

BLACK BEAR (*Ursus americanus*) HABITAT ECOLOGY  
AS RELATED TO  
ASPECTS OF FOREST MANAGEMENT  
IN SOUTHERN NEW BRUNSWICK

by  
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## **ABSTRACT**

To examine aspects of forest management, black bear ecology was studied in a protected area surrounded by intensively harvested and managed habitats. A multiresource survey was performed and bear space use and habitat selection behaviours were analysed. Through cartographic modelling, results were integrated to determine if unsuitable habitats generated a fragmentation effect.

Ten adult female black bears were tracked from 1993 to 1994 and yielded 610 positions. Their large home ranges ( $\bar{x}=62.0 \text{ km}^2$ ;  $SD=34.3 \text{ km}^2$  [95%MCP]) suggested a low quality landscape. Bears used protected and exploited portions as expected by chance.

Hiding cover distance, horizontal cover density, canopy cover, safety tree density, food species ground cover, food species richness and food species diversity were surveyed at 113 sites in 14 habitat types. Younger habitats generally provided more concealment, greater food species ground cover, and richer food species assemblages than mature habitats. For each variable, tests showed significant differences in abundance between habitats. However, due to intra-habitat variability, multiple comparison tests did not detect any independent habitat-type groupings.

Habitat types were thus grouped graphically to perform habitat component selection analyses. Habitat type and component selection behaviour was explored through use versus availability testing. Landscape component (distance to water and area to perimeter ratio of habitat polygons) selection was assessed. Behaviour towards roads could not be assessed due to detectability issues.

Hardwood habitats were strongly avoided whereas others were used according to availability. This atypical avoidance may be linked to a beech bark disease-induced reduction in mast production. Bears preferred immature habitats over mature ones and used non-forested habitats as expected by chance. No selection was shown towards management regime.

Bears showed a preference towards high hiding cover distance and horizontal cover, medium canopy cover and safety tree density and low food species diversity. The latter behaviour relates to the index used: it assigned greater weight to abundant species. Bears showed avoidance of high safety tree density, medium hiding cover, food species richness and food species diversity and low horizontal cover. All other habitat component categories were used according to availability. No selection was shown towards food species ground cover or landscape variables.

Correlations were assessed; of each pair of correlated variables, individual variables retained for the model were those having elicited the strongest selection behaviour. Safety tree density, horizontal cover density and food species diversity apparently drove female bear habitat use. Maps illustrating selection towards each variable were integrated to produce a habitat suitability model map. Area of suitable habitat in each home range was regressed against home range area to assess fragmentation. Area of suitable habitat was shown to vary greatly and in concert with home range size. No fragmentation effect was shown.

Management considerations are presented.

**Keywords:** *Ursus americanus*, habitat, Fundy, national park, New Brunswick, model, geographical information systems, horizontal cover, forest management, forest inventories, beech bark disease.



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*“Lâche pas” - E.R. Chamberland 1892-1987*

### **Introduction:**

Black bears inhabit most forested areas of North America and have adapted better to anthropogenic habitat change than other bear species (Mattson 1990). The ecological consequences of industrial forest management on black bears have been studied throughout their range. However, much remains to be studied and explained owing to the continent-wide distribution of the species and the ensuing variation in forest management practices. In response to humanity's pressures on natural resources, protected areas have been established to conserve natural habitats in an undisturbed state. Although such areas can be set aside, it is naive to think that the wildlife within them will be totally insulated from outside activities. Managers of protected areas must look beyond boundaries to understand their area's role within the local context.

Such a cross-boundary rationale led managers in Fundy National Park, New Brunswick, to initiate a project examining forest management activities' effects on bears inhabiting the Park and its surroundings.

The area provides a contrast between a protected area and an actively exploited area. It lies within two ecoregions. The Fundy Coast ecoregion extends inland approximately 10 km. The Atlantic ocean is the dominant influence: the region is subjected to strong winds, high humidity and fog during the summer and fall. As a result of this maritime influence, the region is slow to warm up in spring, and summer remains cool and wet. Rain is common throughout the year even in winter. The forest is coniferous and principally composed of red spruce (*Picea rubens*), balsam fir (*Abies balsamea*), and red maple (*Acer rubrum*) with scattered white spruce (*P. glauca*) and both white (*Betula papyrifera*) and yellow birch (*B. lutea*). Sugar maple (*Acer saccharum*) and birch (*Betula* spp.) are present at higher elevations. The terrain varies from rolling to steep deeply-cut highlands to undulating plains. Stony glacial till covers the highlands. The lowlands are

blanketed by loamy tills, sandy fluvioglacial sediments, and silty marine deposits. From sea level, elevations rise to about 215 m inland (Ecological Stratification Working Group 1995).

