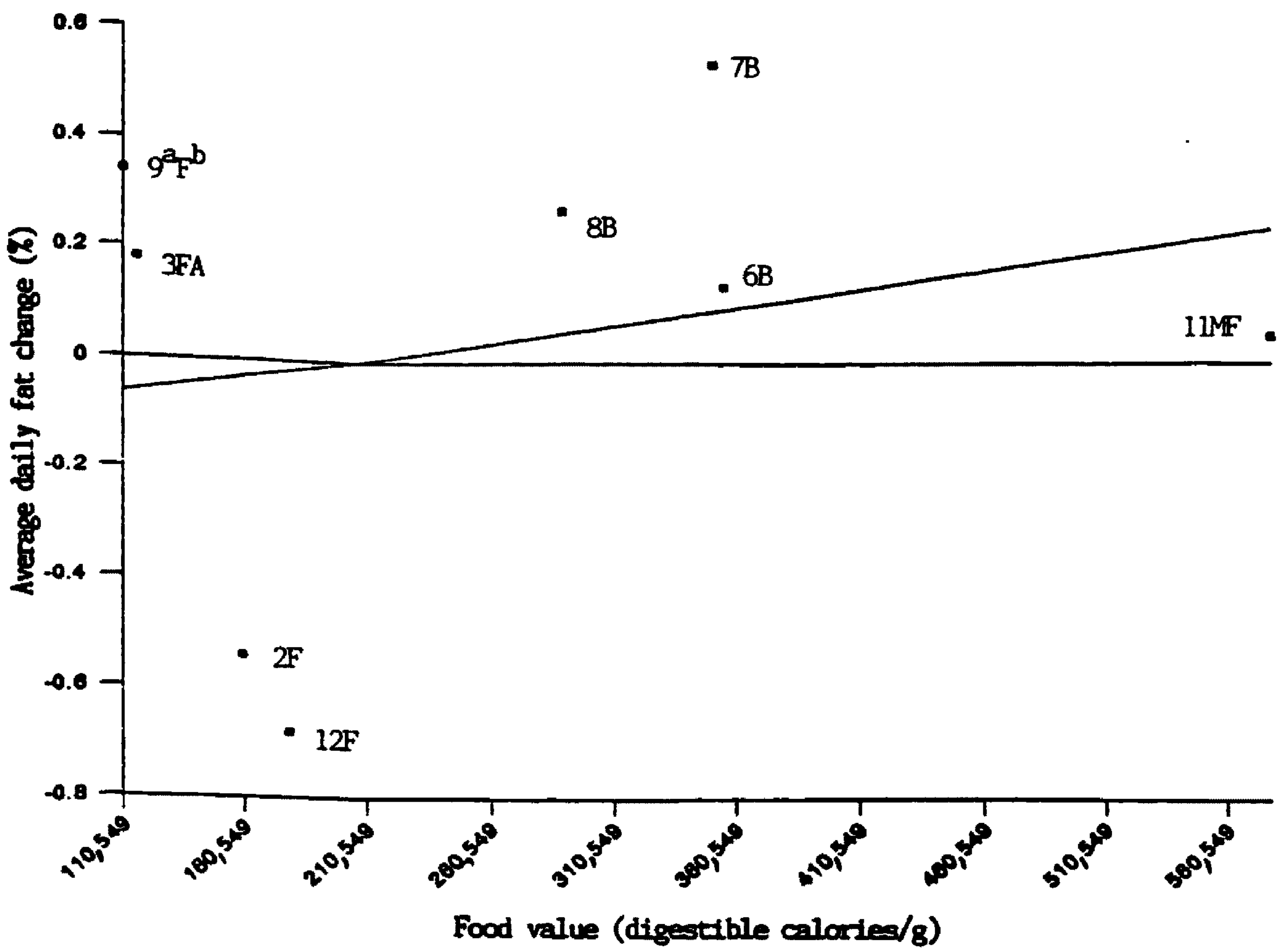

Figure 18. Linear regression results of change in percent body fat versus digestible calories per gram for all recapture collar bears included in analysis. $Y = -0.14 + 6.59E\text{-}07(X)$, $r^2 = 0.06$, $SEE = 0.45$, $n = 8$, $F_{(1,6)} = 0.38$, $p = 0.56$.

[a] Numbers at data points are recapture intervals (Table 3).

[b] Food the bear was eating during the recapture interval. Determined from observation and scat analysis (Table 7). F = forbs and grass, A = ants, B = berries, M = meat.

