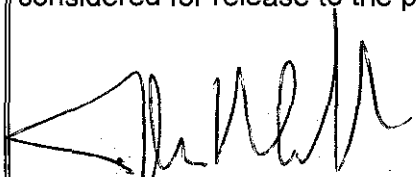
WEST KITIKMEOT / SLAVE STUDY SOCIETY

Re: Grizzly Bear (*Ursus arctos)* Studies in the Northwest Territories:
Final Report to the West Kitikmeot/Slave Study
Component No. 1, Nutritional Ecology

STUDY DIRECTOR RELEASE FORM

The above publication is the result of a project conducted under the West Kitikmeot / Slave Study. I have reviewed the report and advise that it has fulfilled the requirements of the approved proposal and can be subjected to independent expert review and be considered for release to the public.



Study Director

Aug 26/98

Date

INDEPENDENT EXPERT REVIEW FORM

I have reviewed this publication for scientific content and scientific practices and find the report is acceptable given the specific purposes of this project and subject to the field conditions encountered.

Reviewer

Nov. 6/98

Date

INDEPENDENT EXPERT REVIEW FORM

I have reviewed this publication for scientific content and scientific practices and find the report is acceptable given the specific purposes of this project and subject to the field conditions encountered.

Reviewer

17/01/99
Date

BOARD RELEASE FORM

The Study Board is satisfied that this final report has been reviewed for scientific content and approves it for release to the public.

Chair
West Kitikmeot/Slave Study Society

June 14/99
Date

GRIZZLY BEAR (*URSUS ARCTOS*) STUDIES IN THE NORTHWEST TERRITORIES: FINAL REPORT TO THE WEST KITIKMEOT/SLAVE STUDY COMPONENT NO. 1, NUTRITIONAL ECOLOGY

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1. SUMMARY

Bear populations have declined as humans have expanded their population into the remote areas of North America. The diamond industry is currently expanding exploration into the central Canadian Arctic. As a result, a multi-faceted research program into the ecology of grizzly bears (*Ursus arctos*) in the central Arctic was initiated to gather sufficient information on the affected bears to allow enlightened management policies to develop.

The nutritional ecology portion of a larger grizzly bear ecology project examined the feeding patterns and body compositions of grizzly bears living within the region of most active diamond exploration in the Northwest Territories. Feeding patterns of bears were determined using fecal analysis, direct observation, and stable nitrogen isotope analysis. The body compositions of bears were examined by bioelectrical impedance analysis to determine if periods of nutritional stress exist, and to ascertain whether blood parameters reflect stressful nutritional periods.

Caribou (*Rangifer tarandus*) were the most common food item ingested. Barren-ground grizzly bears were adept at killing and consuming large numbers of caribou to meet their dietary protein requirements. However, the fruits of the northern berry species were critically important to the grizzly bear diet as the consumption of berries were essential for the deposition of body fat.

Two critical nutritional periods were identified for the barren-ground grizzly bears examined in our study. The early summer season, before the return of the Bathurst caribou herd from their calving grounds, corresponded to the poorest level of nutritional condition for barren-ground grizzly bears. Usable grizzly bear fat reserves were as low as 1-2% but improved upon the return of mixed post-calving herds of caribou to the study area. The late summer season, when grizzly bears entered a state of hyperphagia, was

also considered critical. Bears need to accumulate large fat reserves during hyperphagia to survive winter hibernation.

The only blood parameter found to reflect the total body fat levels in both adult male and lone female grizzly bears was albumin. However, attempting to determine the nutritional status of bears using any of the blood parameters we examined appears not feasible.

It should be noted that the research detailed in this report has also been summarized by Gau (1998).

2. ACKNOWLEDGEMENTS

We are indebted to many people for making our project worth while. We thank Dr. M.A. Ramsay for agreeing to accept R.J.G. as a graduate student and letting him establish his independence. Ground monitoring of grizzly bears was competently assisted by N. Doctor, F. Martin, M. Svoboda, D. Panayi, and D. Olesen. Radio telemetry locations of grizzly bears were assisted by D. Cluff, L. Buckland, C. Falseness, V. Banci, and D.F. Penner. We especially thank the experienced pilots D. Olesen, C. Falseness, M. Hutcheson, T. Benson, R. Sliger, and J. McIntyre for going above and beyond the call of duty for flying in adverse weather conditions, and assisting with processing tranquilized bears. The handling and processing of grizzly bears was also made easier by teamwork with P. McLoughlin, D. Cluff, and F. Messier.

We acknowledge the University of Saskatchewan's staff at the Department of Veterinary Pathology and G. Parry at the Stable Isotope Facilities for always providing results swiftly. We appreciate the technical and theoretical advice for using stable isotope analysis given by Drs. K.A. Hobson and D. Schell. Bioelectrical impedance technical advise was more than adequate from Dr. S.N. Atkinson. Satellite telemetry protocols

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4. OBJECTIVES

In recent years human activity, particularly that associated with diamond exploration and mining, has increased in the central Arctic. In the spring of 1995 a multi-faceted research program into the ecology of grizzly bears (*Ursus arctos*) in the central Arctic was started with the cooperation of the Government of the Northwest Territories (NWT), University of Saskatchewan, and major companies involved in the diamond industry. Our portion of the barren-ground grizzly bear ecology project involved dietary and physiological research. The overall barren-ground grizzly bear ecology project was designed to gather information so that a comprehensive wildlife management plan for the barren-ground grizzly bear could be made.

The research presented in this final report contains data collected for the nutritional ecology component of the larger barren-ground grizzly bear ecology project. Before bear management considerations are drafted, it must be recognized that it will be impossible to eliminate all the impacts of development on wildlife populations in the central Arctic. As the public and Government of the NWT have supported the development of the diamond industry, they then must accept that access to remote areas will be facilitated, habitat will be disturbed, industrial activity will displace bears from parts of their home ranges, and some bears will be killed (Case and Matthews 1994).

5. DESCRIPTION

The grizzly bear, also known as the brown bear, evolved to exploit the productivity of open habitat types (Herrero 1978). The habitats typically inhabited by grizzly bears in North America have been oceanic coastal areas, river valleys, alpine and subalpine zones, prairie, grasslands, and tundra (Craighead and Mitchell 1982). Although grizzly bear distribution is currently reduced by more than half of its former historical range in North

America, the grizzly bear still occupies many of these ecosystems (Jonkel 1987, McLellan 1989). The key to its use of these varied ecosystems lies in the grizzly bear's ability to exploit a wide range of food sources. For example, some populations depend almost exclusively on fish, while others feed primarily on vegetation, or are opportunistic hunters and scavengers and vary their diet according to food availability (Miller et al. 1982, Nowak and Paradiso 1983, Boertje et al. 1988, Mattson et al. 1991).

Very little is known about the population dynamics, dietary habits, physiology, and patterns of habitat use of grizzly bears on the tundra or barrens of the NWT, particularly in the central Arctic (Bromley and Buckland 1995). Bears were seen as early as 1771 as explorers and trappers moved into the barrens (Banfield 1959). Arctic grizzly bears were believed to be numerous through the 19th century until the appearance of hunters armed with repeating rifles (Harington et al. 1962). Estimates of barren-ground grizzly bear populations in the NWT have been largely conjectured over the last century. In 1991 the number of grizzly bears in the mountains and tundra of the NWT was estimated to be 5000 (Banci 1991). It is also generally believed that the population density declines from west to east, from the mountains through the barrens towards Hudson Bay (Banci 1991).

Most of the previous ecological research focused on grizzly bears in the NWT has been limited to the extreme western tundra or mountain populations (Harding 1976, Miller et al. 1982, Nagy et al. 1983*a*, Mychasiw and Moore 1984, Clarkson and Liepins 1989). There are, however, behaviourial reports of barren-ground grizzlies from the central and eastern regions of the NWT (Gunn and Miller 1982, Case and Stevenson 1991, Clarkson and Liepins 1993).

5.1 BACKGROUND

5.1.1 FEEDING PATTERNS

Feeding patterns of grizzly bear populations from Alaska, Yukon, and the Mackenzie Mountain and Inuvialuit regions of the NWT have been examined (Linderman 1974, Pearson 1975, Nagy et al. 1977, Miller et al. 1982, Nagy et al. 1983*a*, Nagy et al. 1983*b*, Boertje et al. 1988, Clarkson and Liepins 1989), but little quantitative work has been done in the central Arctic of the NWT. We documented the feeding patterns of barren-ground grizzly bears in the NWT through 2 years of data collection involving the analysis of fecal remains, direct observations, and stable nitrogen isotope ($\delta^{15}N$) analyses.

Logistical problems associated with the low topographical relief of the tundra landscape, high frequency of lakes, low grizzly bear population densities and large home ranges (Miller et al. 1982, Nagy et al. 1983*a*, Mueller 1995, Case and Buckland 1997), led us to believe that the determination of feeding patterns based on the traditional methods of scat collection and direct observation alone would be difficult. Such traditional methods have been used successfully in regions of higher bear density (Servheen 1983, Hamer and Herrero 1987, Mattson et al. 1991, McLellan and Hovey 1995). However in attempting to estimate the feeding patterns of grizzly bears for our study, we augmented traditional methods of diet determination using the stable nitrogen isotopic signature of bear body tissues.

