FOOD HABITS OF BROWN BEARS ON NORTHERN ADMIRALTY ISLAND, SOUTHEAST ALASKA

A

THESIS

Presented to the Faculty of the University of Alaska

in Partial Fulfillment of the Requirements

for the Degree of

MASTER OF SCIENCE

By

Thomas M. McCarthy, B.S.

Fairbanks, Alaska

December 1989

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ABSTRACT

The food habits of brown bears on northern Admiralty Island in Southeast Alaska were studied through analysis of fecal samples collected in 1984 and 1985. The diets of two groups of bears were examined, those that used low elevation habitats and anadromous fish streams, and those that remained at higher elevations throughout the year. Selected forage items observed in the diets were analyzed for nutrient content. While most bears used the protein-rich salmon resource, bears at high elevations substituted deer, small mammals, and plant species and parts high in nitrogen. Both groups of bears appeared to seek a high energy diet during the fall pre-denning period. In the second phase of the study, captive brown bears were used in feeding trials to determine the digestibilities of 4 natural forages; sedge (*Carex lyngbyaei*), skunk cabbage (*Lysichitum americanum*), devil's club berries (*Oplopanax horridus*), and salmon (*Oncorhynchus* sp.). Dry matter, protein, and energy digestibilities were highest for salmon and lowest for sedge.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

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I would like to express my sincere thanks to Dr. Frederick C. Dean for his time and effort throughout this project. His ecological insights and editorial abilities have been invaluable. Fred's door has always been open when direction was asked, and independence provided when desired. Fred has become a good friend to me and my family.

I would also like to thank Dr. John Schoen for securing funding for this project, for his assistance in the field, and for sharing his keen understanding of brown bear ecology. John's knowledge of, and concern for, the resources of the Tongass National Forest have been an inspiration to me throughout this work. It has been a privilege to work closely with him.

Committee members Dr. David Klein and Dr. Robert White provided helpful suggestions, laboratory expertise, and much appreciated manuscript review.

The body of this thesis is comprised of two manuscripts prepared for submittal to The Journal of Wildlife Management. While I was responsible for field-work, data collection and analysis, and manuscript preparation, the contributions by Drs. Dean, White, and Schoen to the project's planning and review were substantial. I am honored to be able to list them as co-authors of these publications.

I am indebted to LaVern Beier for his field assistance and for keeping me in one piece during this study. Additional field assistance was provided by Harriet Quasney. Dr. Thomas Hanley of the U.S.F.S. Forest Sciences Lab in Juneau provided expertise, suggestions, and encouragement, in addition to much needed laboratory space. Gordon Noyes and the staff of the Washington Park Zoo are sincerely thanked for allowing, and assisting with, the digestibility study. Booboo and Sarah, the zoo's bears, are thanked for tolerating the experience.

I appreciated the support of all our family and friends who helped us endure.

Finally, my unending thanks to my wife, Danelle, and my sons, Keegan and Kyle, for sharing the experience, enduring the rain, coping with scats in the freezer, and for making our Hawk Inlet camp a home.

For

Leone McCarthy

CHAPTER I

INTRODUCTION

Admiralty Island, in Southeast Alaska, supports one of the largest, relatively undisturbed populations of brown bears (Ursus arctos) in North America. Nearly 85% of the island's 2,734 km^2 was placed in national monument wilderness status by the Alaska National Interest Lands Conservation Act (ANILCA) of 1980. The monument and the national forest lands that make up most of the island, are administered by the United States Forest Service (USFS).

The Alaska Department of Fish and Game (ADF&G) began a study in fall 1981 to determine seasonal distribution, habitat preference, and den site and home range characteristics of brown bears on the northern portion of Admiralty Island (Schoen and Beier 1982). Age, sex, and body measurements were also recorded. To date, 68 bears have been captured, equipped with radio collars, and released. Data obtained through radio relocation from fixed-wing aircraft were used to determine movements, home ranges, and habitat use.

Southeast Alaska brown bears are generally believed to follow a typical pattern of movement between spring and fall denning:(1) they leave high country dens in spring to feed on newly emergent vegetation along beaches and tidal flats; (2) they move upward in early summer to feed on new vegetation; (3) they return to lower elevations to feed on spawning salmon in midsummer; and (4) they return to alpine areas to feed on vegetation prior to denning. However, Schoen et al. (1986) identified a small portion of radio-collared bears that did not use coastal salmon streams during the summer but remained in the interior regions of the island. The terms "coastal" and "interior" are used to differentiate between the 2 groups of bears.

Increased use of higher elevations, extensive foraging on berries, and a decrease in numbers of bears along salmon streams has been observed in Southeast Alaska during years of poor fish runs and good berry crops (Klein 1958). Increased use of alpine habitat by brown bears in mid- to late summer has also been noted by Atwell et al. (1980). In both cases bears used late salmon runs to some degree. The interior bears observed on Admiralty Island, however, were not observed to move onto salmon streams at anytime during summer.

The USFS predicts that recreational use in some areas of the island will reach or be near seasonal use capacity by 1990 (USFS publ. No. 167, 1982). Mining claims in the Hawk Inlet area, although on monument land, are still valid as they were filed prior to ANILCA. A major mining operation is now underway in the Greens Creek area, a drainage in the inlet's watershed which provides excellent brown bear habitat. The tidal flats associated with the streams are important grazing areas for bears during spring greenup. Two major streams support the largest runs of chum and pink salmon (a major late summer bear food) in the Hawk Inlet area. The potential exists for substantial habitat loss and an increase in brown bear-human interaction, particularly in the Hawk Inlet area of the island (Fig. 1-1).

The projected increase in recreational use and impending mineral development in the area, as well as industrial-scale logging and roading throughout the region, require that well-defined goals and objectives be established for brown bear management. Knight (1980) cited several factors related to the brown bear's requirement for large amounts of space. Fluctuations in abundance of major food sources force bears to substitute alternative foods for scarce items. Hence, areas providing these alternate food sources may increase in value as foraging sites when availability of traditional foods is diminished. Retention of such sites must be considered in long-range forest planning.

The present study was carried out to: (1) determine food habits of "coastal" and "interior" bears through direct observation of foraging activities and analysis of fecal samples from both populations in the spring, summer, and fall of 1984 and 1985; (2) determine nutrient content of food items in both diets; and (3) determine dry matter and nutrient digestibility of several natural food items by conducting feeding trials on captive brown bears. The studies were carried out in 1984 and 1985.

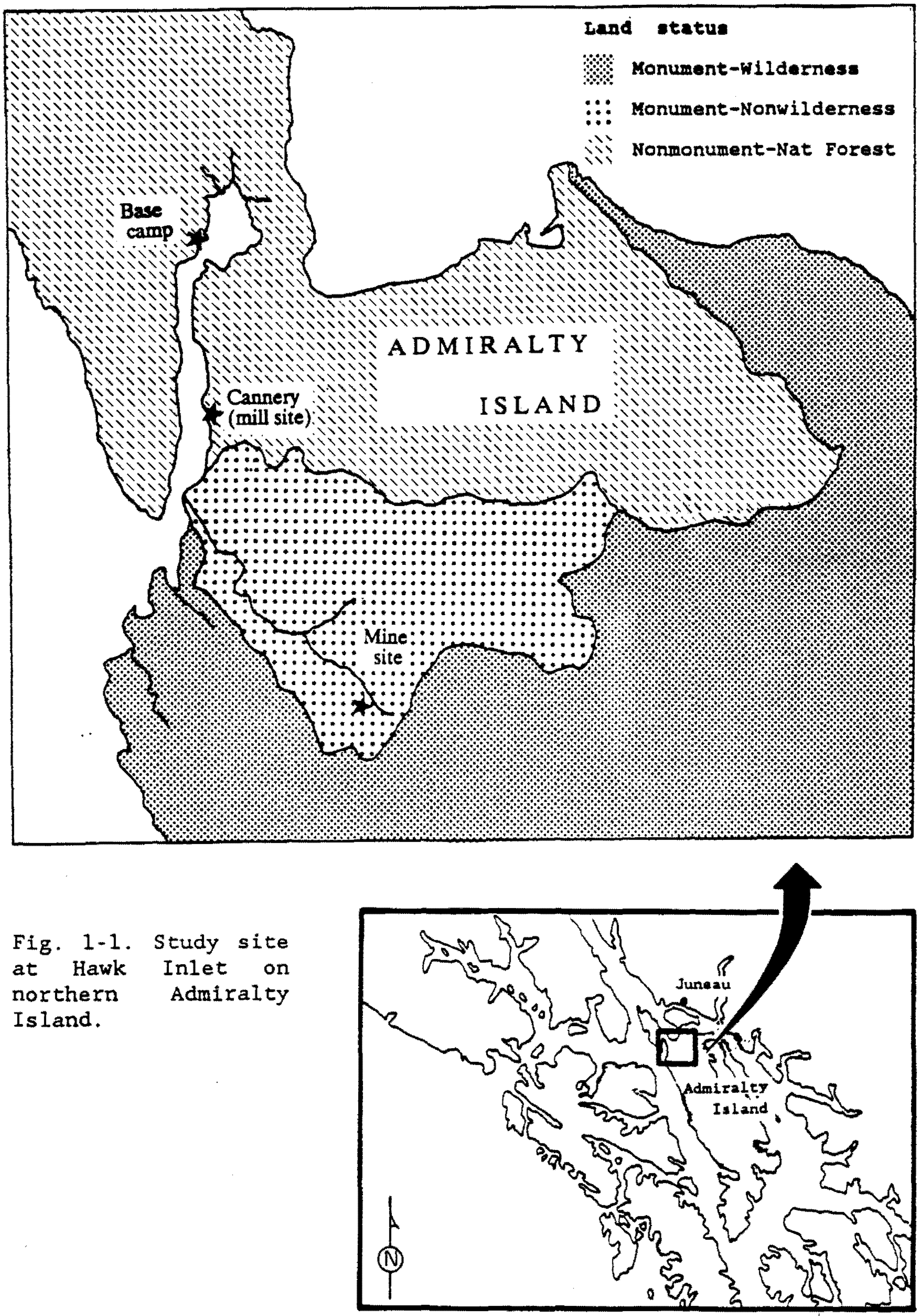

Fig. 1-1. Study site at Hawk Inlet on northern Admiralty Island.