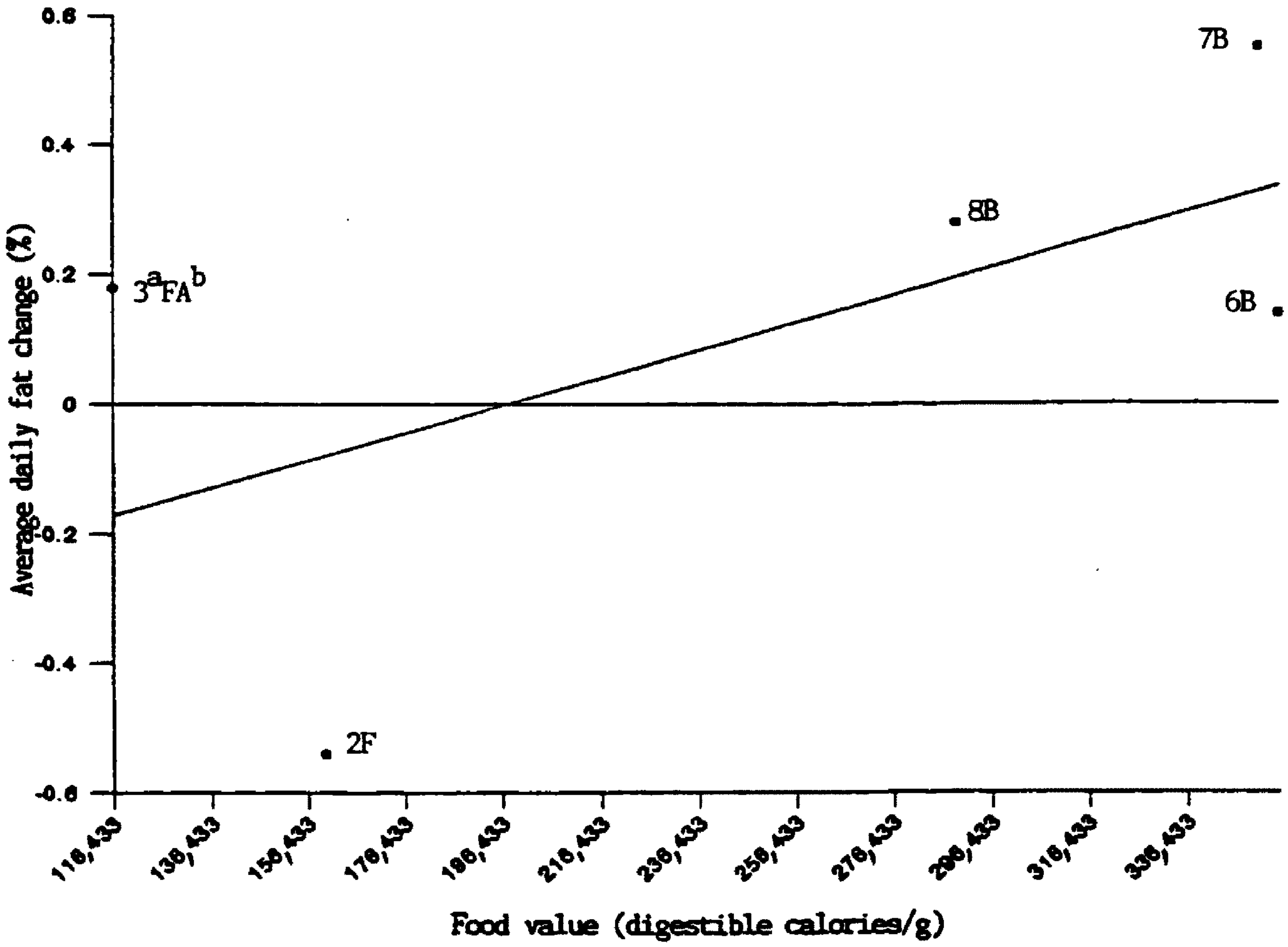

Figure 19. Linear regression results of change in percent body fat versus digestible calories per gram for only bear SAF1, a 3 year old female black bear. $Y = -0.42 + 2.12E\text{-}06(X)$, $r^2 = 0.34$, SEE = 0.38, $n = 5$, $F_{(1,3)} = 1.52$, $p = 0.30$.

[a] Numbers at data points are recapture intervals (Table 3).

[b] Food the bear was eating during the recapture interval. Determined from observation and scat analysis (Table 7). F = forbs and grass, A = ants, B = berries, M = meat.

Weight

The hypothesis that percent change in weight of black bears was positively correlated to the value of the food (digestible calories/g) the bears ate was not accepted (Figs. 20 & 21). Weight was not correlated to transformed values of food value ($r^2 = 0.01$, $p = 0.74$) (Fig. 21).