Measuring the stable isotopes of nitrogen ($^{15}N/^{14}N$) in animal tissues can be useful in estimating the diet of animals in terrestrial environments (Peterson and Fry 1987, Hilderbrand et al. 1996, Kidd et al. 1996). This diet estimation, usually to the nearest trophic level, is made possible by measuring the isotope ^{15}N as it becomes enriched relative to ^{14}N in consumer tissues (DeNiro and Epstein 1981, Minagawa and Wada 1984). The isotopic relationships between consumers and their diet have typically been reported to be separated by differences of 3-4 parts per thousand (Minagawa and Wada

1984, Hilderbrand et al. 1996, Jarman et al. 1996, Keough et al. 1996).

5.1.2 BODY COMPOSITIONS

Hematological and serum chemistry parameters have been shown to vary in bears with hibernation, activity, reproductive status, food supply, and stress due to capture or injury (Halloran and Pearson 1972, Nelson et al. 1983, Hellgren et al. 1993). Blood parameters have also been used in conjunction with morphological data and body weight to indirectly determine body condition and, hence, nutritional status in free-ranging bear populations (Schroeder 1987, Franzmann and Schwartz 1988, Hellgren et al. 1989, DelGiudice et al. 1991, Hellgren et al. 1993). It should be noted, however, that no indirect determination of body condition has been validated using a bear's body composition and no significant relationship has been found predicting nutritional condition from morphological measurements (Cattet 1990, Farley and Robbins 1994).

Farley and Robbins (1994) recently developed the protocols and equations for use of bioelectrical impedance analysis (BIA) on bears. They concluded that BIA is a useful, reliable, and accurate method for estimating body composition. Bioelectrical impedance analysis is a rapid and noninvasive method in which an organism's resistance to conduction of a low-level alternating current is measured (Kushner 1992, Gales et al. 1994). Because the conductivity of body lipids are 4-5% that of lean tissue, body fluids, and bone, the body's electrical resistance is an indicator of total body water content (Farley and Robbins 1994). Knowing the body water content and mass of animals allows for the calculation of body lipid content (Johnson and Farrel 1988, Robbins 1993).

Limited physiological data have been collected from grizzly bears at the northern extreme of their range. Blood chemistries have been reported from the Yukon and northern and central Alaska (Halloran and Pearson 1972, Pearson and Halloran 1972, Brannon 1985*a*,

Brannon 1985*b*). Also, seasonal patterns of weight gains and losses have been examined in the northern Yukon and the northwest Mackenzie River delta area in the NWT (Kingsley et al. 1983, Kingsley et al. 1988). No quantitative physiological data on grizzly bears have been collected from the central Arctic of the NWT.

In studies on black bears (*U. americanus*) and grizzly bears mass, visual assessments, skin-fold thicknesses, or morphometric measurements have been coupled with albumin, albumin-globulin ratio, total bilirubin, erythrocyte count, calcium, creatinine, hematocrit, hemoglobin, phosphorus, total protein, and sodium to estimate body condition during non-hibernation periods (Brannon 1985*a*, Brannon 1985*b*, Schroeder 1987, Franzmann and Schwartz 1988, Hellgren et al. 1989, DelGiudice et al. 1991, Hellgren et al. 1993). Our study is one of the first to correlate the results from an accurate method estimating the body composition of living, free-ranging bears to blood parameters that previous studies have identified as useful indicators of body condition. Our research was designed to determine the seasonal variation in the body composition of bears. The objective was to ascertain whether the bears became nutritionally stressed in the central Arctic, and to see whether blood parameters reflect nutritional stress.

5.2 STUDY AREA

Data collection took place within an approximate 40 000 km^2 area of tundra in the central Arctic of the NWT (Fig. 1). Research was centred around the Daring Lake Research Station (64^{o}52' N, 111^{o}37' W), approximately 300 km northeast of Yellowknife, NWT.

The climate within the study area is semi-arid and characterized by short cool summers, long winters, and large annual ranges in temperature (Mueller 1995). This region is a rocky upland area of the Canadian Precambrian Shield in which glaciation has resulted in patches of exposed bedrock and boulder fields, many shallow river and stream areas,

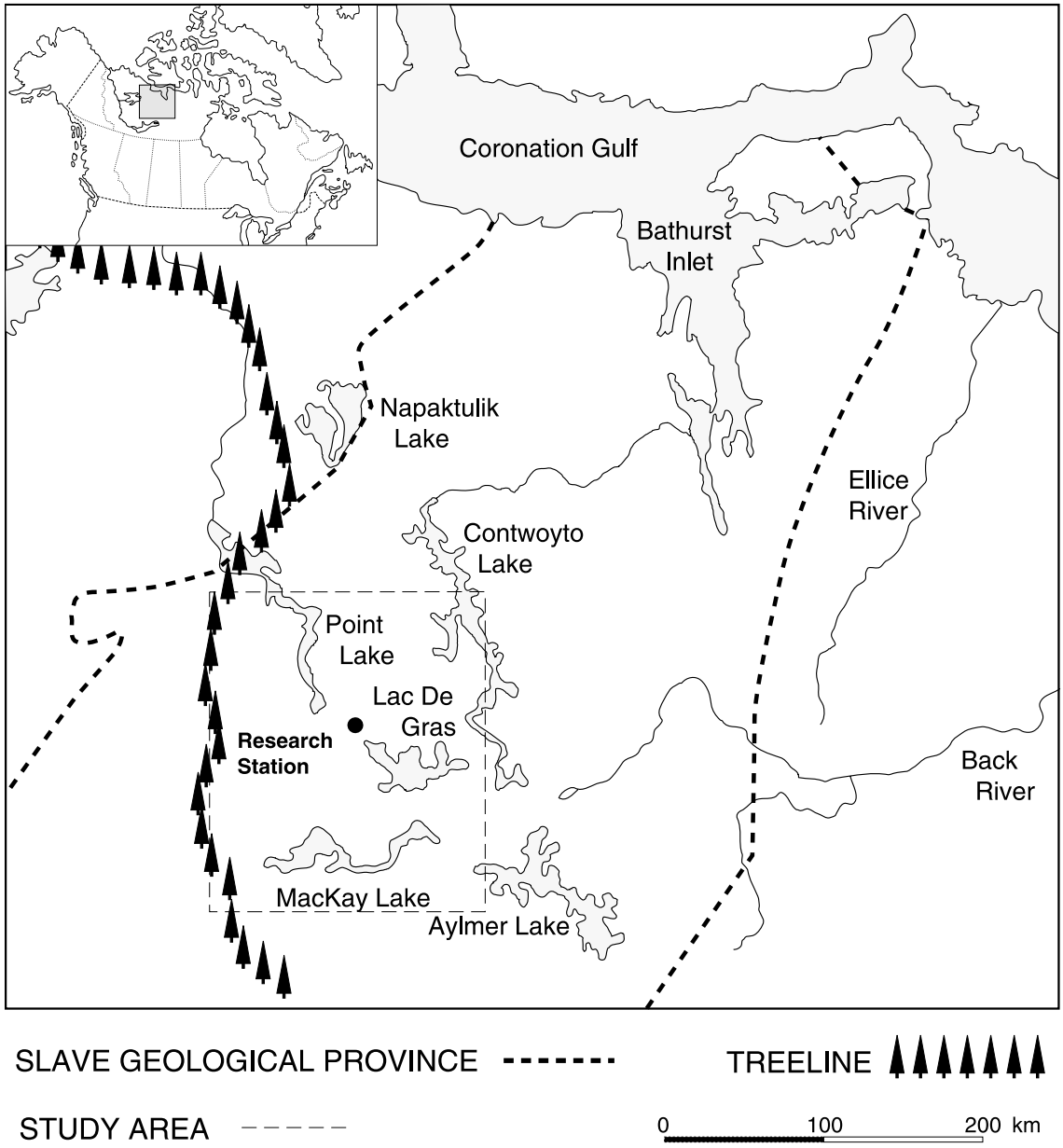

Figure 1. The location of the study area.

numerous lakes, and glaciofluvial features like eskers, kames, and drumlins (Mueller 1995). Typical tundra vegetation within the study area includes Arctic willow (*Salix* sp.), dwarf birch (*Betula glandulosa*), sedges (*Carex* sp.), and various grass and berry species. Most of the study area is treeless although isolated stands of trees are found along the western boundary of the study area.

5.3 METHODOLOGY

Seasons were defined according to changes in the bears' diets as determined by fecal analysis and observed vegetation changes. In this classification system, spring extended from the time bears emerged from winter dens (early to mid May) until June 15. Most of the vegetation was in a brown pre-emergent state after snow melt occurred in the spring season. Early summer was from June 16 to July 6 and had a vegetative landscape characterized by an even mixture of old brown vegetation from the year before and new growth. Mid-summer was from July 7 to August 5 and was characterized by a fully green vegetative landscape. Late summer was August 6 to August 31 and coincided with the ripening of the northern berry species. Autumn extended from September 1 until all the bears denned (mid to late October) and was characterized by the tundra shrub layer changing colour and preparing for winter dormancy.

In late May and early June of 1995 and 1996, 1 to 2 weeks after den emergence, 17 male, 10 lone female, and 8 females with cubs were captured as a part of our study. Bears were tranquilized from a Bell 206B helicopter using a combination of zolazepam hydrochloride and titelamine hydrochloride (Telazol, Ayerst Laboratories Inc., Montreal, PQ) delivered by a dart fired from a Cap-chur gun (Palmer Chemical Co., Douglasville, GA) at a dose of approximately 5 mg/kg of estimated body mass. Bears were then fitted with satellite telemetry collars (Telonics, Mesa, AZ) also equipped with VHF radio transmitters in the 151 mHz range.