STUDY SITE

The study site, situated at the northern end of the Alexander Archipeligo in Southeast Alaska, is located on northern Admiralty Island ($58\text{-}59^{o}$ N x $134\text{-}135^{o}$ W) and includes the Hawk Inlet and Young Bay drainages. The site encompasses about 270 km^2. The maritime climate is cool and moist. Mean temperatures range from a low of -6 C in January to a high of 13 C in July while annual precipitation averages 135 cm with 260 cm of snow (NOAA climatological data). Snow may persist for up to 9 months at elevations above 600-900 m with variable accumulations at sea level during winter.

Most of Southeast Alaska was covered by ice during the Pleistocene's most recent glaciation. Retreat of this vast sheet of ice began about 10,000 to 14,000 years ago; a few remnants remain on Admiralty in the form of small, scattered glaciers.

Vegetation

The area is characterized by temperate rain forest and alpine tundra. Old-growth stands of Sitka spruce-western hemlock (*Picea sitchensis*-*Tsuga heterophylla*) dominate the forested areas. Two broad understory plant associations within the spruce-hemlock forests on Admiralty Island have been identified by Schoen et al. (1981). The first, includes a blueberry (*Vaccinium uliginosum*, *V. alaskaense*)/bunchberry (*Cornus canadensis*)/five-leaved bramble (*Rubus pedatus*)/goldenthread (*Coptis asplenifolia*) association, a single delight (*Moneses* uniflora)/conifer seedling association and Menziesia ferruginea, Maianthemum dilatatum, and heart-leaved thwayblade (Listera cordata). This group was most common on well-drained, more productive sites where the broken canopy of the uneven-aged stands allowed ample light to reach the forest floor. The 2nd major group, which includes a Tiarella trifoliata/fern association, skunk cabbage (Lysichitum americanum), devil's club (Oplopanax horridus), twisted stalk (Streptopus spp.), and violets (Viola langsdorffii, V. glabella), was most common on wet, less productive sites.

Interspersed throughout the forest are poorly-drained muskeg areas characterized by mosses, lodgepole pine (Pinus contorta), mountain hemlock (Tsuga mertensiana), labrador tea (Ledum palustre), crowberry (Empetrum nigrum) and sedges (Carex spp.).

A narrow band of deciduous/shrub complex, seldom more than 15 m wide, is often found between the beach and the coniferous forest as well as along open stream banks. Red alder (Alnus rubra), and an understory of Vaccinium spp., salmonberry (Rubus spectabilis), wild celery (Angelica lucida), cow parsnip (Heracleum lanatum) and fireweed (Epilobium angustifolium) characterize this zone.

Several grass/sedge tidal flats occur in the study area, generally associated with stream deltas. Predominant species in this zone include Carex lyngbyaei, Calamagrostis spp., Festuca rubra, bulrush (Scirpus microcarpus), rye grass (Elymus arenarius), beach lovage

(*Ligusticum scoticum*), silver weed (*Potentilla egedii*), yarrow (*Achillea borealis*), goose tongue (*Plantago maritima*), and *Ranunculus occidentalis*.

The subalpine zone in the study area generally occurs above about 600 m but may be lower on north-facing slopes. Plant communities in parkland-subalpine areas include those dominated by false hellebore (*Veratrum viride*), woodfern (*Dryopteris dilatata*), and a zone of dwarf mountain hemlock. Several plant communities may be found in the treeless-subalpine zone. These include sedge meadows primarily of *Carex macrochaeta*, wet forb meadows characterized by colts foot (*Petasites hyperboreus*), lupine (*Lupinus nootkatensis*), wild geranium (*Geranium erianthum*) and deer cabbage (*Fauria crista-galli*), while the higher alpine areas are dominated by mountain heather (*Cassiope mertensiana*).

Steep, brushy avalanche chutes, a product of continual disturbance, often support a dense growth of berry-producing shrubs and deciduous trees. Sitka alder (*Alnus sinuata*), willow (*Salix* spp.), stink currant (*Ribes bracteosum*), salmonberry, and red alder are common, while devil's club is dominant on sites with shallow, rocky soils and running water.

Mammals

Although large and relatively close to the mainland, Admiralty Island has a depauperate fauna. The Sitka black-tailed deer (*Odocoileus* hemionus sitkensis) is the only ungulate present. Winter densities may be as high as 50 animals per km^2 in areas where high-volume, old-growth forest provide quality winter range (Schoen and Kirchhoff 1985).

Brown bears and mustelids are the only terrestrial carnivores on the island; the mustelids include: marten (Martes americana), mink (Mustela vison), short-tailed weasel (M. erminea), and river otter (Lutra canadensis). ADF&G trapping records indicate moderate use of this resource within the study area. Populations of both otters and marten appear to be stable and healthy. Beavers (Castor canadensis) occur in the study area, although in low numbers. Small mammals, such as deer mice (Peromyscus maniculatus), are abundant at low elevations while voles (Microtus oeconomus and Clethrionomys rutilus) are present in both lowland and alpine areas.

Red squirrels (Tamiasciurus hudsonicus) were absent from Admiralty Island until a recent illicit introduction. While I have seen squirrels in the Funter Bay area, some 8 km northeast of Hawk Inlet, none have been observed within the study area.

Numerous marine mammals inhabit the waters surrounding Admiralty Island. Harbor seals (Phoca vitulina) are frequently observed in Hawk Inlet, often near the mouth of salmon streams. Steller sea lions (Eumetopias jubatus), harbor porpoise (Phocoena phocoena), and Dall porpoise (Phocoenoides dalli) are occasional visitors. Sea lions have been observed hauled out on the rocky shoreline on the northern portion of the island. In August 1984, I observed a pod of 6 killer whales (Orcinus orca) near the head of Hawk Inlet. Humpback whales (Megaptera novaeangliae) may also enter the inlet.

Human Use

Human occupation of the region for at least the last 8,000 to 10,000 years has been archaeologically documented (Arndt et al. 1987). The "traditional" Northwest Coast Culture became established as the dominant culture within the past 5,000 years as the ancestors of today's Tlingit, Haida, and Tsimshian clans migrated down the Stikine, Taku, and Copper Rivers from the interior regions. Several Tlingit tribes established villages on Admiralty: the Auke people, on Mansfield Peninsula; the Taku tribe, around Seymour Canal; and the Angoon tribe, from Point Marsden to Eliza Harbor. Only the village of Angoon, 35 km south of the study area, remains inhabited today.

Admiralty Island was included in the Tongass when this National Forest was established in 1909. Prior to that time, commercial development of the island's resources, in the form of salmon canneries, trap lines, small mining operations, and timber harvest associated with these enterprises, was largely unrestricted (USFS Publ. 126, 1981). A major gold mine and stamp mill began operation in the Hawk Inlet vicinity in 1904. The operation was upgraded as recently as the late 1930's but was closed in 1942.

By the late 1880's several salmon canneries and associated fish traps had been constructed around the island. The fish traps, remains of which are still seen in the area, and unlimited harvests most likely contributed to abrupt declines in salmon packs which occurred as early as the 1920's. The P. E. Harris Company's cannery located at Hawk Inlet was in operation from before 1920 until the mid-1970's. The main cannery building was destroyed by fire over a decade ago. The support buildings remain and are now occupied by Greens Creek Mining Co. The site is currently undergoing major modification as development of the Greens Creek mine continues.

As early as 1938, Admiralty was being considered for National Monument status. Opposition, primarily by Alaskans, caused the proposal to be dropped. Some protection, however, was granted through the establishment of 2 brown bear refuges, Pack Creek and Thayer Mountain.

Most of Admiralty was finally designated Monument by presidential proclamation in 1978. The proclamation emphasized the wildlife, cultural, scientific, recreational, and wilderness values of the island. As part of the Tongass National Forest, Admiralty remains under USFS administration.

With the passage of ANILCA in 1980 most of the monument was designated for wilderness management. Native land selections, allowed by ANILCA, have been made in the area around Angoon by the Kootznoowoo Village Corporation and near Cube Cove and Lake Florence on the west coast of the island, by the Shee Atika Native Corporation. Clearcut logging of Shee Atika's holding (9000 ha) began in 1985 and was in full scale production by 1986. State land withdrawal within the monument is limited to Oliver Inlet State Park, located at the northern end of Seymour Canal.

Under ANILCA, the monument was withdrawn from all forms of new entry, including entry under the United States Mining Laws. However, allowances were made in ANILCA for holders of valid, pre-existing mineral claims. Development of valid claims is subject to regulations that assure, to the extent feasible, compatibility with purposes for which the monument was established.

The Greens Creek claim, a world-class deposit of gold, zinc, silver and lead, with an estimated life of 10-33 years, was first identified in 1973. During 1984 and 1985 work on the mine project was restricted to the cannery site modifications, construction of the main tunnel at the mine site, and the drilling of core samples from numerous test sites to determine the extent of the ore body. From early spring until late fall of both years, approximately 35-50 workers were housed at either the cannery or the mine sites. Transportation between sites was by helicopter.

A road system connecting the mine, cannery site, and a ferry dock at Young Bay, was completed in 1988. This road bisects important dispersal routes used by bears moving onto salmon streams at both the head of the inlet and on the Greens Creek delta.