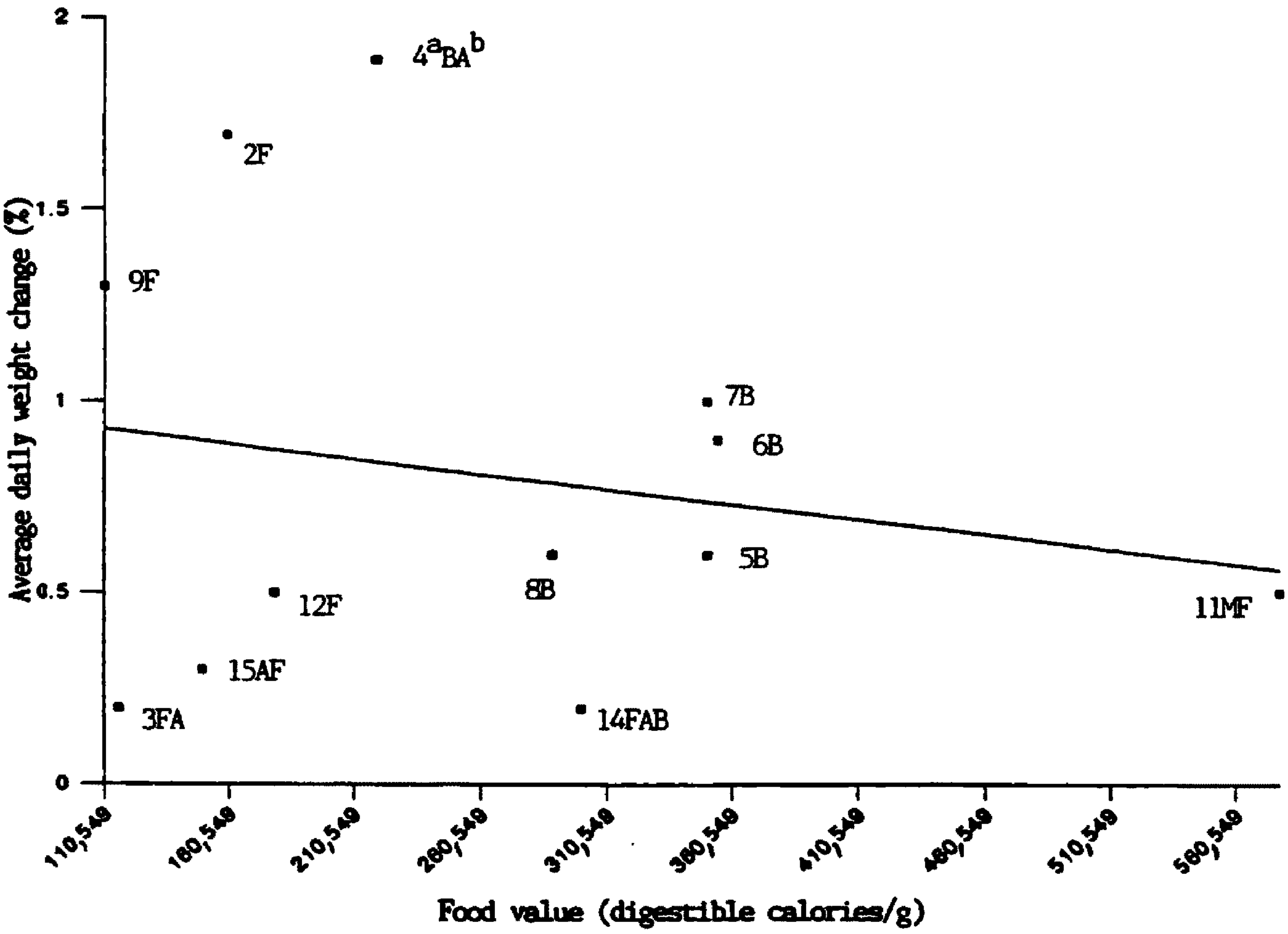

Figure 20. Linear regression results of percent change in weight versus digestible calories per gram. $Y = 1.02 + (-7.91E\text{-}07)(X)$, $r^2 = 0.04$, SEE = 0.58, n = 12, $F_{(1,10)} = 0.37$, p = 0.56.

[a] Numbers at data points are recapture intervals (Table 3).

[b] Food the bear was eating during the recapture interval. Determined from observation and scat analysis (Table 7). F = forbs and grass, A = ants, B = berries, M = meat.