Excluding females with cubs to minimize the risk of cub abandonment, bears fitted with collars were recaptured during mid-summer and autumn. The mid-summer recapture took place in the latter half of that season. Autumn recaptures were conducted 3 to 4 weeks before the onset of winter hibernation (in mid October) to reduce potential disruption of normal denning activities. The purpose of recapturing the bears was to determine body composition changes and for the collection of fecal and blood samples.

Each bear captured was assigned a number printed on a set of tags attached to the ears and tattooed to the left and right sides of the upper lip. Finally, a vestigial premolar tooth was extracted and subsequently sectioned for age determination (Craighead et al. 1970).

5.3.1 FECAL COLLECTION

Fecal samples gathered for analysis were collected by 3 methods. First, samples were collected at the time of bear capture. If fecal samples from tranquilized bears were not voided by the animal within 30 min of capture, then feces were removed from the rectum by hand. Second, samples were collected when a bear was seen to defecate. Lastly, also during ground based observations, if thick cover obscured our view of a grizzly bear and defecation could not be observed, then fecal samples were collected while searching the area that had occupied the bear. All scats collected were frozen in the field and stored at -20^{o}C until analysis.

Scats were analyzed for content in Yellowknife, NWT, using methods developed by the Territorial Government Wildlife and Fisheries Division (Department of Resources, Wildlife, and Economic Development) in discussions with their biologists and wildlife disease specialists.

To eliminate parasites, the frozen scat sample bags were opened, saturated with cold water, and poured into pre-labelled 500 mL glass beakers. The beakers were then filled with additional water to the rim, covering the scat, and placed, uncovered, into in a convectional drying oven (Fisher Isotemp, Series 200). Oven temperatures initially were set at 125°C for 5 hours and then turned down to 100°C for 16 hours. After cooling, each beaker was filled again with water to loosen the samples inside the glass. Scat material was then poured into a no.10 mesh strainer and broken apart with a spoon under running water. After washing, the loose scat material was placed in the glass beaker and filled with water to help mask the smell. The uncovered beaker was again placed into the oven with temperatures set at 125°C for 5 hours and turned down to 100°C for 16 hours to remove most of the moisture. Scat material was then air dried on paper towels for 48 hours.

Dietary items were identified from laboratory reference collections using dissecting and compound microscopes. For each sample, the volumes of the various diet items were estimated visually on a grid with 1×1 cm cells, overlain with larger 10×10 cm cells. The mean proportion of each food item was calculated for each season and expressed as a percentage.

5.3.2 GROUND OBSERVATIONS

Approximately 175 hours were spent, with field assistants, observing barren-ground grizzly bears in 1995 and 1996. Using a Piper SuperCub or Aviat Husky aircraft equipped with floats, an individual bear would be located by radio-telemetry and the plane would land nearby. Bears were approached from downwind to avoid detection and spotting scopes were set up 500-1000 m away. Observations were made to determine feeding behaviours by focal-animal sampling protocols (Altmann 1974). Feeding sites were investigated when the bear had left the area. Monitoring times ranged from 0.5 hours to 5 hours. Bears that slept or rested in one spot for more than 2 hours were

abandoned.

5.3.3 STABLE NITROGEN ISOTOPE ANALYSIS

Blood was chosen for analysis because it can be easily obtained from live animals. Blood can also be separated into serum and cellular components, each having its own particular protein turnover rate. Dietary information can therefore be derived for two different periods from the same blood sample (Hobson and Clark 1992, Hobson and Clark 1983). There is evidence that stable isotope analysis on grizzly bear serum reflects dietary habits over 4-10 days, and the cellular fraction reflects a period of at least 40 days (Hilderbrand et al. 1996).

Blood was collected on each occasion a bear was sampled. Samples were drawn from either the femoral artery or jugular vein using 10 mL Vacutainer serum separating tubes (Becton-Dickinson, Rutherford, NJ). Upon returning to the field station, the samples were centrifuged, the serum extracted, and both serum and cellular portions frozen and stored at -20^{o}C until laboratory analysis.

An effort was also made to determine the δ^{15}N signature of the various food items barren-ground grizzly bears consumed. Representative foods determined from the 1995 scat analysis were collected in 1996. Arctic cotton grass (*Eriophorum* sp.) and sedge samples were collected as they emerged in early summer. A sample consisted of the green emergent growth of an individual plant >15 cm in length. Fruits of crowberry (*Empetrum nigrum*), blueberry (*Vaccinium uliginosum*), and cranberry (*Vaccinium vitis-idaea*) plants were collected in late summer. A fruit sample consisted of 6 or 7 ripe berries picked from an individual shrub. Herbivores were represented by muscle tissue from caribou (*Rangifer tarandus*) and northern red-backed voles (*Clethrionomys rutilus*). Bathurst caribou muscle samples were collected by workers on another research project in the

winter of 1995. Red-backed vole samples were collected by workers on another research project during the summer of 1994 in snap-traps set 500 m from the Daring Lake Research Station.

Frozen blood and tissue samples were placed in a freeze-drier (FTS Systems Inc., Stone Ridge, NY) for 60 hours, the time required to reach constant weight. Plant samples were oven dried for 48 hours. All samples were then powdered with a mortar and pestle. A 0.9-1.2 mg portion of each powdered sample was then weighed in a tin sampling capsule and assayed in a mass spectrometer (Europa Scientific 20/20, Crewe, UK) at the University of Saskatchewan Stable Isotope Facility in the Department of Soil Science. The natural abundance of the heavy-to-light stable nitrogen isotopes were reported in δ notation as parts per thousand (‰) deviations from a standard reference material according to the following equation:

$$\delta^{15}N = [(R_{sample} / R_{standard}) - 1] \times 1000$$

(Eqn. 1)

where R is the corresponding ratio $^{15}N/^{14}N$. The standard reference material used was atmospheric N_2 (air).

Isotopic fractionation is a mass dependant phenomenon (Peterson and Fry 1987). The addition of neutral mass, or neutrons, does not alter chemical reactivity therefore the different isotopes of nitrogen are functionally equivalent in chemical reactions. However most biological reactions involve kinetic isotope effects as light nitrogen isotopes react faster than their heavy isotope counterparts (Nadelhoffer and Fry 1994). This discrimination, or fractionation, between substrate and product can be approximated as the ‰ difference. Higher δ values that are detected in isotopic analyses denote an increased amount of the heavier isotope in the sample. Conversely, decreases in δ values denoted decreases in the heavy isotope content, and a reciprocal increase in the light isotope component (Peterson and Fry 1987).

5.3.4 HEMATOLOGY AND SERUM CHEMISTRY

Blood was collected from all the captured bears either from the femoral artery or jugular vein. The amount of time a blood sample is stored after collection has been shown to alter the laboratory analysis of some hematology parameters (Coles 1980, Kerr 1987). The maximum refrigerated storage time for whole blood samples was 7 days between collection and determinations. Both hematological and serum chemistry samples that were returned from the lab labelled as lipemic or hemolyzed were omitted from analysis to avoid skewed results (Meyer et al. 1992, Duncan et al. 1994). The drug used for capture has little effect on the blood parameters examined (Bush et al. 1980).

Hematology samples were collected with 7 mL Vacutainer tubes (Becton-Dickinson, Rutherford, NJ) coated with ethylene-diamine-tetra-acetate (EDTA) and then refrigerated in the field. These samples were analyzed for erythrocyte count, hematocrit, and hemoglobin concentration by a Coulter Counter ST (Rochester, NY) at the Stanton Yellowknife Hospital in Yellowknife, NWT. Leucocyte count was also measured and considered an indicator of stress level at the time of capture.

Serum chemistry samples were collected in 10 mL Vacutainer serum separating tubes. Upon returning to the field station at the end of each day, the tubes were centrifuged, the serum extracted to a separate labelled container, and stored at -20^{o}C until analysis. Serum was analyzed for albumin, albumin:globulin (A/G ratio), total bilirubin, calcium, creatinine, inorganic phosphorus, total protein, sodium and urea by an Abbott Spectrum II blood chemistry analyzer (Dallas, TX) at the University of Saskatchewan, Department of Veterinary Pathology.

5.3.5 BIOELECTRICAL IMPEDANCE ANALYSIS

We followed a snout to tail technique for BIA initially developed by Farley and Robbins

(1994) for bear species. Snout-to-tail resistance (STAILR) readings were made with the BIA Model 101A meter (RJL Systems, Detroit, MI). Movements by the bear during BIA can produce erroneous resistance readings so all measurements were performed while the bears were fully sedated (Farley and Robbins 1994). After sedation, bears were placed on a plastic sheet (to avoid current losses to the ground) in a sternally recumbent position with the back legs fully extended, forearms extended parallel to the length of the body, and the head straight and flush on the tarp between the forearms (Farley and Robbins 1994, Atkinson and Ramsay 1995). The ground surface underneath the plastic sheet was made as flat as possible but inclination was not considered an important factor. Electrode placement followed Farley and Robbins (1994). The cranial electrode pair were alligator clips affixed to the left and right upper lips at the level of the canines. The black current-carrying electrodes were always kept on the bear's right side and electrical contact was ensured by wetting the lips. The posterior electrode pair were Vacutainer needles (21G, 3.8 cm) with the short end inserted subcutaneously into the bear at 3 cm on either side of the junction of the sacrum and the first coccygeal vertebra, at the base of the tail. Because the bear's pelage was so thick, the hair had to be parted to ensure that the needle went directly into the flesh. After an impedance reading was taken, the electrodes were removed, the bear's body position checked, and the electrodes attached a second time. A second impedance reading was then taken to ensure consistency.