The future status of nonwilderness Monument land, that area containing the Greens Creek mining project (Fig.1-1), is unclear. Monument boundary changes proposed for the area could seriously affect management priorities.

Management for that portion of the study area which is nonwilderness is prescribed by the Tongass Land Management Plan (TLMP). Under current TLMP schedules, 78% of the study area's nonwilderness land is scheduled to be logged.

Recreational use of the island has increased in recent years. Hawk Inlet is easily reached by floatplane or small boat from Juneau. While there are no USFS recreational cabins in the study area, 3 private cabins are located at Hawk Inlet.

The study area receives moderate deer hunting pressure from sportsmen taking day trips via boat to the easily accessed Young Bay area. Brown bear hunters harvest about 30-35 bears from Admiralty each year. Since 1961 an average of 1.9 bears per year have been killed within the study area (ADF&G records). This figure, which has increased in recent years, includes both sport harvest and those bears killed in defense of life and property.

CHAPTER II

BROWN BEAR FOOD HABITS ON ADMIRALTY ISLAND, S.E. ALASKA[1]

Brown bears (Ursus arctos) in Southeast Alaska are generally believed to follow a typical pattern of movement and habitat use. During their active season on Admiralty Island, bears: 1) leave high country dens in spring to feed on young vegetation on south-facing avalanche slopes, along beaches, and on tidal flats; 2) move upward in early spring following snow melt and feed on new vegetation; 3) return to lower elevations to feed on spawning salmon from mid- to late summer; and 4) move to berry-producing avalanche slopes and sub-alpine zones in the fall prior to denning. Relocation data from radio-collared bears, collected since 1981 by the Alaska Department of Fish and Game (ADF&G), indicate that a portion of the brown bear population on northern Admiralty Island in Southeast Alaska does not conform to this pattern (Schoen et al. 1986). A relatively small number of bears exhibit a distribution differing from that of the general population, usually remaining at higher elevations throughout their annual cycle. Schoen et al. (1986) have used the terms "coastal" and "interior" to differentiate between the 2 groups of bears. Most relocations of

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[1] Authors: Thomas M. McCarthy, Alaska Dept. of Fish & Game, P.O. Box 20, Douglas, Alaska, 99824, and John W. Schoen, Alaska Dept. of Fish & Game, P.O. Box 20, Douglas, Alaska, 99824 (prepared for submission to The Journal of Wildlife Management).

"interior" bears (95%) are from elevations above 400 m. However, relocation data suggest that home ranges of "coastal" and "interior" bears overlap to a great degree especially at elevations above 400 m. Potential food habit differences between the 2 groups of bears are most obvious during late summer, July 15 through early September, when most "coastal" bears are near low elevation salmon streams.

Increased use of high elevations, extensive foraging on berries, and a decreased number of bears along anadromous fish streams have been observed in Southeast Alaska during years of diminished salmon runs (Klein 1958). Atwell et al. (1980) also noted an increased use of alpine habitat during the late summer by brown bears on Kodiak Island. Only on Admiralty Island, however, have bears been identified that made no use of low elevation habitats and salmon streams over several consecutive years.

Based on general food nutrient analyses in the literature, it is predicted that those bears using salmon have a considerable nutritional advantage over those that do not. However, prior to testing such an hypothesis the full range of foods consumed by bears while inhabiting either the "interior" or "coastal" locales must be determined. The objectives of this study were to make such a determination and to examine diet quality through qualitative analysis of the major food items in each diet.

The study was funded by ADF&G as part of Federal Aid in Wildlife Restoration Project W-22-2. Laboratory space and equipment was provided by the U.S. Forest Service, Forest Science Laboratory in Juneau, Alaska. Appreciation is extended to L. Beier for assistance in the field and for sharing his invaluable knowledge and insights into brown bear behavior. We especially thank Drs. F. Dean., D. Klein, and R. White for discussion and manuscript review.

STUDY AREA AND METHODS

Admiralty Island is located in the northern portion of the Alexander Archipeligo in Southeast Alaska. The study area, on northern Admiralty Island (58-59^{o} N, 134-135^{o} W), includes the Hawk Inlet and Young's Bay drainages and encompasses about 270 km^2 (Figure 1-1). Mean temperatures in Juneau, 12 km to the northeast, range from a low of -6 C in January to a high of 13 C in July. Annual precipitation averages 135 cm with 260 cm of snow. Snow may be persistent for up to 9 months at elevations above 600-900 m, with variable accumulations at sea level during the winter. Small, scattered glaciers are found in the study area, remnants of the vast ice sheets that covered most of Southeast Alaska during the late Pleistocene.

The study area is characterized by temperate rain forest, alpine tundra, and several grass/sedge-covered tidal flats. Old-growth stands of Sitka spruce-western hemlock (Picea sitchensis-Tsuga heterophylla) dominate the forested area. Plant associations of the forest zone have been detailed by Martin et al. (1985).

Fecal samples were collected from June through October 1984 and from May through October 1985. A field camp established near the head of Hawk Inlet allowed access by boat to stream and tidal flats, while alpine, avalanche slopes, and forest zones were accessed by foot or helicopter. Scats were collected weekly from the 3 tidal flats, along 6 salmon streams, and from several established trails within the study area. Alpine samples were occasionally collected in conjunction with ADF&G bear capture efforts. Generally, both alpine and avalanche slopes were visited at least once every 2 weeks depending on weather and availability of helicopter support.

All scats encountered were collected or sampled. We did not have the problem of distinguishing brown from black bear scats because black bears do not occur on the island. Age of scats collected from trails, tidal flats, or stream sides was known because all scats were cleared on each weekly visit. Age of scats collected from areas that were not visited regularly was estimated. General condition and color of scats, presence of insects or larvae, and degree of degeneration due to exposure and weathering were noted. Scats consisting primarily of fibrous material, such as sedges, often persist through winter, while pure salmon scats may wash away in a few days. Thus, scat content was also considered when estimating age. Entire scats were collected unless they were too large to fit in a 1-L plastic bag. Care was taken to include as few substrate fragments as possible. While scats generally appeared homogeneous, occasional scats had distinct portions of differing constituents. When such scats exceeded 1 L, a fraction of each section was collected proportional to its occurrence. Samples were sent to Juneau and frozen pending analysis.

During the 1984 field season a reference collection of plants and plant parts (leaves, stems, flowers, fruits, seeds, and underground portions) from throughout the study area was made. Three different preparations were used for each reference specimen: 1) entire plants were pressed until dry and mounted; 2) samples of various plant parts were stored in 70% alcohol; and 3) samples of leaves, stems, and roots were used to prepare voucher slides for use in microhistological analysis of plant epidermal fragments found in scats (Stewart 1967). Preparation of slides followed the methods of Davitt and Nelson (1980).

Laboratory examination of bear scats generally followed the techniques detailed by Smith (1984). We found it necessary to use a sieve with larger openings than suggested by Smith when scats contained primarily poorly digested grasses and sedges. After the scat material had been washed and settled on the sieve bottom, a subsample representing approximately 20% of the scat was removed and constituents identified.

Following identification, an ocular estimate was used to classify each food item into one of the following volume categories: trace to 5%, 6-25%, 26-50%, 51-75%, and 76-100%. This is a common technique for bear scat analysis (Clark 1957, Tisch 1961, Hatler 1967, Mealey 1980). Other methods (e.g., water displacement or point sampling) would have allowed exact volumetric calculations but are extremely time consuming. Further, due to differential rates of digestion and post-deposition changes in volume (e.g., weathering, disturbance by insects) the relative amount of undigested material in the scat is not indicative of the amount of each food item ingested.

Data, including date of collection, approximate age of scat, map location, habitat type, elevation, and volume category for each food item, were recorded for each of the 298 scats collected during the study.

Due to the overlap in range we did not attempt to assign scats to either "coastal" or "interior" bears. The assumption was made, however, that scats collected from above 400 m would contain food items available to "interior" bears. This was later borne out as only 1 of 112 scats collected from above 400 m contained food material unavailable at that elevation. Scats were placed into 1 of 2 elevation classes. Elevation class one (E_1) included sea level to 399 m, and elevation class two (E_2) 400 m and above. Contents of E_1 and E_2 scats were assumed to be indicative of the food habits of bears utilizing those areas.

Data from scat analysis were grouped by season as well as elevation. Three season classes that corresponded to food availability, and activity and foraging patterns of the bears, were defined. Season class one (S_1) included the time period from den emergence through the first entry of salmon into local streams (July 25 1984 and July 17 1985). Season class two (S_2) ran through September 15 and was characterized by intense use of salmon by "coastal" bears. Season class three (S_3) ran from September 16, by which time most bears had begun to move off anadromous fish streams, through denning. More discrete seasons were not defined for 2 reasons: 1) broader seasons meant less likelihood of error when season of scat deposition was estimated, and 2) the subsample sizes would have been smaller than desirable if more season classes had been employed.

Samples of food items were collected for chemical analysis during both years of the study. Samples were collected from a variety of sites over time, enabling comparisons of nutrient values among sites and seasons. In most cases only those plant parts eaten by bears were collected.

Samples were weighed, dried at 50 C for 48 hours, and reweighed to determine percent dry matter. Dried material was ground in a Wiley mill and passed through a 1-mm screen. These samples were submitted to the Wildlife Habitat Management Lab, Washington State University, Pullman, Washington, for analysis. Gross energy was determined by bomb calorimetry, crude protein by the Kjeldahl method, and fiber and ash as outlined by Goering and Van Soest (1970).

RESULTS AND DISCUSSION

Scat Analysis

Analysis of scats collected from both elevation classes indicate that food habits varied with season (Figures 2-1 and 2-2).