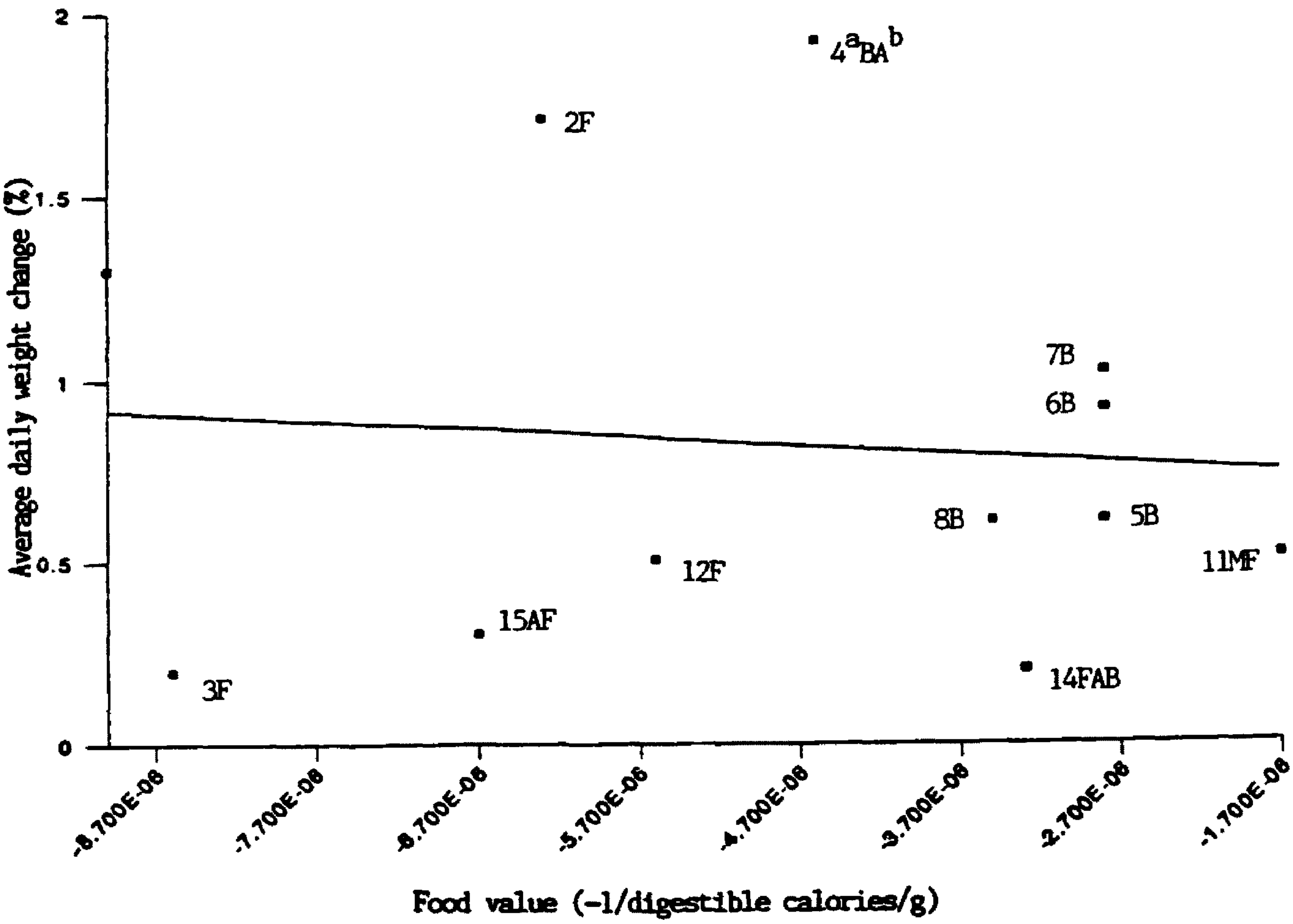

Figure 21. Linear regression results of percent change in weight versus transformed values of digestible calories per gram. Transformation = - 1/X. Y = 0.69 + (-25040.81)(X), r^2 = 0.01, SEE = 0.59, n = 12, $F_{(1,10)}$ = 0.11, p = 0.74.

[a] Numbers at data points are recapture intervals (Table 3).

[b] Food the bear was eating during the recapture interval. Determined from observation and scat analysis (Table 7). F = forbs and grass, A = ants, B = berries, M = meat.