While bears were in sternal recumbency, the snout-vent length (SVL) was measured in centimetres using a cloth measuring tape. The SVL is the distance between the tip of the nose and the base of the tail while following the dorsal contours of the body. The SVL is measured because when combined with STAILR, Farley and Robbins (1994) found it to provide the best resistance measure.

Either immediately before or after the bear had been processed, body weight (± 200 g) was recorded using a multi-sampling digital scale (Senstek, Saskatoon, SK). Body weights were determined after a bear was placed in a known-weight, 3×3 m, cargo net

and lifted with the helicopter having the load cell placed between the lanyard and net.

The values of STAILR, body mass BM (kg), and SVL (cm) were then applied to a multiple linear regression equation to estimate total body water (TBW, kg):

$$TBW = 2.785 + [0.175 \times (SVL^2 \div STAILR)] + [0.186 \times BM]. \quad \text{(Eqn. 2)}$$

Farley and Robbins (1994) derived equation 2 from their calibration of the BIA technique with estimates of TBW obtained from isotopic dilutions on grizzly bears.

Total body water was then expressed as a percentage of the total BM and applied to a regression equation to estimate the total body lipid content (% BLC):

$$\%\ BLC = 98.01 - [1.28 \times (TBW \div BM) \times 100]. \quad \text{(Eqn. 3)}$$

Farley and Robbins (1994) derived equation 3 from their calibration of the BIA technique with the whole body chemical extraction of black bears and grizzly bears. Lipids are a diverse class of compounds that include fats and oils however we assumed the % BLC to represent a bear's total body fat. Farley and Robbins (1994) reported the error in determining the % BLC by BIA for grizzly and black bears to be ±2.2%.

A posteriori, we developed a model based on the density of a sphere (density = mass ÷ volume) using sphere volumes (volume = $[4 \times \pi \times radius^3] \div 3$), bear weights (kg), and axillary girths (cm) as an independent test to check the validity of our BIA results. This bear density model was based on the principle that water and fat have an inverse relationship in the body (Robbins 1993). Lean bears would thus have greater water accumulations, and therefore higher densities, relative to bears with larger fat accumulations.

5.3.6 STATISTICS

Statistical testing followed Messier et al. (1987) who correlated blood parameters to

actual body compositions of caribou. In the present study, analyses for sex effects were by independent samples *t*-testing. Data were pooled that exhibited no significant difference. When necessary, the analyses of seasonal effects were made by one-way analysis of variance and Tukey's multiple comparisons tests. Relationships between blood values and the level of body fat as indicated by BIA were evaluated using Spearman's rank correlation coefficients.

Statistical analyses were conducted using the statistical package for the social sciences (SPSS version 6.1). Means are presented with 1 standard error (SE). Values of $P < 0.05$ were considered significant.

6. RESULTS

6.1 SEASONAL CHANGES IN DIET DETERMINED BY SCAT ANALYSIS

Of the 98 scats, 60 were collected at capture and 38 were from the ground. The undigested portions of food found in the feces were visually estimated as volumes and seasonal dietary changes were evident (Table 1). Birds, fish, and microtine rodents were grouped in the miscellaneous category for the spring and early summer seasons. Miscellaneous food items in spring consisted of ptarmigan (*Lagopus* sp.) (4% volume, 10% frequency) and northern red-backed voles (1% volume, 3% frequency). In early summer, miscellaneous food items consisted of longnose sucker (*Catostomus catostomus*) and unidentified fish remains (2% volume, 25% frequency), and ptarmigan (1% volume, 10% frequency). In late summer the only miscellaneous food item was bearberry (*Arctostaphylos alpina*) (7% volume, 10% frequency).

Labrador tea (*Ledum decumbens*), dwarf birch, Diptera larvae, northern pintail (*Anas acuta*), green-winged teal (*A. crecca*), grizzly bear hair, unidentifiable wasps, garbage, dirt, and sand that appeared in the fecal samples were excluded from analysis because

Season	*n*	caribou	Arctic ground squirrel	horsetail	sedge	Arctic cotton	crowberry	cranberry	blueberry	miscellaneous
Spring	30	61 (80)	8 (30)	0	2 (10)	3 (20)	13 (60)	5 (63)	3 (30)	5 (13)
Early summer	20	9 (10)	0	38 (65)	37 (60)	12 (40)	0	1 (35)	0	3 (35)
Mid-summer	15	78 (93)	0	7 (7)	0	0	2 (20)	11 (60)	2 (40)	0
Late summer	10	20 (40)	12 (20)	0	0	0	46 (70)	3 (40)	12 (80)	7 (10)
Autumn	23	62 (96)	16 (48)	0	0	0	11 (52)	7 (65)	4 (26)	0

Table 1. Percent volume and percent occurrence (in parentheses) of food items in barren-ground grizzly bear scats classified by season and collected from the central Arctic in 1995 and 1996.

they were either considered to be items ingested incidentally, or had volumes that totalled < 1%.

Caribou was most common consumed food identified by fecal analysis with high volumes appearing in the spring, mid-summer, and autumn seasons. The spring diet was the most diverse, although caribou was the most prevalent food item (61% of the scat volume). Overwintered berries were also common and totalled 21% of scat volume in spring samples.

In the early summer, caribou remains constituted only 9% of scat volume whereas green vegetation represented by horsetails (*Equisetum* sp.), sedges, and Arctic cotton grass were the major constituents.

Caribou peaked in the diet in mid-summer at 78% of scat volume and dropped to 20% of scat volume in late summer. Crowberries, blueberries, and Arctic ground squirrels (*Spermophilus parryii*) made up the majority of late summer food items.

Most of the autumn scats were collected 3 to 4 weeks before denning. Caribou remains represented 62% of scat volume and berries collectively made up 22% of scat volume.

6.2 PERSONAL OBSERVATIONS OF GRIZZLY BEARS

We had intended to monitor individual bears for a period lasting a minimum of three hours, whenever possible, following a focal-animal sampling method (Altmann 1974). For each sample period, all behaviour types and the amount of time spent performing each behaviour was to have been recorded. Focal-animal sampling proved extremely difficult as dense shrub cover often obstructed the view of the bear for long or irregular periods. As a result, ground based observations were used primarily to document bear

habitat use (Gau 1998) and secondarily to document the food items consumed and to allow collection of fresh fecal samples. The only food known by direct observation to have been consumed that fecal analysis did not detect was willow leaves.

Direct observation, and communication with other researchers working within the study area, in 1995 and 1996 showed that while barren-ground grizzly bears in the central Arctic region did use caribou carrion, they were also effective predators of caribou. In a 3328 km^2 region within our study area, environmental monitoring in 1995 by BHP Diamonds Inc. documented grizzly bears killing 26 caribou, including of adults, yearlings, and calves. In 1996, grizzly bear monitoring by BHP was more intensive and they documented 61 caribou killed by bears (Banci and Moore 1997). We discovered an additional 11 sites where caribou were killed. We also observed bears chasing caribou 3 times although none were successful captures. our primary monitoring periods, however, occurred when caribou were found at relatively low density in our study area (early summer) and when berries were fully ripened (late summer).

A notable observation was that 14 of the 26 scats collected by induced defecation in the mid-summer and autumn seasons were dark red-brown in colour and liquid to tar-like in consistency. Caribou was identified as the primary fecal component in each of those 14 scat samples. A loose and runny scat has been reported in carnivores to be the first type deposited after a meal comprised primarily of fresh meat and blood (Floyd et al. 1978, Pritchard and Robbins 1990). The consistency of the scats was, therefore, considered as further evidence of caribou predation.

6.3 STABLE ISOTOPE SIGNATURES AND NITROGEN LEVELS OF SAMPLED PLANTS AND ANIMALS

Mean $\delta^{15}N$ values for the samples collected ranged from -5.1‰ in cranberries to 8.0‰ for

grizzly bear serum sampled in the spring (Table 2). The $\delta^{15}N$ signal of grizzly bear serum samples, which were higher than the erythrocyte samples, may reflect a recent diet relatively rich in animal protein for a portion of the spring, mid-summer, and autumn seasons. The grizzly bear $\delta^{15}N$ erythrocyte samples may reflect slightly more vegetation in the diet during the spring-early summer and mid- to late summer seasons.

Stable nitrogen isotope analysis reflect what endogenous and exogenous sources of nitrogen were utilized in the metabolic protein requirements of an animal (Hobson and Stirling 1997). The mass spectrometer simultaneously determines the $\delta^{15}N$ and the natural abundance of nitrogen in each sample tested (Table 3). Digested foods that are higher in nitrogen content can better contribute to an animal's metabolic protein requirement. The sampled vegetation contained very little nitrogen, whereas caribou was the food with the richest source of nitrogen. Indeed, mammalian prey or carcasses are frequently the highest quality foods available to bears for sources of protein in their diet (Pritchard and Robbins 1990, Robbins 1993).

6.4 SEXUAL DIFFERENCES IN THE BODY COMPOSITION DATA

Body composition data are presented from 47 captures on 23 bears. The only hematological parameters that differed between sexes were erythrocyte count (t = -2.51, df = 41, P = 0.02) and hemoglobin (t = -2.11, df = 42, P = 0.04), and the only serum chemistry parameter was total bilirubin (t = -2.78, df = 37, P = 0.01). Blood parameters between sexes were pooled where differences were not significant (Table 4).