Elevation Class One (E_1) Scats.--During the spring/early summer period bear diets at low elevations were dominated by sedge, other green vegetation, and roots. The sedge *Carex lyngbyaei* was by far the most frequently occurring herbage in E_1S_1 scats, appearing in 91.3% of the samples (Table 2-1). Sedges and grasses grow in closely associated bands along the upper reaches of tide flats in the study area. Although grasses have been shown to make up a significant portion of the diets of both brown and black bears in other studies (Mealey 1980, Graham 1978, Servheen 1983, Graber and White 1983), they were seldom found in low elevation scats on Admiralty where a single sedge dominated.

The green vegetation component (exclusive of sedge and grass) of the E_1S_1 diet contained primarily horsetail (*Equisetum arvense*) and stems of cow parsnip (*Heracleum lanatum*), found in 38.2% and 3.7% of the scats, respectively. While at least 3 species of *Equisetum* grow in the area all identifiable fragments found in scats were of *E. arvense*. Hamer (1985) also determined that brown bears in Alberta preferred *E. arvense* over closely related species.

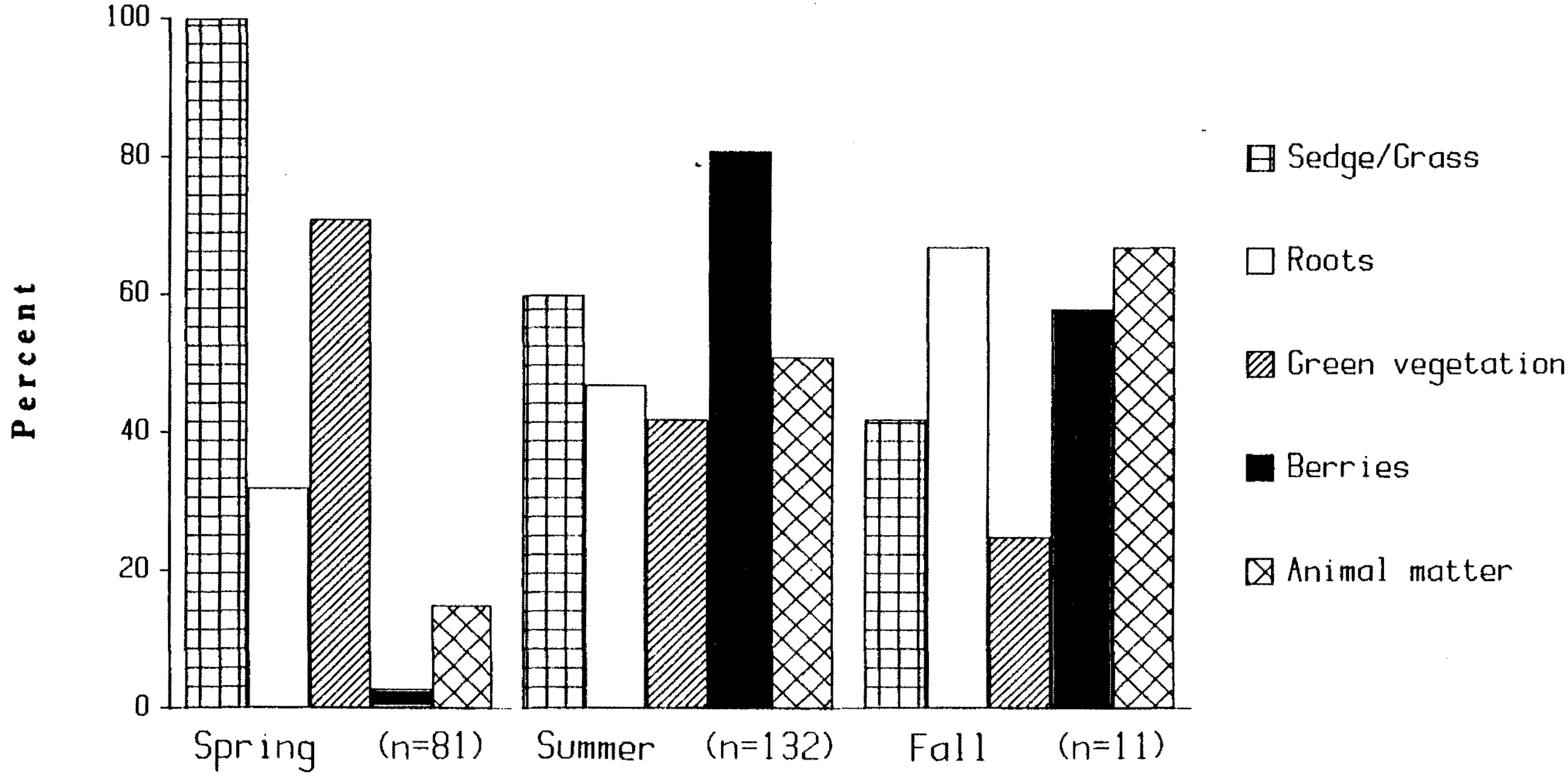

Fig. 2-1. Frequency of occurrence, by season, of major food types in the diets of brown bears, as determined through analysis of scats collected from below 400 m elevation at Hawk Inlet, Admiralty Island, Southeast Alaska, 1984-85.

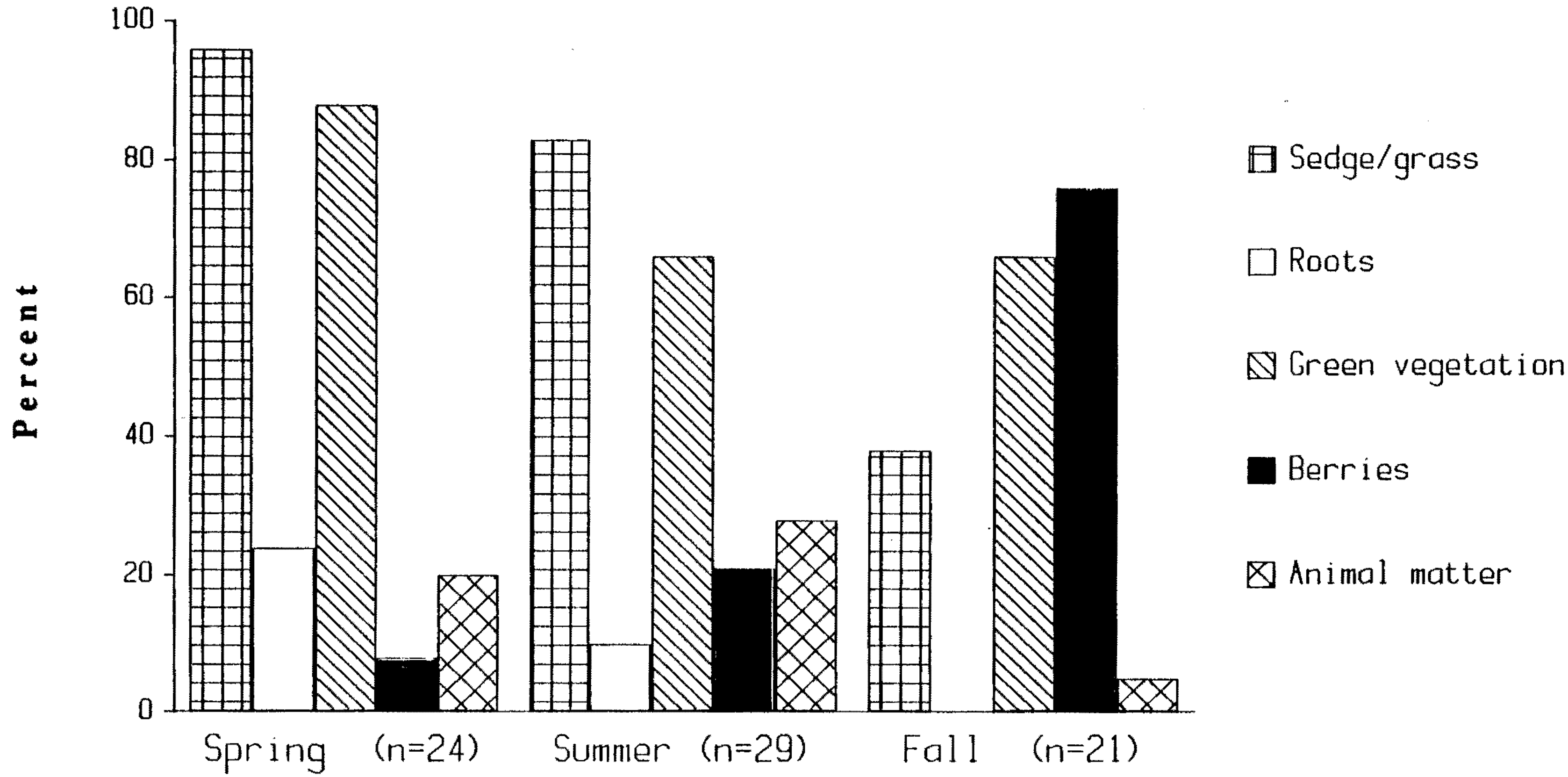

Fig. 2-2. Frequency of occurrence, by season, of major food types in the diets of brown bears, as determined through analysis of scats collected from above 400 m elevation at Hawk Inlet, Admiralty Island, Southeast Alaska, 1984-85.

Table 2-1. Seasonal frequency of occurrence of major foods identified in brown bear scats collected below 400 m elevation in the Hawk Inlet area of Admiralty Island, Southeast Alaska, 1984-85.