DISCUSSION

Scat Composition

Recall that the foods included in the biomass estimations were: *Angelica arguta*, *Equisetum* species, gramminoids, *Heracleum lanatum*, *Shepherdia canadensis*, and *Vaccinium* species. Although these foods were some of the most important foods in the recapture bear diets, not all these foods were used during each recapture interval. Many other foods were also eaten. The above bear foods comprised 68.1 percent of bear SAF1's estimated dietary content, 87.7 percent of bear AM1's estimated dietary content, 19.2 percent of bear AF2's estimated dietary content, and only 3.6 percent of bear AF3's estimated dietary content during the period that they wore the recapture collars and were followed intensively.

Of the foods available during the seasons when the bears were intensively tracked, bear SAF1 used six out of six of the foods included in the biomass analysis, bear AM1 used two out of four, bear AF2 used four out of four, and bear AF3 used three out of four. Bears AM1, AF2, and AF3 were not followed during the berry season.

Because not all the bears used the foods that I measured biomass for and because other foods besides those measured for biomass were used, the estimations of food value developed from the biomass measurements were biased. Because of this bias, it is likely that the food values developed from the biomass measurements do not accurately represent the true food value of the habitat the bears used.

Relationship Between Food Value and Body Condition

The results indicate that there is little or no correlation between change in percent body fat and food value or between percent change in weight and food value. There are several reasons why the data may not adequately describe the true relationship.

As with the biomass plot analysis, the number of bears used in the analysis was small due to the expense of the recapture collars. Additionally, the number of scats for each recapture interval was small. The number of scats for each interval was small partly because some scats were eliminated to maintain independence and partly because the average number of days between captures was low. The number of scats was also low because, although the bears were located daily, scats were not found at each location. The small sample sizes increase the possibility that the samples were not representative of the population as a whole. The small number of scats for each bear also increases the possibility that the percent scat composition is not representative for individual bears.

The calculation of the scat indices includes estimations in some cases for both scat correction factors and digestible energy values. When these factors were not known for a particular food type, suggested representative values were used (Hewitt 1989). In some cases, the values used were possibly different from the actual values. Until both digestible energy and scat correction factors have been calculated for all bear foods, the amount of error explained by using representative factors will be unknown.

Interannual variation in the quality of food may also introduce unknown error. Digestible energy of foods varies by season, and the estimate most representative for the season the scats were collected in was used. However, the quality of food may also vary between years. Because the food quality estimates used were not based on foods collected during the two field seasons involved in this study, there is an additional amount of unknown error.

Three other factors, rate of passage, amount of food eaten, and energetic costs were not measured. Rate of passage affects the amount of food eaten and amount of food eaten is needed to accurately determine energetic intake. Although energetic costs may be calculated (Sizemore 1980), the energy equation is incomplete without an accurate estimate of energetic intake (energetic intake + energetic cost = net energetic gain).

CONCLUSION

The scat data show that the recapture collar bears had a varied diet that included foods for which biomass was not measured. Small sample sizes, error introduced in the collection of scats, and error introduced in the food value indices may explain why the hypothesis was not accepted in the scat analysis. Because the amount of food eaten was not measured, the food value indices developed from scat analysis do not include an accurate measure of energy intake.

Although neither the scat analysis technique nor the biomass measurement technique estimates food values with enough accuracy to replace the current methods used to estimate food value for the Cumulative Effects Model, both show promise. Both techniques can include values of foraging efficiency that the current techniques do not. With some refining, food value indices calculated from scat analysis may be the best choice in the future. Scat correction factors and quality (digestible calories/g) need to be calculated for all bear foods. The scat food value indices also need to include measurements of the amount of food eaten to obtain accurate energy intake estimates.

The scat analysis technique only uses foods that are actually eaten by individual bears, while the biomass measurement technique assumes that researchers know what the most important foods are to particular bears. The biomass measurement technique also assumes that the bears are eating those foods. These two assumptions may be accurate for a population as a whole, but not for individual bears.

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APPENDICES

APPENDIX A: Use and Performance of Recapture Collars on Bears.

INTRODUCTION

Recapture collars have been used on wolves and white-tailed deer in Minnesota (Mech et al. 1990, Kunkel et al. 1991, DelGiudice et al. 1990). These collars were first tested on black bears in the North Fork of the Flathead, British Columbia during 1989. This study continued the performance testing of the recapture collars on seven black bears and one grizzly bear (Table 1).

METHODS

Bears were initially captured using conventional techniques. Recapture collars were placed on the bears when they fit the criteria discussed in Chapter One.

The bear was weighed as soon as it became immobile because the capture weight was needed to accurately estimate the bear's weight for the next recapture. Each dart was loaded with enough drug to completely tranquilize the bear. One dart was loaded for the first recapture while the other dart was loaded for the second recapture. The smallest dose and lowest concentration possible was used that would fit within the 1.5 ml capacity of the recapture collar darts and would adequately immobilize the bear until it could be found.