The percentage of total body fat reserves of both adult male and lone female grizzly bears were pooled for analysis because no significant differences were detected between the sexes (t = 1.14, df = 42, P = 0.26).

Sample	*n*	$\delta^{15}N \pm SE$
grizzly bear serum - spring collection	29	8.0 ± 0.1
grizzly bear serum - autumn collection	11	7.6 ± 0.2
grizzly bear serum - mid-summer collection	12	7.4 ± 0.1
grizzly bear erythrocytes - mid-summer collection	13	6.6 ± 0.1
grizzly bear erythrocytes - autumn collection	11	6.2 ± 0.1
northern red-backed vole	5	4.6 ± 1.2
Arctic cotton grass	5	3.5 ± 1.1
sedge	5	3.5 ± 0.4
caribou	5	2.6 ± 0.1
blueberry	5	-0.8 ± 0.4
crowberry	5	-3.9 ± 0.8
cranberry	5	-5.1 ± 1.0

Table 2. Nitrogen stable isotope signatures of plant and animal tissues sampled from the central Arctic of the NWT in 1995 and 1996.

Food item (n = 5)	% ± SE
caribou muscle	12.6 ± 0.5
northern red-backed vole muscle	9.6 ± 0.3
sedge	1.9 ± 0.1
blueberry	1.0 ± 0.3
Arctic cotton grass	0.9 ± 0.1
cranberry	0.7 ± 0.1
crowberry	0.4 ± 0.1

Table 3. The mean nitrogen content of the representative bear food items sampled for isotope analysis from the central Arctic of the NWT in 1995 and 1996.

Blood parameter	Season	*n*	means ± SE
albumin	spring	20	39.6 ± 0.5
(g/L)	mid-summer	13	37.2 ± 0.8
	autumn	6	40.7 ± 3.6
bilirubin, female	spring	9	5.4 ± 0.3
(µmol/L)	mid-summer	7	5.7 ± 0.5
	autumn	4	6.8 ± 1.7
bilirubin, male	spring	10	4.2 ± 0.2
(µmol/L)	mid-summer	6	4.3 ± 0.8
	autumn	2	6.0 ± 1.0
erythrocyte count, female	spring	9	6.1 ± 0.1
(10^6/mm^3)	mid-summer	7	6.1 ± 0.2
	autumn	7	6.5 ± 0.2
erythrocyte count, male	spring	10	5.9 ± 0.2
(10^6/mm^3)	mid-summer	6	5.7 ± 0.2
	autumn	4	6.0 ± 0.1
hematocrit	spring	20	42.7 ± 0.8
(%)	mid-summer	13	42.3 ± 0.8
	autumn	11	45.1 ± 0.8
hemoglobin, male	spring	11	15.3 ± 0.4
(g/dL)	mid-summer	6	15.2 ± 0.5
	autumn	4	16.3 ± 0.4
sodium	spring	20	137.9 ± 1.0
(mmol/L)	mid-summer	13	142.6 ± 2.0
	autumn	6	136.8 ± 7.2

Table 4. The seasonal means of measured blood parameters for adult male and lone female grizzly bears in 1995 and 1996 that did not exhibit a seasonal affect (ANOVA, $P > 0.05$).

6.5 PHYSIOLOGICAL STATUS AT THE TIME OF CAPTURE

Bears are reported to have relatively low serum urea and relatively high serum creatinine levels during hibernation and for a short period after they leave their dens in spring (Nelson et al. 1983, Nelson et al. 1984, Ramsay et al. 1991). Mean creatinine levels in the spring were significantly higher than mid-summer and autumn values (Table 5). Also, mean urea levels in the spring were significantly lower than mid-summer and autumn values. Thus, bears in our study were assumed to be in a walking hibernation state during spring captures.

Numerous studies have identified elevated leucocyte counts as an indicator of elevated stress levels at the time of wildlife or lab animal blood sampling, even if stress was only placed on the animal for a short time (Lee et al. 1977, Jain 1986, Schroeder 1987, Meyer et al. 1992). Elevated leucocyte counts in grizzly bears have also been reported when they experienced an increased stress or excitement level from their capture effort (Brannon 1985*a*). The leucocyte counts from the mid-summer and autumn seasons led us to believe that the bears captured were more stressed from the capture effort than in the spring season.

Tukey testing also revealed that A/G ratios, total protein, hemoglobin, inorganic phosphorus, and calcium also exhibited significant seasonal changes. Mid-summer A/G ratios were significantly lower than spring and autumn values. Spring total protein levels were significantly lower than mid-summer and autumn levels. Autumn hemoglobin levels for females were significantly higher than spring and mid-summer means. Mid-summer inorganic phosphorus levels were significantly higher than spring and autumn values. Calcium levels in the autumn were significantly lower than spring and mid-summer levels.

				ANOVA	
Blood parameter	Season	*n*	means ± SE	*F*	*P*
urea	spring	20	4.9 ± 0.9[a]	39.9	<0.0001
(mmol/L)	mid-summer	13	20.0 ± 1.9		
	autumn	6	24.1 ± 3.4		
albumin:globulin	spring	20	1.8 ± 0.1	27.7	<0.0001
	mid-summer	13	1.1 ± 0.1[a]		
	autumn	6	1.6 ± 0.1		
creatinine	spring	20	111.1 ± 4.9[a]	11.3	0.0002
(µmol/L)	mid-summer	13	83.7 ± 3.8		
	autumn	6	81.2 ± 5.5		
total protein	spring	20	62.4 ± 0.9[a]	6.7	0.0034
(g/L)	mid-summer	13	70.3 ± 1.1		
	autumn	6	67.3 ± 5.4		
hemoglobin, female	spring	9	15.6 ± 0.4	6.4	0.0072
(g/dL)	mid-summer	7	15.9 ± 0.4		
	autumn	7	17.4 ± 0.3[a]		
inorganic phosphorus	spring	20	1.5 ± 0.1	5.2	0.0103
(mmol/L)	mid-summer	13	1.9 ± 0.1[a]		
	autumn	6	1.6 ± 0.1		
leucocyte count	spring	20	8.7 ± 0.7[a]	4.8	0.0136
(10^3/mm^3)	mid-summer	13	11.1 ± 0.9		
	autumn	11	11.9 ± 0.9		
calcium	spring	20	2.3 ± 0.0	4.0	0.0277
(mmol/L)	mid-summer	13	2.3 ± 0.0		
	autumn	6	2.1 ± 0.1[a]		

[a]Seasonal values that Tukey testing determined to be significantly different.

Table 5. Blood parameters for adult male and lone female grizzly bears in 1995 and 1996 that differed significantly among seasons.

6.6 SEASONAL CHANGES IN TOTAL BODY FAT LEVELS AND DENSITY

Bear ages were assigned year categories based on whole numbers. The mean age of the male bears sampled (n = 24) was 8.8 ± 1.1 years. The mean age of the lone female bears sampled (n = 23) was 6.5 ± 0.5 years. Regardless of age, the bears differed markedly in body condition when they emerged in the spring (Table 6). Additionally, a one-way ANOVA and Tukey test determined that the percentage of total body fat accumulated in the autumn season was significantly higher than the spring and mid-summer seasons ($F_{2,41} = 27.2$, $P < 0.0001$).

Bioelectrical impedance testing was checked against calculated bear densities and the BIA results were supported (Table 7). A one-way ANOVA and Tukey test determined mean bear density in the mid-summer season to be significantly lower than the autumn season mean ($F_{2,31} = 4.6$, $P = 0.0184$). The mid-summer and autumn seasons correspond to the lowest and highest mean total body fat levels respectively, thus should correspond to the highest and lowest mean densities respectively.

6.7 CORRELATIONS OF TOTAL BODY FAT TO BLOOD PARAMETERS

The aforementioned blood parameters, which were suggested as reliable indicators of body condition for black and grizzly bears, were measured from the bears captured in our study and correlated to their total body fat levels. The only blood parameter found to correlate with the total body fat levels in both adult male and lone female grizzly bears was albumin (Table 8). For lone female grizzlies, hemoglobin was an additional parameter found to correlate with total body fat levels.

Season	*n*	mean ± SE	range
spring	20	13.2 ± 1.4	6.4 - 26.7
mid-summer	11	10.8 ± 1.4	6.3 - 20.4
autumn	13	25.5 ± 1.3	16.7 - 33.6

Table 6. The percentage of total body fat determined by bioelectrical impedance analysis for adult male and lone female grizzly bears sampled from the central Arctic of the NWT in 1995 and 1996.

Measurement	Season	*n*	means ± SE	range
girth	spring	18	104.0 ± 5.0	78 - 157
(cm)	mid-summer	10	105.7 ± 3.2	94 - 123
	autumn	6	127.3 ± 15.1	99 - 200
mass	spring	18	114.0 ± 13.8	48.0 - 261.5
(kg)	mid-summer	10	113.7 ± 13.6	92.4 - 215.8
	autumn	6	157.4 ± 25.8	98.4 - 265.4
density	spring	18	5.8 ± 0.2	4.0 - 7.5
($\times 10^{-3}$ kg/cm^3)	mid-summer	10	6.6 ± 0.2	5.2 - 7.3
	autumn	6	4.9 ± 0.6	2.0 - 6.0

Table 7. Axillary girth, mass, and the calculated density for the adult male and lone female barren-ground grizzly bears sampled by bioelectrical impedance in 1995 and 1996.