Spring (S_1) (n = 81)		Summer (S_2) (n = 132)		Fall (S_3) (n = 11)	
Item	% Freq. Occur.	Item	% Freq. Occur.	Item	% Freq. Occur.
Carex spp.	91.3	_Carex_ spp.	55.3	_Oncorhynchus_ spp.	72.7
Equisetum spp.	38.2	_Oncorhynchus_ spp.	42.4	_Oplopanax horridus_ berries	45.4
Lysichitum americanum	29.6	_Lysichitum americanum_	41.6	_Lysichitum americanum_	45.4
Odocoileus hemionus sitkensis	9.9	_Oplopanax horridus_ berries	37.1	_Carex_ spp.	45.4
Elymus spp.	4.9	_Vaccinium_ spp.	34.0	_Ligusticum scoticum_	27.2
Heracleum lanatum	3.7	_Equisetum_ spp.	15.1	_Ribes bracteosum_ berries	9.1
Herring roe	3.7	_Streptopus_ spp. berries	6.1	_Streptopus_ spp. berries	9.1
Coptis asplenifolia	2.5	_Heracleum lanatum_	5.3	_Heracleum lanatum_	9.1

Sitka black-tailed deer appeared in 9.9% of E_1S_1 scats but was rarely found in mid- or late-summer scats. Whether deer had been killed by bears or taken as carrion was not possible to determine. Fawns, and carrion in the form of winter-killed animals, which have been found to make up the bulk of cervid remains in other studies (Chatelain 1950, Tisch 1961, Hatler 1972, Graber and White 1983), were readily available to Admiralty bears. In E_1S_2 scats salmon became the primary source of animal protein for "coastal" bears, and remained so through the fall season (Table 2-1). Although insects, primarily ants, have been shown to be important in brown bear diets in parts of North America (Tisch 1961, Hatler 1972, Beeman and Pelton 1980, Smith 1984, Hamer 1985) we noted only 1 instance where the ingestion of insects was apparently intentional: ants in 1 E_1S_2 scat. Ants are not common in the study area.

The roots of beach lovage (Ligusticum scoticum), a small umbellifer that grows alongside streams and on tidal flats, were taken by bears in late summer and fall, appearing in 27.2% of the E_1S_3 scats (Table 2-1). The fragrant tap root of this plant was dug during the period of high salmon use and was frequently found in scats containing salmon and devil's club berries. Use of skunk cabbage roots was also most prevalent in the fall season, making roots second only to salmon in percent frequency of occurrence.

Berry use at elevations below 400 m was highest during mid-summer, decreasing slightly in fall when those "coastal" bears remaining at low elevations fed primarily on roots and salmon. Devil's club, blueberry (Vaccinium ovalifolium/alaskaense), and huckleberry (V. parvifolium) made up the bulk of the berry component of the E_1S_2 diet with the fruit of twisted stalk (Streptopus spp.) contributing a smaller fraction (Table 2-1). By fall, Vaccinium berries were detected in less than 2% of the scats, use of devil's club berries remained strong, and stink currant berries (Ribes bracteosum) had began to appear in the diet.

Elevation Class Two (E_2) Scats.--Carex macrochaeta was the most frequently occurring food item in scats collected from above 400 m. The high frequency of sedge use persisted from den emergence through the midsummer period, as was true for scats from low elevations (Table 2-2). Woodfern (Dryopteris dilatata) was a common food in the spring/early summer diet of bears at higher elevations but was not detected in scats from low elevations where it is less abundant. These ferns were present in 33.3% of E_2S_1 scats but were seldom utilized later in the year.

Animal remains were discovered in more than 20% of the E_2S_1 scats (Table 2-2). Deer was the primary animal food identified in scats collected from elevations above 400 m in both early- and mid-summer. In contrast, use of deer by bears at lower elevations was restricted to the spring. Voles, a second source of animal protein, were identified in 8.3% of the E_2S_1 scats, increasing to 10.3% during the midsummer season.

Table 2-2. Seasonal frequency of occurrence of major foods identified in brown bear scats collected above 400 m elevation in the Hawk Inlet area of Admiralty Island, Southeast Alaska, 1984-85.

Spring (S_1) (n = 24)		Summer (S_2) (n = 29)		Fall (S_3) (n = 21)	
Item	% Freq. Occur.	Item	% Freq. Occur.	Item	% Freq. Occur.
Carex spp.	79.1	*Carex* spp.	82.7	*Ribes bracteosum*	71.4
Dryopteris dilatata	33.3	*Equisetum* spp.	17.2	*Oplopanax horridus* berries	61.9
Lysichitum americanum	25.0	*Odocoileus hemionus sitkensis*	13.7	*Carex* spp.	38.0
Graminoids	20.8	*Lysichitum americanum*	10.3	*Heracleum lanatum*	9.5
Equisetum spp.	12.5	*Angelica lucida*	10.3	*Sambucus callicarpa*	9.5
Odocoileus hemionus sitkensis	12.5	*Clethrionomys rutilus*	10.3	*Angelica lucida*	9.5
Clethrionomys rutilus	8.3	*Rubus spectabilis*	10.3		

The occurrence of grasses was markedly higher in E_2 scats (20.8%) than in E_1 scats (4.9%). Unlike Carex, use of grasses was limited to the early season (S_1). Trace quantities of grasses found in low elevation scats composed primarily of Carex may suggest incidental consumption. It is less clear whether the slightly higher volumes of grasses in E_2 scats (3-5%) suggest intentional consumption by bears at high elevations. In E_2 scats grasses were nearly always found in scats containing similar amounts of Carex. In mixed E_1 scats the volume of Carex was always much greater than that of the grass component. Grasses may appear in E_2 scats more frequently and in greater relative quantities due to their close association in alpine meadows. In contrast, grasses and sedges are clearly separated into distinct bands along tidal flats, allowing bears to easily select one species.

The species of berries used, and frequency of use, differed between elevation classes. Salmonberries (Rubus spectabilis) were found in 10% of high elevation scats during midsummer but were observed in less than 2% of low elevation scats during the same period. Salmonberry grew at elevations that would make them readily available to both groups of bears but were generally more abundant at higher elevations. Perturbations in weather patterns make production of fruits unpredictable and contribute to yearly variations in bear diets. Heavy rains during June and early July of the first year of the study likely contributed to the failure of salmonberries at low elevations in 1984. Berry production in the study area may have been affected less at higher elevations due to the delayed phenology.

Devil's club berries, routinely observed in low elevation scats by mid-July, were not detected in high elevation scats until fall when they were present in 61.9% of the samples. This could be expected as devil's club berries ripen later at higher elevations, and "interior" bears do not generally move into areas that support large quantities of these berries, such as avalanche slopes, until late in the year.

Elderberry (Sambucus callicarpa), common on moist recently disturbed sites throughout the study area, was only found in scats collected from above 400 m, appearing in 9.5% of the E_2S_3 scats.

Stink currant was the predominant food item in high elevation scats during the fall season, with a frequency of occurrence of 71.4%. Scats composed primarily of currant contained many undigested stems, indicating that bears were ingesting the entire raceme, a practice that may allow bears to increase intake rates. Currant and devil's club were often found together in scats, with the former making up the bulk of the volume in most cases.

Forage Analysis.--Seasonal variations in the diets of both brown and black bear probably result in maximization of either net energy or protein intake (Bunnell and Hamilton 1983, Hamilton and Bunnell 1987, Mealey 1980). The food habits determined in this study suggest that both "interior" and "coastal" bears may be attempting to maximize intake of animal protein from den emergence through late summer, and then switch to a high energy, lower protein diet in fall.

Carex macrochaeta, C. lyngbyaei, and skunk cabbage were among the forages for which several samples were analyzed (Table 2-3). Caloric values for both sedges were fairly constant from succulence through post-flowering. However, total fiber and acid-detergent fiber increased from succulence through post flowering, suggesting that by late summer much of the gross energy was in the form of indigestible cell wall carbohydrates and generally unavailable for use by bears. An early to late summer decrease in crude protein was noted for Carex from both sea-level and alpine samples. While the use of Carex was substantial during all 3 seasons, frequency of occurrence steadily declined over time, i.e. as nutritive value decreased. Skunk cabbage had high protein levels well into late summer and remained an important food item throughout the active season with increased frequency of use at low elevations as summer progressed. Conversely, use of woodfern by alpine bears decline as protein content diminished.

While in the den male brown bears may lose up to 22% of their fall weight and lactating females as much as 40% (Kingsley et al 1983). Fat reserves that allow bears to survive such losses are laid down primarily during the fall predenning hyperphagic period when a bear may take in as much as 20,000 kcal per day of foods high in fat and carbohydrate (Nelson et al. 1983). Both "coastal" and "interior" bears on northern Admiralty spent most of the fall season in areas where

Table 2-3. Nutrient values of major food items in brown bear diets on northern Admiralty Island, Alaska, 1984-85.

Food item	Energy Kcal/g	% by dry weight: Crude protein	NDF[a]	ADF[b]
Carex lyngbyaei				
beach-June	4.9	19.0	57.3	22.3
beach-July	4.3	12.0		
beach-Aug	4.5	16.8	51.2	23.6
beach-Sept	4.6	11.9	61.1	28.2
Carex spp.				
alpine-July	4.8	23.9	48.0	21.1
alpine-Aug	4.0	8.7	55.6	25.5
alpine-Sept	4.6	8.5	61.6	29.5
Lysichitum americanum				
June	4.3	19.1	22.0	17.0
July	4.5	27.2	24.1	13.4
Aug	4.3	27.9	23.2	11.8
Sept	4.1	22.8	14.2	10.2
Equisetum arvense				
June	4.5	19.5	31.3	17.5
August	4.6	15.6	42.6	24.0
Oplopanax horridus				
berries	5.9	8.4	39.0	31.0
Heracleum lanatum				
stems	5.5	10.8	35.9	33.9
Vaccinium spp.				
berries	5.0	8.1	26.7	17.2
Ribes bracteosum				
berries	5.1	14.5	25.3	20.2
Rubus spectabilis				
berries	5.2	14.9	39.2	29.8
Dryopteris dilatata				
June	4.8	34.1	26.2	14.0
August	5.0	16.6	20.1	13.9
Ligusticum scoticum				
root	4.4	6.7	41.3	13.3
Oncorhynchus spp.	5.4	78.1		

[a] Neutral detergent fiber.
[b] Acid detergent fiber.

abundant and varied high energy berry resources are available, primarily on avalanche slopes.