Darts were loaded with Telazol at a concentration of either 300 mg/ml or 400 mg/ml depending on the size of the bear and the dose used. I initially used 7.9 mg/kg (3.6 mg/lb); however, because of the predictable recovery signs from Telazol, I found this dose could be safely reduced. I normally used 5.5 to 6.6 mg/kg (2.5 to 3 mg/lb) based on the predicted weight at the next recapture. Because the doses were figured on the estimated weight of the bear at the next recapture, actual doses received varied from 5.3 mg/kg (2.4 mg/lb) to 8.8 mg/kg (4.4 mg/lb). The smaller doses were enough to keep the bear immobilized until found.

Before the darts were placed on the collar, the collar was adjusted so it would have minimal movement on the neck. This was necessary to keep the darts in the correct position. The collar was adjusted until I could just insert four fingers, with my palm up, between the back of the neck and the collar. Adjusting the collar on the animal's neck included attaching a "rot off", a piece of cotton fire hose designed to eventually break and release the collar in case the collar's normal release mechanism failed. The "rot off" was placed between the collar's release mechanism and the end of the collar webbing. To quicken its deterioration, the "rot off" was perforated with holes using a leather punch.

The darts were attached to the collar so they would inject the needles into the thickest muscle mass on the back of the neck behind the collar. To keep the collar balanced, the darts were positioned equal distances on either side of the spinal column. After all the components were attached, the collar was placed on the animal's neck and programmed. The complete process of putting a recapture collar on a bear took an experienced crew fifteen to twenty minutes.

Recapturing a bear using the recapture collars began by obtaining a specific location from either the air or from a road. Once this was known, the recapture crew radio tracked the bear by foot until the bear's exact location was pinpointed and the crew was within several hundred meters of the bear's location. After a dart was fired, the crew waited until the activity signal from the collar indicated the bear was inactive. If the bear did not become inactive within fifteen minutes, the decision whether to fire the second dart was made. This decision depended on the location and movements of the bear.

RESULTS

Twenty recaptures were attempted using the recapture collars during 1991, 1992, and 1993. Of these recaptures, eighteen (90%) were ultimately successful, while two (10%) never resulted in recaptures. Of the eighteen that were successful, five (28%) required the use of two darts. Overall, twenty-seven darts were fired during twenty attempted recaptures. Collars went dead on only two occasions (Table 8).

Table 8. Performance of recapture collars on seven black bears and one grizzly bear from 1991 - 1993.

Bear	#Succ. recaps.	#Unsucc. recaps.	#Succ. recaps. needing 2 darts	Total # darts used	Complete collar failure
SAF1	7	1	1	10	1
AF1		1		2	
AM1	1			1	
AF2	2		1	3	
AF3	2		1	3	
AF4					1
AF5	3		1	4	
AF6	3		1	4	
TOTALS	18	2	5	27	2

DISCUSSION

Seven darts were unsuccessful in drugging an animal. Of these seven, five were unsuccessful because of drug problems while the other two were unsuccessful because they had broken off the collar. Both the broken darts occurred with bear SAF1 and neither dart had a protective carnivore dart cover on. The other five unsuccessful darts all fired, but did not drug the animal. Most likely the drug either became inactive or precipitated out of solution while it was stored in the darts.

Reconstituted Telazol will become inactive over time. The manufacturer of Telazol (A.H. Robins Company 1987) recommends that unused doses of Telazol be discarded after four days when stored at room temperature and discarded after fourteen days when refrigerated. However, mixed Telazol stored in the darts was routinely and successfully used after periods longer than twenty days and a few times thirty days. Mech et al. (1990) also used darts loaded for long periods. Their longest interval between when a dart was loaded and used was fifty days. In my study, the times the darts were unsuccessful were not always the longest periods the drugs were in the darts. However, when a dart fired but was unsuccessful, it was always the oldest of the two darts on the collar.

Reconstituted Telazol will also precipitate out of solution. I mixed Telazol at the lowest concentration possible to mitigate precipitation since higher concentrations will precipitate more readily.