Blood parameter	n	r_s	P
albumin	36	0.51	<0.01
hemoglobin, female	23	0.48	0.02
erythrocyte count, female	23	0.33	0.12
total protein	36	0.23	0.17
inorganic phosphorus	36	-0.21	0.21
hematocrit	41	0.18	0.26
bilirubin, male	16	0.28	0.29
albumin:globulin	36	0.17	0.32
hemoglobin, male	18	0.22	0.37
creatinine	36	-0.13	0.45
calcium	36	-0.13	0.46
erythrocyte count, male	17	-0.16	0.54
bilirubin, female	20	0.14	0.57
sodium	36	0.07	0.69

Table 8. Spearman rank correlation coefficients between blood parameters and the percentage of total body fat as determined by BIA for adult male and lone female grizzly bears in 1995 and 1996.

7. DISCUSSION

7.1 SEASONAL VARIATIONS IN DIET

Feeding behaviour in bears often varies seasonally as the animals track the availability of high-quality foods (Hamer and Herrero 1987, French et al. 1994, Kasbohm et al. 1995). It should be noted, however, that no systematic attempts at determining animal or plant food availability were made during our study.

Barren-ground grizzly bears in the central Arctic region in 1995 and 1996, upon leaving their dens in the spring season, fed on caribou of the Bathurst herd as they migrated north to their calving grounds. In early summer, when caribou were scarce in the study area, emergent shoots of horsetails, grasses, and sedges appeared in the diet. As mixed post-calving herds of caribou moved south through the study area in the mid-summer season, they again became the primary food of the bears. In late summer, the bears became hyperphagic to accumulate the fat reserves necessary for hibernation making use of the ripened berries. More berries were consumed by grizzly bears in the late summer season than from all other seasons combined. The diet at the end of the grizzly bear's active period in the autumn season was similar to its start in the spring season. Grizzly bears in autumn fed primarily on caribou as they migrated south to the treeline for winter.

7.2 BIAS AND ERROR IN FECAL ANALYSES

Analyzing the remains in bear fecal samples is the most common method for determining feeding patterns. Using scat analysis alone to determine feeding habits has inherent problems (O'Gara 1986, Reynolds and Aebischer 1991). Each scat does not have an equal chance of being collected, fecal residues produced after consumption vary among food types, and typically there is considerable variation in the size of the scat collected (McLellan and Hovey 1995).

Another bias involved the difficulty we experienced travelling on the tundra. The collection of ground deposited scats may have been biased to collections from the areas we could most easily sample (McLellan and Hovey 1995). When open areas and eskers were travelled, scats were generally easy to spot. Additionally, some scats were less cryptically concealed than others. Berry patties and scats containing green vegetation were more visible than scats containing animal hair and bones. Finally, if the loose and liquid type scats that were collected by induced defecation were to be deposited on the ground, they would likely have been unrecognizable as grizzly bear scat.

Scat analysis is based on the identification of partially digested or undigested food (Frackowiak and Gula 1992). Hatler (1972) and Poelker and Hartwell (1973) found that in comparing stomach to scat samples in bears, the proportions of animal matter were greatly reduced in the latter. As a carnivore, the grizzly bear's digestive system is more efficient extracting energy from meat than plants (Pritchard and Robbins 1990). The consumption of foods with different digestibilities would, therefore, produce fecal residue volumes that were not representative of the foods consumed (McLellan and Hovey 1995).

Another source of error in scat analyses can result from variation in the sizes of the scats collected and that each scat is considered to contribute equally to the data set. This bias would tend to overestimate food items found in small scats and underestimate food items found in large scats (McLellan and Hovey 1995).

7.3 ISOTOPE DIET DETERMINATION

Erythrocyte samples from the bears were collected in spring, mid-summer, and autumn. Erythrocyte samples collected in mid-summer reflected bear diet through the seasons we defined as spring and early summer. Erythrocyte samples collected in the autumn, by contrast, reflected the bears' diet through the mid- and late summer seasons. The data

from the erythrocyte samples collected in the spring are not presented as it was believed that the samples would reflect the endogenous sources of nitrogen during hibernation.

The primary spring and early summer foods identified by observations and fecal analysis were caribou and green vegetation respectively. The bear diet represented by the $\delta^{15}N$ signature of erythrocyte samples through the spring and early summer seasons, if the consumed items contributed equally to the metabolic protein pathways of the bears, should reflect the caribou and green vegetation isotopic signatures combined (Keough et al. 1996). However, sedge and Arctic cotton grass had very low nitrogen contents compared to caribou. It would therefore require a relatively larger volume of these types of vegetation to meet the metabolic protein requirements of bears that could be met by caribou in relatively modest amounts.

The primary foods identified by observations and fecal analysis in the mid- and late summer were caribou and berries respectively. The bear diet represented by the $\delta^{15}N$ signature of erythrocyte samples through the mid- and late summer seasons, if the consumed items contributed equally to the metabolic protein pathways of the bears, should reflect the caribou and berry isotopic signatures combined. It is unlikely, however, that caribou and berries contributed equally to the metabolic protein pathways of barren-ground grizzly bears as the berry species we sampled had low nitrogen levels relative to caribou. It would therefore require a relatively larger volume of berries to meet the metabolic protein requirements of bears that could be met by caribou in relatively modest amounts. Thus, the erythrocyte samples collected in mid-summer and autumn may reflect an influx of vegetation to the diet while the bulk of the metabolic protein requirements were made via caribou or some other exogenous or endogenous source.

The nitrogen isotope signature of the grizzly bear serum samples were assumed to reflect the diet for the week prior to sampling. The signatures were higher than those for

erythrocytes, suggesting that recently ingested foods were rich in protein. Based on the $\delta^{15}N$ serum signatures of the bear tissues, nitrogen contents of the food items sampled, high number of caribou kill sites reported, and the high frequencies and volumes of caribou found in the fecal remains, we conclude that barren-ground grizzly bears were adept at killing and consuming large numbers of caribou, and depended on caribou to meet their protein requirements in the spring, mid-summer, and autumn seasons.

7.4 ISOTOPE SAMPLING

The serum and cellular fractions of the bear blood we analyzed may have been contaminated by the gel in the serum separating test tubes used for collection. The gel was described by the 1996 Becton-Dickinson product release guide as a polymer gel and silica activator, however, we were unable to ascertain it had any affect on the subsequent isotope assays.

There may have been problems in choosing the particular caribou samples that represented the diet of grizzly bears in our study. The caribou muscle sampled was from the Bathurst herd but it was collected from animals on their wintering grounds. If the tissues sampled were new muscle growth, then the isotopic analyses would reflect the sources of nitrogen that contributed to its growth. As the winter diet of caribou differs from summer (Heard 1989), winter and summer isotopic values in caribou muscle may thus differ. The Bathurst caribou herd also has a large land-use area (Heard 1989), and our samples may have been collected from animals that did not use the region defined as our study area. Regional variations in caribou $\delta^{15}N$ signatures may exist as isotope values higher than our study have been reported for caribou from the Porcupine and Delta caribou herds in northern Alaska (Barnett 1994). Future studies on barren-ground grizzlies should include tissue samples with relatively short protein turnover rates from any caribou carcasses found concurrent to their studies, and in their region of interest.

There was also a high degree of variability in the isotope signatures of the green vegetation and berries we sampled. The $\delta^{15}N$ differences in these primary producers suggested that they were using various pools of soil nitrogen. Similar findings have been made by Schulze et al. (1994) and Michelsen et al. (1996) who noted that plants from nutrient deficient northern environments may have a wide range of nitrogen isotope signatures.

7.5 GRIZZLY BEARS AS CARNIVORES

Mammalian prey or carcasses are often the richest sources of protein and gross energy available to bears (Pritchard and Robbins 1990). Compared with other plant foods, the roots of Eskimo potato (*Hedysarum alpinum*) and various edible nuts are also relatively rich in protein (Pritchard and Robbins 1990, Robbins 1993, McLellan and Hovey 1995). Indeed, hedysarum roots are reported to be an important source of seasonally available protein for bears in other northern environments (Miller et al. 1982, Nagy et al. 1983*a*, Hechtel 1985, MacHutchon 1996).

Porsild and Cody (1980) do not indicate that *Hedysarum alpinum* has an even distribution through the mainland NWT. There may, thus, be a gap in the distribution of *H. alpinum* in our study area. Plant inventories conducted by the Government of the NWT and our personal observations in the study area seem to confirm this. Therefore, the bears examined in our study may not have access to plants that are naturally rich in protein. However, barren-ground grizzly bears do have access to the Bathurst caribou herd which was estimated at 349 000 ± 95 000 non-calf caribou in 1996 (Gunn et al. 1997).

Previous observations have shown that Arctic grizzly bears can be successful predators of muskox (*Ovibos moschatus*), caribou, and even seals (Gunn and Miller 1982, Case and Stevenson 1991). Studies in Alaska and northern British Columbia have shown that

grizzly bears may significantly affect moose (*Alces alces*) and caribou population dynamics through high rates of calf predation (Page 1985, Bergerud and Page 1987, Boertje et al. 1988, Chetkiewicz 1993, Adams et al. 1995). In contrast, studies on grizzly bears in the Yukon and the western NWT have determined that the bears are predominantly herbivorous and predation is opportunistic (Pearson 1975, Miller et al. 1982, Nagy et al. 1983*a*, Nagy et al. 1983*b*, Bromley 1988, MacHutchon 1996).