The feeding strategy of bears that do not move away from anadromous fish streams until late in the fall also supports a suggested shift from a protein rich diet to an energy rich diet. Fall scats from low elevations indicated that salmon remained important well into the pre-denning period. Salmon are rich in both protein and fats. Through examination of fish remains along streams it became apparent that early in the salmon runs bears consume nearly the entire fish, leaving only the jaws, opercle, milt sack, and fins. Late in the run, however, only the lipid-rich eggs and that part of the head containing the brain were consumed.

CONCLUSIONS

From mid-July until early September, when "coastal" bears are feeding on a protein-rich diet, "interior" bears may compensate for the lack of salmon in their diet by increasing their intake of deer, small mammals, and green vegetation high in crude protein (e.g., skunk cabbage, horsetail). Such parallel seasonal shifts in diet by "coastal" and "interior" bears is consistent with the literature. Brown bears in Alberta (Hamer 1985), Montana (Servheen 1983, Mealy 1980, Sizemore 1980), and British Columbia (Hamilton and Bunnell 1987) utilize many dissimilar forages but exhibit similar seasonal shifts in diet focus. The Ursidae evolved from the Canidae during the Miocene (Herrero 1972) with few adaptations to a predominantly herbivorous diet. Bears lack the gut microbes and cecum that would allow more efficient digestion of plant material. They have, however, replaced the shearing carnassial teeth of their obligate carnivore ancestors with bunodont crushing molars, and increased their relative gut length (Bunnell and Hamilton 1983, Mealy 1980). Though limited, such adaptations have made possible the omnivorous flexibility that allows brown bears to inhabit such diverse habitats as temperate coastal rain forests and the arctic coastal plain. This flexibility, in conjunction with the abundance and diversity of food types available to bears on Admiralty Island, has allowed them to perpetuate dichotomous, yet parallel, feeding strategies.

The study site supports approximately 0.4 bears per km^2 (Schoen and Beier 1988), increasing to as many as 8 bears per km^2 along salmon streams in late summer. Such high densities suggest that intraspecific strife or resource partitioning, rather than food abundance, may limit bear numbers and influence distribution. The pattern of habitat use attributed to Admiralty's "interior" bears is apparently learned and passed on from female to offspring (Schoen et al. 1986). Hamer (1985) suggests that such learning as well as partitioning of food resources are fundamental to selection of habitat. The exclusive use of interior portions of the study area through the entire active period by "interior" bears, when areas more abundant in high quality forage are easily attainable, seems contrary to the axioms of optimal foraging theory. Bunnell and Gillingham (1985) suggest that an animal may adopt an approach in which it acts not to optimize its diet or any particular variable, but simply to stay alive and reproduce. Because brown bears are long-lived the primary measure of a female's life-time fitness may be her survivorship, reducing the likelihood of short-term optimization or optimization specifically for foraging (Hamilton and Bunnell 1987). It is tempting then to speculate that "interior" bears may be increasing their long-term fitness, measured in young surviving to enter the breeding population, by removing themselves and their offspring from areas with high potential for intraspecific aggression. To surmise that the "interior" distribution is more than an anomaly would imply that some benefit by the behavior had been noted, such as a reduced frequency of aggression resulting in above average cub survival rates. Certainly none have been determined here. In fact, few of the numerous variables providing cues to bears in their complex environment were examined in this study. In addition to fiber and nutrient content, food values in terms of vitamin and trace mineral constituents and non-food related habitat components, are criteria that could be examined when attempting to determine if and how optimization is functioning.

The habitat selection exhibited by Admiralty's "interior" bears may not be the consequence of an optimization process or attempt to increase fitness. Brown bears survive in northern portions of Alaska where the diet afforded may be closer nutritionally to that of "interior" bears than "coastal" bears. The "interior" bears of this study may be foraging well above any minimal threshold for the species as a whole and their choice of habitat simply a learned behavior without underlying adaptive significance.

Many bear foods are of an ephemeral nature or are subject to failure in any given year. Availability of areas that support alternate food resources may be critical when salmon runs are poor or berry crops fail. While a few "interior" bears are able to meet at least minimum nutritional needs while foraging only in the restricted habitat of the alpine-subalpine and avalanche slopes, the importance of entire intertidal-oldgrowth-alpine ecosystem to the total population is apparent.

Many of the home ranges of the bears in this study lay entirely, or in part, within lands protected by wilderness status. The northern portion of Admiralty, as well as much of adjacent Chichagof and Baranof Islands, however, are National Forest lands subject to timber harvest. A perfunctory look at the data from this study may suggest that timber harvest would have only limited effects on bear forage production. Production of Vaccinium berries may increase in young clearcuts. While bears made use of Vaccinium berries in mid-summer they showed a preference for devil's club and stink currant berries when available, 2 species that are less likely to do well in clearcuts. The value of logged areas would be reduced to even lower levels as the area reaches the pole-sapling stage in 25-50 years. The sterile understory of a closed canopy second growth forest produces little in the way of bear forage.

Timber harvest under current guidelines would arguably have little physical impact on tidal sedge flats. However, even with required leave strips, the loss of adjacent cover and travel routes may substantially reduce the value of tidal areas in drainages that have been harvested.

Management of brown bears in Southeast Alaska will be accomplished on a finer scale as development and roading of the region continues. As the capability to support a large bear population declines in areas where timber harvest is severe, hunting opportunities may necessarily be diminished.

CHAPTER III

DIGESTION OF FOUR NATURAL FORAGES IN THE BROWN BEAR[2]

The food habits of brown bears (Ursus arctos) have frequently been estimated using fecal analysis (Clark 1957, Mealey 1980, Mace and Jonkel 1980, Servheen 1983, Hamer 1985). However, to take the information gained through such studies and relate a bear's ecological requirements to the available food resources requires quantification of the bear's ability to extract nutrients and energy from its diet (Robbins 1983). Provided that the forage item being analyzed is the sole source of the nutrient and natural non-digestible marker in a scat, the nutrient digestibility of the diet can be estimated. Mealey (1980), attempted to determine nutrient and energy digestibilities for numerous foods contributing to the diets of brown bears in the Yellowstone ecosystem through such a comparison of the proximate analyses of food items and scats that contained the residues of these same items. However, upon microscopic examination, brown bear scats that appear to be composed of only 1 forage species are frequently found to contain additional foods or non-food items. Contamination of

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feces by trace amounts of other materials can cause relatively large errors in marker concentration factors, and subsequent calculations of digestibilities may be highly erroneous. Bunnell and Hamilton (1983) avoided these potential problems by using captive brown bears fed a controlled diet to determine apparent digestibilities of 2 natural food types, blueberries and salmon.

The results in Chapter 2 point to the importance of a limited number of food items in the diet of both "coastal" and "interior" bears. Therefore, it is useful to obtain estimates of their nutritive value, including nutrient digestibility. Feeding trials appear the most reliable method of gaining such estimates. Due to palatability problems and factors associated with bear health it is usually not possible to feed a diet made up solely of a single food type to be tested. It is then necessary to feed a basal ration and add the food types of interest to this base. Provided that the digestibility of the basal ration is known, and that there is no interaction between the basal ration and test component, digestibility of the test food components can be estimated. These estimates are termed partial digestibilities. In the present study it was not possible to collect all feces to determine mixed feces output and overall digestibilities. Therefore it was necessary to use a non-digestible marker naturally occurring in the food to determine digestibility according to the internal marker technique. The internal marker used was acid-insoluble ash (AIA).

This paper summarizes feeding trials on 2 captive brown bears to determine the partial digestibilities of dry matter, gross energy, and crude protein for sedge (Carex lyngbyaei), skunk cabbage (Lysichitum americanum), devil's club berries (Oplopanax horridus), and pink salmon (Oncorhynchus gorbuscha), 4 foods which are important in the diets of bears on northern Admiralty Island in Southeast Alaska (McCarthy, unpubl. data).

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METHODS

Two brown bears, a 28-year-old female and her 4-year-old daughter housed at the Washington Park Zoo in Portland, Oregon, were utilized for this study. The adult originally captured on Kodiak Island, Alaska, had been given to the zoo as a cub by ADF&G.

Plant material used in the trials was collected from the mainland coast near Juneau, Alaska, while salmon were obtained from the Hawk Inlet area of Admiralty Island. Foods were weighed, packaged individually by meal, and shipped to Portland by air on the day of collection. Two collections were made per trial, each shipment containing a 7 or 8 day supply. Plant foods were kept refrigerated at the zoo, and salmon was frozen.

The standard diet of the zoo bears consisted of a commercial dry omnivore chow (Zu/Preem) supplemented with fruits and vegetables or fish for a total of 3 kg of feed per bear per day. Experimental diets were a mixture of the basal ration (omnivore chow) and trial feed. While on the Carex or skunk cabbage diet, each bear was given 1.5 kg of trial feed and 1.5 kg of dry chow per daily feeding. When feeding devil's club berries or salmon, 1.0 kg of trial feed and 2.0 kg of dry chow were offered daily. Each diet was administered for a total of 15 days, which included a 5-day pretrial acclimation period and a 10-day trial period.