The failure of darts to drug the animals may have been associated with cool or freezing temperatures. Freezing temperatures will increase the chance of precipitation. However, Mech et al. (1990) successfully used Telazol reconstituted in sterile water in recapture collars in Minnesota during the winter where ambient temperatures ranged from -37 to 22 C. Richard Chapman (pers. comm., Wildlink Inc., MN) suggested using Telazol mixed in 0.75 ml propylene glycol and 0.75 ml of 100 mg/ml xylazine Hcl if freezing temperatures were expected. Because I did not expect freezing temperatures during June, July, and August, I did not mix Telazol in propylene glycol during 1991 and

1992. McLellan (pers. comm., B.C. Min. of Forests) did mix Telazol with propylene glycol during 1993; however, multiple darts were still required for several captures.

Recapture collars went dead twice. The recapture collar on bear SAF1 died from a low battery while the bear was denned. This collar did not self release in response to the low battery voltage as it was designed to do. Wildlink (1990) indicates that a collar may attempt to release itself when it detects low voltage but might be unsuccessful. The collar was removed when the bear was caught conventionally.

The recapture collar on bear AF4, a female grizzly bear, went dead before she could be recaptured. This collar was never recovered so the reason for its failure is unknown. Bear AF4 was photographed wearing the collar later in the year but was recaptured the next year with out the collar (Hovey, pers. comm., B.C. Min. of Forests). This collar was attached with a "rot off".

The electronic release mechanism did work on bear AF1 after her unsuccessful recapture attempt. Although she was drugged by both darts, she was never found. The collar was electronically released and recovered the next day.

The most persistent problem with the collars was the malfunction of the query that indicated whether darts had fired or not. Wildlink (1990) says that this query may give a false report if the collar is wet. Rain was common during the 1992 field season and the query of the dart status often gave false readings. I assumed that every time I fired a dart, the dart actually fired. Ultimately, the activity signal of the collar best indicated if a bear was drugged.

In only one case, excluding the cases with the broken darts, did a dart fail to fire. AF2's last recapture with the capture collar took place over nine days. Both darts were fired the first day. Although the collar appeared to receive the commands to fire the darts, the bear never became inactive.

A second attempt was made the next day. The first dart was fired again. The bear became inactive after the dart had fired; however, within a few minutes, the signal became active and the bear moved away. The second dart was not fired at this time. Eight days later, the second dart was successfully fired and the bear was recaptured. For an unknown reason this dart failed to fire on the first attempt at this recapture.

The only neck sore from a collar, other than regular puncture wounds from the darts, also occurred during bear AF2's last recapture collar capture. The first dart fired on either the first or second day of this recapture but failed to immobilize the bear. The needle dug a one inch deep conical hole in the bear's neck over the next seven or eight days. A conventional recapture of this bear a week later showed that this wound was healing fine.

CONCLUSION

The collars usually accomplished what they were designed to do: recapture animals (recapture success rate was 84 percent). However, the problems I encountered with the collars sometimes postponed the recapture of an animal. Although most of the collars' malfunctions can be mitigated by planning around them, I do not recommend using this model of recapture collar on grizzly bears at this time. The collars do not provide the level of certainty that a bear is drugged that is necessary to approach a free ranging grizzly bear.

APPENDIX B: 1992 Huckleberry Production.

During the summer of 1992, huckleberry biomass was sampled in various habitat types. The sampling technique followed Vandehey (1991) with the exception that blocks sampled within a habitat type were not chosen randomly. Sampled blocks were chosen because they were easily accessible and because they were close to operating trap sites. Sampling was conducted between August 11, 1992 and September 3, 1992.

A total of 121 macro plots were done in six blocks. The following grizzly bear habitat type units (Fuhr et al., 1988) were sampled in the Cauldrey Creek/Frozen Lake area: HB1, HB4, DF1HB3, and DF1HB1. These types generally have medium to high fall use by bears. One other block sampled in Desolation Creek falls outside the area mapped by Fuhr et al. (1988) and did not have a designated grizzly bear habitat type. This area however has historically had high fall use by bears (Bruce McLellan, pers. comm., B.C. Min. of Forests).

Mean biomass in one block of HB1DF1 sampled on August 11, 1992 was 0.8 kg/ha (s = 0.8 kg/ha, n = 20). Mean biomass in another block of HB1DF1 sampled on August 28, 1992 was 0.06 kg/ha (s = 0.06 kg/ha, n = 20). Mean digestible energy for these blocks was 3280 kcal/ha (s = 3280 kcal/ha) and 246 kcal/ha (s = 246 kcal/ha).