Bears with access to high quality protein sources such as fish or large mammals generally reach sexual maturity earlier, have shorter breeding intervals, and maintain higher population densities than others (Craighead and Mitchell 1982, Jonkel 1987). Grizzly bears on the tundra of the NWT typically exhibit delayed sexual maturity, long breeding intervals, small body size, and low population densities (GNWT Renewable Resources 1991, Case and Buckland 1997). A possible reason barren-ground grizzly bears in the central Arctic, seemingly dependant on a high quality source of a food, may not be as large or prolific as coastal or mountain populations is that their active period is relatively short. Bears in rich coastal environments may only have to hibernate 1 to 2 months of the year, if at all (Storer and Tevis 1955, Jonkel 1987). Grizzly bears occupying our study area are occupants of winter dens for up to 7.5 months (P. McLoughlin and F. Messier, unpub. data).

7.6 GRIZZLY BEARS AND BERRIES

Thus far we have highlighted the importance of protein in the barren-ground grizzly bear diet. It is also important to emphasize the significance of berries. The consumption of berries in the late summer and autumn seasons are critical as they are rich in carbohydrates (Robbins 1993). It has been previously noted that a large consumption of carbohydrates from soft mast leads to the deposition of fat reserves, and that the accumulation body fat is necessary for survival during hibernation (Pearson 1975, Mace

and Jonkel 1983, McLellan and Hovey 1995). Also, it is essential for female bears to accumulate large fat reserves before going into hibernation to facilitate reproductive success (Atkinson and Ramsay 1995). Thus crowberries, blueberries, cranberries, and bearberries are critically important to the diet of barren-ground grizzly bears in the late summer and autumn seasons to ensure winter survival and successful parturition.

It has also been suggested that a bear's digestive physiology shifts during the late summer and autumn to increase the animal's ability to digest the carbohydrates from berries (Brody and Pelton 1988). This digestive shift would further facilitate the rapid accumulation of body fat during hyperphagia.

A lack of *Hedysarum alpinum* may require the barren-ground grizzly bears in our study area to be dependant on mammals for their primary source of dietary protein. The studied bears were also dependant on the carbohydrates from berries which facilitated the collection of fat reserves during hyperphagia. The most serious threats to bear populations in our study area are declines in the caribou population or crop failures of the fruits from the northern berry species.

7.7 USING BLOOD PARAMETERS TO ASSESS NUTRITIONAL STATUS

This study is among the first to correlate the body composition of free-ranging grizzly bears to blood hematology and metabolite levels. The blood values obtained for the bears we measured are within the ranges reported for grizzly bears in the southwestern Yukon Territory, central and northeastern Alaska, and an area along the Arctic coast of the NWT near the Coppermine River (Halloran and Pearson 1972, Pearson and Halloran 1972, Brannon 1983, R. Case and R.J. Gau unpub. data). The low number of significantly correlated blood parameters to total body fat levels should emphasize that blood parameters are poor indicators of body condition in grizzly bears.

Albumin is the major fraction of total serum protein and varies because of many influences (Duncan et al. 1994). Strenuous exercise and stress in grizzly bears have been shown to elicit an increase in total protein levels and, thus, in serum albumin levels (Brannon 1985*b*). Seasonal variations in serum protein characteristics have also been noted by other researchers (Halloran and Pearson 1972, Brannon 1985*b*, Duncan et al. 1994).

Modifications in hemoglobin levels have been associated with changes in bear diet (Schroeder 1987, Hellgren et al. 1993). It has also been noted hemoglobin levels vary for bears in response to stressful situations (Lee et al. 1977, Beeman 1981, Brannon 1985*a*).

Unlike albumin and hemoglobin, serum calcium and phosphorus did not exhibit a significant relationship with total body fat levels. They did however show a significant difference in their seasonal means. Other researchers have attributed seasonal fluctuations in serum calcium and phosphorus levels to increased stress levels, strenuous exertion, and changes in diet (Halloran and Pearson 1972, Guyton 1981, Brannon 1985*b*).

Overall we would discourage the practice of attempting to determine the nutritional status of bears using albumin, A/G ratios, bilirubin, calcium, creatinine, erythrocyte counts, hematocrit, hemoglobin, inorganic phosphorus, leucocyte counts, total protein, sodium, and urea because they seem not to be exclusively related to the nutritional status of the animal.

7.8 SEASONAL VARIATIONS IN TOTAL BODY FAT

Before the implementation of our study, the goal was to capture the same 5 male and 5 female bears 6 times over 2 years. After the first capture session it was apparent that not enough females were captured, or collared males remained in the study area, to recapture

the same 10 bears at each subsequent recapture session. As a result the only adult male and lone female bears recaptured were the individuals that remained in the study area. Even though the study area encompassed ≈40 000 km^2, satellite telemetry has revealed that male barren-ground grizzly bears can move from the centre of the study area, out of it, and back again in a relatively short period of time (P. McLoughlin and F. Messier, unpub. data).

Using BIA to determine body composition has been standardized for bears and the results have proven, with certain limitations and assumptions, to be accurate (Farley and Robbins 1994). Factors producing erroneous BIA readings include small abscesses and tissue traumas located along the conductor path, and large ingesta volumes (Farley and Robbins 1994). Impedance readings can also be affected by the animal's hydration status which is hard to judge under field conditions (Brodie et al. 1991). Six of the 24 bears captured in mid-summer and autumn entered water in an attempt to escape capture. Although the pelage seemed to dry quickly after the bear left the water, a wet bear would weigh more, leading to an overestimate of fat content.

Total body fat levels appeared to decline through the early summer until the mid-summer season when caribou returned from their calving grounds and were available as a food. The early summer period for barren-ground grizzly bears may be what Eagle and Pelton (1983) described as a negative foraging period in black bears. Negative foraging was characterized by a spring period when weight was lost while feeding largely on indigestible green vegetation, high in fibre (Hellgren et al. 1989). To confirm that barren-ground grizzly bears are in a negative energy balance in early summer, and lose part of their fat reserves accumulated the year before, further studies in the central Arctic on grizzly bears should focus on early summer captures to complement the BIA data obtained in our study. Late summer captures would also complement the data obtained in our study and provide further information pertaining to the onset of hyperphagia for bears in the central Arctic.

It has been maintained that bears rely on fat reserves for hibernation but only recently have studies begun to quantify changes in the bear's body composition during long periods of fasting (Atkinson and Ramsay 1995, Hilderbrand 1997). Our study is one of the first to report seasonal mean body fat levels for a free-ranging grizzly bear population. As expected, mean body fat levels were the highest in the autumn season. Bears were assumed to be hyperphagic in autumn and gathering the fat reserves necessary to endure hibernation. It can be assumed that up to 99% of the energy used during hibernation is from the catabolism of body fat (Atkinson et al. 1996).

7.9 CRITICAL PERIODS IN THE NUTRITIONAL STATUS OF GRIZZLY BEARS

There were two critical nutritional periods for the barren-ground grizzly bears examined in our study. The poorest level of condition was the time before the Bathurst caribou herd returned to the study area from their northern calving grounds. Assuming that cellular and structural components of adipose tissue account for ≈5% of total body fat levels, some bears measured were so lean that their fat reserves dropped to just 1-2% usable body fat. As caribou returned from their calving grounds, they again became the primary food of the bears and nutritional condition improved.

The timing of the caribou herd returning to the central Arctic from their calving grounds seems to play a role in the forage ecology of barren-ground grizzly bears. The lack of *Hedysarum alpinum* in our study area may require these bears to depend on mammals as their primary source of dietary protein. A decline in caribou populations could negatively affect the bear populations in our study area.

We believe that the second critical nutritional period for barren-ground grizzly bears is the time they are hyperphagic. Hyperphagia has been previously recognized as a

behavioural period where bears acquire the large amounts of fat reserves necessary to survive winter hibernation (Nelson et al. 1983). In a study currently underway along the coastal salmon spawning areas of south-central Alaska, female grizzly bears averaged 40% total body fat immediately before hibernation (Hilderbrand 1997). The accumulation of body fat for bears is necessary to sustain life during hibernation and essential for the reproductive success of pregnant females (Atkinson and Ramsay 1995). Berries seem to play a pivotal role in the forage ecology of barren-ground grizzly bears in that they are the primary food responsible for the accumulation body fat. During the hyperphagic period, a prolonged disturbance to bears consuming berries in our study area could affect the accumulation of fat reserves necessary for survival and reproduction. In southerly bear populations such disturbances have been previously noted as declines in food intake, loss of critical habitat, and increased energy expenditures resulting from permanent road construction, increased human access to remote areas, and vehicle harassment (McLellan 1989).

8. CONCLUSIONS

Economic pressures in the NWT have led Governments on the Territorial and Federal levels to support the development of the diamond industry. Our study set out to identify seasonal changes in the feeding pattern and body composition of barren-ground grizzly bears in a region with the highest density of diamond exploration within the NWT.

Our study was limited by the necessity of being completed over a short 2 year time-frame. Although useful data were collected, our conclusions should only be considered preliminary and further information should be collected. Multi-year data are needed to support or reject our interpretations.