For nutrient analyses, 8 to 10 replicate samples of each forage item were retained at the time of collection. Samples of omnivore chow were taken at the beginning of each trial period. Scats deposited on days 3, 6, and 10 of the trial were collected. Feed and fecal samples were dried in a forced air oven at 50° C for 48 hours. The dried material was then ground in a Wiley mill or by mortar and pestle. Dry matter percent was determined by difference. Nitrogen content was determined by the macro-Kjeldahl technique. Gross energy was estimated by calorimetry using a Parr adiabatic oxygen bomb calorimeter. Acid detergent fiber (ADF) and neutral detergent fiber (NDF) percentages were determined for Carex, devil's club berries, and skunk cabbage according to the methods outlined by Goering and Van Soest (1970). A variation on the method described by Van Keulen and Young (1977) was used to estimate the concentration of the natural marker, acid-insoluble ash (AIA), in feed and fecal samples. Ten to 12 1-gram samples were dried, weighed and placed in calibrated volumetric tubes containing 100 ml of 4N HCL. This mixture was boiled for 30 minutes in a block digester, filtered through ashless paper (Whatman No. 41) and washed with hot distilled water. The sample and filter paper were then placed into weighed aluminum crucibles, and ashed for 12 hours at 650^0 C, the residue being the acid-insoluble ash fraction of the sample.

Digestibility coefficients for dry matter and 2 of its constituents, crude protein and gross energy, were calculated for the mixed trial diets using the following equations:

$$\text{Dry matter digestibility (apparent)} \; (\%) = \frac{\%\text{ AIA in feces} - \%\text{ AIA in feed}}{\%\text{ AIA in feces}} \times 100$$

$$\text{Nutrient digestibility (apparent)} \; (\%) = 1 - \frac{\%\text{ AIA in feed} \times \%\text{ nutrient in feces}}{\%\text{ AIA in feces} \times \%\text{ nutrient in feed}}$$

Dry matter digestibility (DMD) and nutrient digestibility (ND) of trial feeds were then determined by the equations:

$$\text{DMD of trial feed (apparent)} = \frac{\text{DMD of trial diet} - \text{Basal component of trial diet (\%)} \times \text{DMD of basal}}{\text{Trial feed component of diet (\%)}}$$

$$\text{ND of trial feed (apparent)} = \frac{\text{ND of trial diet} - \text{Basal component of trial diet (\%)} \times \text{ND of basal}}{\text{Trial feed component of diet (\%)}}$$

Fecal losses include not only the undigested portion of the feed but cellular material abraded from the gastro-intestinal tract and substances arising from metabolic secretions. Presence of such material leads to an underestimation of the proportion of the feed actually absorbed by the animal (McDonald et al. 1973); hence, all digestibilities in this study are termed apparent (gross) as opposed to true (net). The influence, if any, of the basal ration on the digestibility of the trial forages was not addressed in this study. The resultant partial digestibilities reported here should be viewed with this in mind.

RESULTS AND DISCUSSION

The nutritional composition of the basal ration, 4 trial feeds, and the mixed experimental diets (basal plus trial feed) were determined (Table 3-1). The crude protein content of salmon was significantly higher than all other food types ($p < 0.05$). Basal ration and skunk cabbage crude protein levels were similar and also significantly higher than either devil's club or *Carex*. Percent AIA was highest for *Carex* when comparing individual feeds and in the basal/*Carex* mixed diet.

Two separate trials were conducted to determine basal chow digestibility. The first trial was conducted in June 1985. The results of this trial were used to estimate partial digestibilities of *Carex*, skunk cabbage, and devil's club berries. These trials were conducted between June and August of that year. Because the salmon feeding trial was administered in December, a second determination for the basal chow was deemed necessary. Conducting 2 trials on the same ration provided an opportunity to determine seasonal change in digestive efficiency. While apparent dry matter and nutrient digestibility were all determined to be greater in the December trial

Table 3-1. Composition of individual food items and mixed diets fed to brown bears in digestibility trials conducted at the Washington Park Zoo, Portland, Oregon, 1985.

	Composition on dry matter basis			
Diet	% dry matter	% crude protein	Gross energy (kcal/g)	% AIA[a]
Basal (commercial chow)	92.4	26.8	4.4	0.65
Carex lyngbyaei	27.8	12.0	4.3	1.49
Oplopanax horridus	22.8	8.4	5.9	0.38
Lysichitum americanum	8.1	25.8	4.0	0.59
Oncorhynchus sp.	24.3	78.1	5.4	0.45
Basal/C. lyngbyaei	60.1	23.1	4.4	0.85
Basal/O. horridus	69.7	25.0	4.5	0.62
Basal/L. americanum	50.2	25.6	4.4	0.65
Basal/Oncorhynchus sp.	69.7	33.8	4.5	0.63

[a] Acid-insoluble ash.

(Table 3-2), the differences were not found to be statistically significant ($p > 0.05$), possibly due to small sample sizes.

In most cases upon presentation of a new trial diet the bears took longer than normal to consume the meal. The basal/devil's club and basal/Carex diets were not consumed in their entirety during the first few days of the acclimation period by either animal. The skunk cabbage mixture was similarly treated by the 4-year-old; not until the fourth day would she consume the entire offering. The adult female, however, refused the skunk cabbage diet for 3 consecutive days of the pretrial period and was removed from the test on the 4th day. The amount of food rejected did not exceed 5% per day during any trial period.

The bears' total fecal output, though not measured, was markedly reduced while on the diet containing salmon. In each trial, traces of the experimental diet appeared in the feces within 24 hours after 1st feeding. Passage rates of experimental feeds and time required to clear the gut were not examined in this study.

Apparent digestibilities of the trial diets are displayed in Table 3-3. Dry matter, crude protein, and gross energy digestibilities were all highest in the basal/salmon diet. The high digestibility of animal matter is apparent through direct comparison of individual feed types (Table 3-4).

Table 3-2. Apparent dry matter, crude protein and gross energy digestibilities of the basal diet (Zu/Preem omnivore chow) used in brown bear feeding trials conducted at the Washington Park Zoo, Portland, Oregon, 1985.

		Percent apparent digestibility					
		Dry matter		Crude protein		Gross energy	
Trial date	N	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE
June 1985	7	68.6	8.71	79.3	6.36	73.3	7.23
December 1985	7	76.6	2.56	84.7	4.07	80.2	2.20

Table 3-3. Apparent digestibility of dry matter, crude protein, and gross energy of experimental diets fed to captive brown bears at the Washington Park Zoo, Portland, Oregon, 1985.

Diet	Apparent digestibility (%)		
	Dry matter	Crude protein	Gross energy (kcal/g)
Basal/*Carex lyngbyaei*	58.9	72.3	62.7
Basal/*Oplopanax horridus*	67.3	79.3	69.7
Basal/*Lysichitum americanum*	66.3	80.1	71.2
Basal/*Oncorhynchus* sp.	75.2	88.4	79.2

Table 3-4. Estimated partial digestibilities for dry matter, crude protein, and gross energy of individual trial forages fed in mixed diets to captive brown bears at the Washington Park Zoo, Portland, Oregon, 1985.

Diet	Percent apparent digestibility		
	Dry matter	Crude protein	Gross energy
Carex lyngbyaei	26.6	20.2	26.8
Oplopanax horridus berries	56.1	79.8	69.7
Lysichitum americanum	39.6	88.9	54.6
Oncorhynchus sp.	65.1	97.4	73.3

In ruminants, when food intake is restricted, long rumen retention time allows an increase in diet digestibility. When food is freely available food consumption is influenced by digestibility, which in turn depends on the chemical and physical composition of the food. Fibrous foods are broken down more slowly and retained longer in the rumen; hence, voluntary intake is limited by absolute rumen space available for fermentation processes. While ruminants are the most efficient processors of highly fibrous feeds, many non-ruminants possess the ability to digest a large portion of the fiber in their diets through lower-tract or cecal fermentation. In simple-stomached animals, microbial activity occurs in both the cecum and large intestine. In these hind-gut fermentors the breakdown by bacteria of polysaccharides, including cellulose that is not digested in the small intestine, yields mainly volatile fatty acids. The efficiency of this process varies, being greatest in those hind-gut fermentors such as the horse, which are highly adapted to fibrous diets. Even in the short simple digestive tract of the pig, microorganisms facilitate breakdown of over half of the cellulose fraction of their feed (McDonald et al. 1973). The tradeoff underlying the latter approach is the extraction of fewer nutrients from the food ingested in exchange for a higher rate of passage through the digestive tract.

Except for bunodont crushing molars and a slightly increased intestine to body length over what could be expected for obligate carnivores (Mealey 1980), omnivorous brown bears have evolved from their carnivore ancestors with relatively few adaptations to herbivory. With simple stomachs, brown bears are not faced with the stringent constraints placed on food consumption by space and passage rate as are ruminants. Lacking a cecum as well as intestinal microorganisms necessary for the digestion of cellulose, bears have expanded on the digestive strategy of other monogastrics, quickly passing large volumes of relatively low-quality food through their digestive systems while extracting mainly soluble nutrients (Hamer 1985). At the same time, bears have retained the carnivore's capability to assimilate animal food material efficiently (Mealey 1980).

The effect of ADF content on dry matter, crude protein, and gross energy digestibility determined in this study are compared with those documented by Stelmock (1981), and Bunnell and Hamilton (1983) (Table 3-5). There was not a strong correlation between dry matter digestibility (DMD) and ADF ($r^2 = 0.12$) or NDF ($r^2 = 0.26$).

Hemicellulose, the added factor of NDF, is a structural carbohydrate composed of a variety of monosaccharide units and bonds, and is not well understood (Robbins 1983). It is, however, known to be somewhat digestible in the acid environment of the stomach, which may explain the slightly higher correlation between NDF to DMD. To determine if the relative composition of the forage fiber (ADF:NDF ratio) was influencing digestibility a rank correlation test (Spearman's Rho) was employed to test for dependence. The small sample indicated a weak positive correlation, however, the r value of 0.6 was not significant at the $p = 0.1$ level.