Mean biomass for the blocks I sampled in the HB1, HB4, and HB3DF1 are as follow: HB1 (x = 0.6 kg/ha, s = 1.2 kg/ha, n = 20), HB4 (x = 0.02 kg/ha, s = 0.05 kg/ha, n = 20), and HB3DF1 (x = 0.01 kg/ha, s = 0.02 kg/ha, n = 15). The mean digestible energies for these same blocks are as follow: HB1 (x = 2460 kcal/ha, s = 4920 kcal/ha), HB4 (x = 82 kcal/ha, s = 205 kcal/ha), and HB3DF1 (x = 41 kcal/ha, s = 82 kcal/ha). Mean biomass for the block sampled in Desolation Creek was 3.2 kg/ha (s = 2.2 kg/ha, n = 26), while mean digestible energy was 13120 kcal/ha (s = 9020 kcal/ha).

During 1992, berry production in the study area was poor. Most of the huckleberry plants I observed in 1992 had few berries and brown leaves. However, plants at higher elevations did appear more vigorous and had more berries than plants at lower elevations. The huckleberry habitat data I collected confirm, when compared to 1990 data, that 1992 was a poor huckleberry year (Table 9).

The differences between my 1992 huckleberry data and Vandehey's (1991) 1990 data cannot be statistically tested because the blocks I tested were not randomly chosen while Vandehey's were. Vandehey's data provide huckleberry biomass estimates for two habitat types throughout the study area, while my data provide estimates only for the blocks sampled.

Table 9. Comparison of 1992 and 1990 huckleberry habitat.

1992 Huckleberry Habitat				1990 Huckleberry Habitat[a]		
Hab. unit[b]	Dry biomass (kg/ha)	Dig. energy (kcal/ha)	n	Dry Biomass (kg/ha)	Dig. Energy (kcal/ha)	n
HB1DF1	0.8	3280	20	9.6	39500	8
HB1DF1	0.06	246	20			
HB1	0.6	2460	20			
HB34				11.4	46600	23
HB4	0.02	82	20			
HB3DF1	0.01	41	15			
DESOLA-TION CK	3.2	13120	26			

[a] From Vandehey (1991).
[b] From map produced by Fuhr et al. (1988)

Some differences between my data and Vandehey's data can be explained by the fact that, although our plots were done in similar habitat types, they were not done in the same area. All of Vandehey's plots were done east of the North Fork of the Flathead River, while mine were done to the west of the river. However, a quick reconnaissance of the areas sampled by Vandehey in 1990 also showed few berries.

APPENDIX C: Description of Scat Content Abbreviations. Plant scientific names follow Hitchcock and Cronquist (1973).

Abbreviations	Scientific Names	Common Names
Amal	*Amelanchier alnifolia*	Serviceberry
Anar	*Angelica arguta*	Angelica
Camb		Tree cambium
Ceel	*Cervus elaphus*	Elk
Cisp	*Cirsium* species	Thistle species
Cost	*Cornus stolonifera*	Red-osier dogwood
Debr		Debris
Epan	*Epilobium angustifolium*	Fireweed
Eqsp	*Equisetum* species	Horsetail
Gram		Gramminoids
Hela	*Heracleum lanatum*	Cow parsnip
Lasp	*Lathyrus* species	Sweet pea, Peavine
Lica	*Ligusticum canbyi*	Canby's lovage
Lysp	*Lycopodium* species	Club moss species
Odvi	*Odocoileus virginianus*	White-tailed deer
Osch	*Osmorhiza chilensis*	Mountain sweet-cicely
Risp	*Ribes* species	Currant, Gooseberry
Shca	*Shepherdia canadensis*	Buffaloberry
Sosi	*Sorbus sitchensis*	Sitka mountain-ash
Taof	*Taraxacum officinale*	Common dandelion
Trsp	*Trifolium* species	Clover species
Vagl	*Vaccinium globulare*	Huckleberry
Vasc	*Vaccinium scoparium*	Grouseberry
Vesp	*Vespid* species	Wasps

APPENDIX D: Equations Used to Calculate Body Composition for Black Bears Using Snout to Tail Resistance (Farley and Robbins 1994).

$$TBW = -0.224 + (0.197 * SVL^2 / STAILR) + (0.137 * BM)$$

$$\% BW = TBW / BM * 100$$

$$\% BLC = 98.01 - (1.28 * \% BW)$$

$$\% BPC = 0.835 * (100 - \% BW - \% BLC)$$

$$\% BAC = 0.165 * (100 - \% BW - \% BLC)$$

TBW = total body water (liters).

SVL = Snout - vent length (cms).

STAILR = Snout - tail resistance.

BM = body mass (weight in Kgs).

% BW = percent body water of fresh weight.

% BLC = percent body fat content (percent fat).

% BPC = percent body protein content.

% BAC = percent body ash content.

Total percent = % BW + % BLC + % BPC + % BAC.