8.1 SEASONAL CYCLES IN THE FORAGE ECOLOGY OF BARREN-GROUND GRIZZLY BEARS

Barren-ground grizzly bears appeared to follow seasonal patterns in dietary intake and body composition throughout their active periods. Upon leaving their winter dens in May, the bears examined in our study had the most variable mean body fat levels and primarily used the migrant Bathurst caribou herd as food. Numerous caribou are available through the spring season as part of the Bathurst caribou herd pass through the study area then as they head north to their calving grounds (Gunn and Miller 1986).

Through June, caribou were largely absent from the study area and bears switched their diet to the new shoots of horsetails, grasses, and sedges. However these plants being of poor nutritive value to the bears, combined with the added stresses of reproduction and high daily movements (P. McLoughlin and F. Messier unpub. data), resulted in the loss of a portion of the bears' fat reserves. As caribou returned to our study area from their calving grounds, they again became the primary food of the bears whose nutritional condition then improved.

In mid to late August bears began a hyperphagic state as the main northern berry species became fully ripened. Crowberries, cranberries, blueberries, and bearberries in particular were consumed.

In autumn, 2-3 weeks before denning, with a significantly higher percentage of body fat reserves accumulated than in any other season observed, bears were primarily feeding on caribou that were heading south to treeline for the winter. The actual quantities of caribou consumed during the latter portion of the autumn period may be low compared to the other seasons studied. Bears may only "top-up" on caribou before the start of hibernation. Further studies on the energetics of barren-ground grizzly bears might focus on rates of food intake based on methods using radioactive sodium (^{22}Na) (Gallagher et

al. 1983, Green et al. 1984, Farley and Robbins 1997).

Seasonal cycles in feeding patterns and mean body fat levels exhibited by the bears examined in this study only span through 2 years of data collection. It has been suggested for bears that data from multi-year studies are necessary to separate the effect of seasonal rhythms in physiology from habitat generated changes in nutritional condition (Hellgren et al. 1993). It has also been recommended that long-term studies are necessary to adequately document bears' food habits in variable environments (Mattson et al. 1991). The research presented in this final report should be considered as groundwork for the building of a detailed management plan for the barren-ground grizzly bear. Further aspects of the ecology of grizzly bears in the central Arctic, including population delineation, home range delineation, denning habits, spatial and temporal movements, and habitat analyses through satellite telemetry methods are currently being studied (P. McLoughlin and F. Messier unpub. data). Body composition analysis will continue but due to limited resources, will only be conducted during the primary spring capture phases for the overall barren-ground grizzly bear ecology project.

8.2 ESTIMATED ENERGY REQUIREMENTS

The basal metabolic rate (BMR) is the daily energy expenditure of an animal in muscular and psychic repose although not sleeping, in a thermoneutral environment, and in a postabsorptive state (Brody 1945, Kleiber 1961). However, calculating the daily energy expenditure of wildlife present special problems as additional energy is required for activity and thermoregulation (Robbins 1993). Thus, estimates for the BMR and daily energetic demands for some free ranging wildlife are, at the very least, limited to best guesses. It has been previously estimated that captive black bears, that are active, require 8000 kcal to satisfy their daily energy expenditures (Nelson et al. 1983). Also, the energy requirements of captive black bears have been estimated to increase to 20 000 kcal during

hyperphagic periods (Nelson et al. 1983).

We estimated the BMR for the grizzly bears in our study using the formula determined by McNab (1988) for vertebrate-eating carnivores ($91.8 \times \text{weight}^{0.813}$). Also, we assumed the mean weight of the adult males (165.1 kg, $n = 21$) and females without cubs (105.9 kg, $n = 23$) captured for bioelectrical impedance analysis to be representative for all barren-ground grizzly bears. Using these assumptions, if the daily energy requirements for the bears in our study were twice their BMR, then males and females have daily requirements of 11665 kcal and 8130 kcal respectively. During hyperphagia if the daily energy requirements for bears were quadruple the BMR, then males and females have daily requirements of 23331 kcal and 16261 kcal respectively.

We determined caribou and berries to be the primary foods for grizzly bears during their normal active and hyperphagic periods respectively. Using previously reported energy values for caribou tissue (Reimers et al. 1982, Tyler 1987) and blueberries (Pritchard and Robbins 1990), it is thus possible to estimate the minimum quantity of food that must be consumed to fulfil a bear's daily energy requirement during normal active or hyperphagic periods. Also by accounting for the digestive efficiencies of grizzly bears, calculated by Pritchard and Robbins (1990), a better estimate of the minimum daily food intake can be made. Thus the minimum amount of food that must be consumed equals:

$$\frac{\textbf{daily energy requirement}}{\textbf{energy of the food} \times \textbf{\% digestibility.}} \qquad \textbf{(Eqn. 4)}$$

Reimers et al. (1982) and Tyler (1987) examined Svalbard reindeer intramuscular fat and muscle protein. They determined the fresh composition of caribou meat as 70% water, 23% muscle protein, 5% fat, and 2% ash. They also determined the energy values of water and ash to be minimal, and fat and muscle protein to be 9.4 kcal/g and 4.3 kcal/g (dry weight) respectively. Thus, using their composition of caribou meat as a guide, we determined a fresh weight energy content of 1.5 kcal/g. Pritchard and Robbins (1990)

determined meat to be 94.6% digestible therefore according to equation 4 the minimum daily energy demands, during normal active periods, can be met by the ingestion of 8.2 kg and 5.7 kg of caribou meat per day for male and female bears respectively. The viscera, skeletal muscle, bone, and other body components of caribou have variable energy contents. We only determined the fresh weight quantity of skeletal muscle that bears need to ingest to meet their energy demands. We also assumed the energy values meat from Svalbard reindeer and caribou of the Bathurst herd to be comparable.

Pritchard and Robbins (1990) determined the dry weight energetic content of blueberries to be 4.5 kcal/g. Also, Robbins (1993) estimated the water content of all berries to be between 80-90%. Exact numbers for the structural composition of a berry are not necessary for our purposes. Therefore, we are assuming a typical berry in the central Arctic of the NWT has 80% water, a 15% soluble sugar and protein component, and a 5% indigestible cellular material component. We are also assuming the energy values of water and the indigestible cellular material are minimal, and soluble sugar and protein to be 4.5 kcal/g (dry weight). Thus, using this composition of a berry as a guide, a typical berry has a fresh weight energy content of 0.7 kcal/g. Pritchard and Robbins (1990) determined blueberries to be 62.7% digestible therefore according to equation 4 the minimum daily energy demands, during hyperphagic periods, can be met by the ingestion of 55.1 kg and 38.4 kg of berries per day for male and female bears respectively. To meet the increased energy demand during hyperphagia, bears have been reported to feed for twenty hours a day to accrue the fat necessary for hibernation (Nelson et al. 1983), with weight gains up to 1.8 kg a day (Nagy et al. 1983*a*).

8.3 CONCLUDING REMARKS AND MANAGEMENT RECOMMENDATIONS

Overall we found that barren-ground grizzly bears were adept at killing and consuming large numbers of caribou. Bears were also seasonally dependant on caribou as their

primary nutritional source of protein. A predominantly carnivorous lifestyle for certain grizzly bear populations is not unheard of (Hamilton and Bunnell 1987, Barnes 1990, Adams et al. 1995). However, a high degree of carnivorous activity has not yet been reported for grizzly bears in the central Arctic of the Northwest Territories. As grizzly bears have evolved to be adaptable within a variety of environments (Herrero 1978), in at least one part of the central Canadian Arctic, an adaptation of bears to the open tundra habitat is taking advantage of the large herds of caribou.

Plant biodiversity and productivity in Arctic tundra environments are lower than temperate regions (Bliss 1988). Thus, bears in the central Arctic of the NWT do not have a wide selection of plant foods available for ingestion relative to ecosystems in the mountains or along the Pacific coast. For the bears in our study during hyperphagia, the ingestion of carbohydrates from berries are essential for survival. Since the central Arctic does not have an abundance or wide diversity of plants rich in carbohydrates relative to mountain or coastal ecosystems, the distribution of crowberry, blueberry, cranberry, and bearberry plants may be a factor limiting the distribution of grizzly bears across the central Arctic.

Grizzly bears on the tundra of the NWT typically exhibit delayed sexual maturity, long breeding intervals, small body size, and low population densities relative to mountain and coastal bear populations (GNWT Renewable Resources 1991, Case and Buckland 1997). With the development of large scale industrial activity in the central Arctic of the NWT, particularly with the threat of multiple diamond mines, wildlife managers in our study area should act to minimize human caused disturbances that unnaturally alter the migration pathways of caribou and ensure grizzly bears have access to habitats supporting abundant berry growth. Declines in the caribou population, or long term absences, are serious threats to the bear population in our study area. Also, habitats supporting abundant berry growth will be critical to maintain and should be recognized as critical habitats for barren-ground grizzly bears.

9. LINKS WITH PARALLEL STUDIES

The research detailed in this report completes the *GRIZZLY BEAR STUDIES IN THE NORTHWEST TERRITORIES: COMPONENT NO. 1, NUTRITIONAL ECOLOGY* program. *COMPONENT NO. 2* (headed by Phil McLoughlin and Dr. François Messier from the University of Saskatchewan) is investigating the spatial ecology of barren-ground grizzly bears, and is currently in progress.

10. EXPENDITURES AND SOURCES OF FUNDS

Expenditures and sources of funds for *GRIZZLY BEAR STUDIES IN THE NORTHWEST TERRITORIES: COMPONENT NO. 1* and *COMPONENT NO. 2* will be submitted independently by Dr. François Messier.

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