Table 3-5. Comparison of apparent dry matter digestibilities of forages with different NDF[a] and ADF[b] concentrations.

Forage	NDF(%)	ADF(%)	% apparent digestibility Dry matter
Carex lyngbyaei (This study)	48.1	27.0	26.6
Oplopanax horridus berries (This study)	33.9	26.3	56.1
Lysichitum americanum (This study)	23.2	11.8	39.6
Blueberries (Bunnell and Hamilton 1983)		15.0	88.4
Equisetum sp. (Stelmock 1981)		19.9	40.0
Empetrum nigrum (Stelmock 1981)		20.4	30.0
Shepherdia canadensis (Stelmock 1981)		9.8	53.0

[a] NDF = neutral detergent fiber.
[b] ADF = acid detergent fiber.

Brown bears adjust their diets seasonally in response to changes in plant phenology and availability of high protein animal matter (Atwell et al. 1980, Graham 1978, Hamer 1985, Mealey 1980, Servheen 1983). On northern Admiralty Island, brown bears were also found to make such seasonal dietary shifts (Schoen et al. 1986). There, most bears departed their high elevation den sites upon emergence in the spring, moving to tidal grass flats and associated forest habitat, or south-facing avalanche slopes. At that time they foraged primarily on newly emergent Carex, horsetail (Equisetum spp.), and the below-ground portion of skunk cabbage stems. In early summer, bears began to move upward as snowmelt exposed subalpine sedge meadows where new growth of grasses, sedges, and forbs was available. By August, most Admiralty Island bears had again left the alpine/subalpine for low elevation riparian habitat along anadromous fish streams and were feeding on the abundant salmon resource. Atwell et al. (1980), discussing similar patterns of alpine habitat use by brown bears on Kodiak Island, Alaska, thought that the timing of the bears' movement away from the alpine Carex meadows was as much a function of plant phenology as the arrival of fish in coastal streams.

On Admiralty, Schoen et al. (1986) found that some bears did not travel to coastal salmon spawning streams, but remained in higher elevation interior habitat throughout the year. Snowmelt at these high elevations continues into late summer on Admiralty, and plants in their early phenological stages remain readily available. Nutritive quality is highest in most plants during the early phenological or succulent stages when they are low in lignin and cellulose and high in soluble nutrients (Klein 1970, Hanley and McKendrick 1983). Admiralty's "interior" bears are apparently meeting their nutritional requirements without utilizing the highly-digestible, nutrient-rich salmon resource by using plant matter, berries, and small mammals (McCarthy and Schoen In Prep).

Increasing intake has been shown to lower forage digestibility in non-ruminant herbivores (Castle and Castle 1956, McDonald et al. 1973, Harlow 1981, Rerat 1978). Carex, which is poorly digested even when intake is restricted (Table 3-3), was the most prevalent food item in the diet of "interior" bears through the late summer period. "Interior" bears may not be able to attain the same level of nutrition as those bears feeding on salmon and devil's club berries by maximizing intake of this lower-quality diet. Thus, "interior" bears may be at a competitive disadvantage. It has been demonstrated that animals on a relatively lower plane of nutrition may exhibit decreased juvenile growth rate and smaller adult body size leading to delayed sexual maturation and poorer reproductive success (Verme 1967, Jonkel and Cowan 1971, Robbins 1983, Knight and Eberhardt 1985).

Digestibilities of both crude protein and gross energy were found to be higher in December than in summer (Table 3-2). An increase in digestive efficiency during the autumn hyperphagic period may serve to minimize the depressive effects of elevated intake. Other physiological-biochemical adaptations to denning are known to be in place several weeks before dormancy (Nelson et al. 1973, Nelson et al. 1984).

Brody and Pelton (1988) noted an increase in quantity of food consumed in late fall when identical rations were offered to black bears in August and November. In contrast to our findings, digestibility of crude protein was lower in the November trial while digestibility of gross energy increased. They suggest a hormonal control whereby fat and carbohydrates are selectively assimilated at the expense of protein during the hyperphagic predenning period. We contend that the endogenous loss of protein associated with any increase in dry matter intake (Foose 1981, Robbins 1983) should increase maintenance nitrogen requirements during this period.

Our understanding of brown bear feeding ecology with respect to nutrition and digestive efficiency is rudimentary, yet increasing. Differential digestibility of a large number of food items should be determined to formulate correction factors applicable to results of fecal analysis studies. The importance values that are frequently assigned to forages based on percent composition in scats could be improved if digestibility of diet items was known. As most diets consist of more than one food type, the effect of associative digestion (e.g., how the characteristics of one food affects the digestibility of other foods in the diet) is important but, as yet, poorly understood in bears.

CHAPTER IV

CONCLUSIONS

This study investigated the food habits of both "coastal" and "interior" brown bears on northern Admiralty Island, and estimated nutrient digestibility of 4 frequently used food types. In many studies of brown bear food habits, researchers have attempted to place an "importance" value on each food item. These values have been based on frequency of occurrence, and the volume of food remains in scats. I believe the use of volume categories to establish importance values, without a discussion of the associated shortcomings and assumptions, is misleading. For example, when berries of Vaccinium are ingested, the small seeds of these berries are often all that remain in scats. When mixed with coarse, poorly digestible forages such as sedges or graminoids, the volume of the seeds would account for only trace amounts of the fecal material. By determining the number of seeds in the scats, and using a predetermined seed to berry volume ratio, it is possible to estimate the volume of berries that have been ingested. I found seeds made up less than 2% of the fecal material by volume in some cases, while a corresponding number of berries would have equated to 60% of the diet volume (similar comparison on a dry weight basis would have yielded a lower figure).

The results of this study provide data on nutrient content and digestibility which are necessary for estimating importance values for 4 key food items. Importance rankings using digestibility and nutrient content would be an improvement over past efforts but would still fail to consider intake. A rough estimate of intake could be determined by back calculation from scat volume using dry matter digestibility values determined in this study. A method to more accurately estimate intake from scat analysis data is desirable. A study currently underway at Washington State University, Pullman, Washington, is expected to produce such diet correction factors for several forage types. In that study bears will be fed a diet of mixed natural forages and intake compared with output volumes and weights as determined through scat analysis (C. Robbins, pers. commun.).

Associative digestion (e.g., how digestibility of one food is altered by the presence of other foods in the diet), is another factor yet to be investigated. Partial digestibilities, such as those determined in this study, must then be interpreted with caution. If similarly derived digestibility or diet correction figures are to be used in the calculation of importance values, the inherent limitations and assumptions will need to be addressed.

Consideration of seasonal changes in nutrient demand is a key part of determining importance values of bear foods. Results of this study suggest that forages providing high levels of digestible protein may be most important in the post-denning through late-summer season, while foods of high caloric value are more important during the fall hyperphagic period. In addition to detailed studies of macro nutrient demands we must ultimately consider factors such as vitamin and mineral requirements (particularly trace elements) and their role in diet selection if we wish to derive meaningful importance value rankings.

We are not yet at a point where the relative importance of forage types can be more than cursorily examined. Because such values are relative, and I have estimated digestibilities of only 4 forages, any attempt to establish such values now would be premature.

Brown bear food habits have been well documented from diverse areas of their current range. Nutritional requirements, energetics, and the bear's ability to break down and assimilate their food resources are now receiving more attention. A better knowledge of these parameters will be of significant value in our understanding of brown bear ecology as resource development further encroaches on bear habitat in Southeast Alaska.

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Appendix 1. Food habits of brown bears on northern Admiralty Island, Southeast Alaska, expressed in percent volume categories of items identified in feces, 1984-1985.

SEAS=season
5,6 = S_1
7,8 = S_2
9,1 = S_3

ELEV= elevation
1,2 = E_1 (<400m)
3,4 = E_2 (>400m)

Food items:
CASP=*Carex* sp.
EQAR=*Equisetum arvense*
LYAM=*Lysichitum americanum*
OPHO=*Oplopanax horridus*
RIBR=*Ribes bracteosum*
ONSP=*Oncorhynchus* sp.
UKVG=Unknown vegetation
LISC=*Ligusticum scoticum*
ANLU=*Angelica lucida*
HELA=*Heracleum lanatum*
VASP=*Vaccinium* sp.
ODHE=*Odocoileus hemionus*
GRAM=Graminoid
STST=*Streptopus streptopoides*
COAS=*Coptis asplenifolia*
RUPE=*Rubus pedatus*
UKFS=Unknown fish
ANTS=Ants
EMNI=*Empetrum nigrum*
SACA=*Sambucus callicarpa*
MEFE=*Menziesia ferruginea*
FETH=Feather
ELAR=*Elymus arenarius*
UKHR=Unknown hair
RUSP=*Rubus spectabilis*
CLRU=*Clethrionomys rutilus*
BARN=Barnacles
SNAI=Snails
HROE=Herring roe
POAN=*Potentilla anserina*
MOSS=Moss
DRDI=*Dryopteris dilatata*
VEVI=*Veratrum viride*
LARV=Insect larvae
URAR=*Ursus arctos*

Volume Categories:
1=trace-5%
2=6-25%
3=26-50%
4=51-75%
5=76-100%

SEAS	ELEV	CASP	EQAR	LYAM	OPHO	RIBR	ONSP	UKVG	LISC	ANLU	HELA	VASP	ODHE	GRAM	STST	COAS	RUPE	UKFS	ANTS	EMNI	SACA	MEFE	FETH	ELAR	UKHR	RUSP	CLRU	BARN	SNAI	HROE	POAN	MOSS	DRDI	VEVI	LARV	URAR
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A	E	S	A	A	H	B	S	V	S	L	L	S	H	A	S	A	P	F	T	N	C	F	T	A	H	S	R	R	A	O	A	S	D	V	R	A
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