Further inland lies the Southern New Brunswick Uplands ecoregion. Warm rainy summers and mild snowy winters characterize the area. The mixedwood forest is dominated by sugar and red maple, white and red spruce, and balsam fir. Sugar maple and beech (*Fagus grandifolia*) occupy warmer, moister sites whereas drier sites frequently host white pine (*Pinus strobus*). The forest becomes conifer-dominated at lower altitudes. The region's surface is southeast-sloping Appalachian peneplain and can reach elevations above 350 m. The terrain gradually decreases in elevation and levels out to the west (Ecological Stratification Working Group 1995).

For both ecoregions, the mean annual temperature is approximately 5-6° C. The mean summer temperature is 15°C and the mean winter temperature is -4°C. The mean annual precipitation ranges from 1100 to 1400 mm. (Ecological Stratification Working Group 1995).

Less than 10% of either ecoregion is farmed; forestry is the dominant land use throughout. The area surrounding the Park is primarily Crown land with some commercial freehold. It is characterized by a history of intense forest harvesting and management.

Past forestry activities consisted of clearcutting areas of many hectares and preparing them for reforestation by bulldozing slash into windrows that were later burned. The areas were replanted into what Hirvonen and Maddill (1978) predicted would “evolve into an artificial community of nearly pure conifers far removed from its natural counterpart”. These plantations have been treated with herbicides and thinned. Plantations of non-indigenous softwood species, such as Norway spruce (*P. abies*) are common and sometimes grow where hardwood stands once stood. The “industrially” managed stands

surrounding the Park are predominantly young (less than 30 years old), even-aged, consist of coniferous species, are geometrically simpler, and also larger than natural stands.

The natural disturbance regime in both ecoregions is characterised as one of “gap disturbance” (Woodley and Forbes 1997). However, up to the time of the study in 1993-1994, management had not mimicked this regime but had imposed a “stand-replacing” one instead (Woodley and Forbes 1997). For example, when an outbreak of “gap-disturbing” spruce budworm (*Choristoneura fumiferana*) occurred in the 1980s, affected stands were salvage-logged to recover dying timber. These stands were replaced with even-aged, single species plantations that are now very different from “unsalvaged” sites that were left to regenerate naturally. Harvesting activities have required the construction of an elaborate road network. The roads not only remove habitat but, as they are publicly-accessible, they allow access to previously unfrequented areas. Some land-use conversion has occurred as commercial blueberry fields have been established. However, these, along with abandoned farms, represent less than 1% of the study area.

Fundy National Park (FNP) is set on the Bay of Fundy coastline in Southern New Brunswick (Figure i.1). It lies at approximately 45.5° N and 65.0°W. It is 206 km<sup>2</sup> in area



**Figure i.1:** Location of Fundy National Park, New Brunswick. Canada.

and represents the Maritime Acadian Highlands within the National Parks System. It was established in 1948 and has been allowed to evolve naturally since. The disturbance regime is thus the naturally-occurring one of gap-disturbance. The Park is managed with the preservation of ecosystem ecological integrity as its legally-mandated priority (National Parks Act 1988). As such, all exploitative activities are prohibited within it. However, this does not mean that viable populations of bears or other wide-roaming animals are fully protected and can be maintained in the Park in a natural state *ad infinitum*; outside activities remain influential.

Though twice as large as Fundy National Park, La Mauricie National Park in Québec was shown to be much too small to serve this “refuge” function for bears (Samson 1995). Therefore, the habitat alterations occurring outside Fundy National Park must be understood to assess the Park’s role in bear conservation within the greater ecosystem that encompasses it. Thus the main objective of this study was to investigate the reactions of bears to anthropogenic habitats.

In light of criticisms of wildlife research (Romesburg 1981, Keppie 1990, Sinclair 1991) and the need for “question-driven” science (Gavin 1991), the rationale that guided this project will be presented by describing the chapters to follow.

To start explaining “why are bears where they are?”, the initial question of: “where are the bears?” is asked in the first chapter. The other question addressed in the section is: “do they show any behaviours in relation to the Park boundary or is it apparently undiscernable to them?”.

Knowing where the bears are provides only half of the answer; “what lies where the bears are?” must be determined. Thus, the second chapter describes and quantifies a range of resources available to bears in each habitat.

Following this, the question “do bears show any preference towards or avoidance of what is available to them?” is asked and their selection behaviour is described. This essentially answers the question: “Why are the bears there?”

The final chapter uses the information obtained to assess possible fragmentation effects of the presence of non-preferred habitats. The hypothesis tested assesses whether or not bears use an identical quantity of preferred (good quality) habitat regardless of home range size. This would imply that avoided and neutral habitats dilute the concentration of good habitat within the habitat matrix; bears would thus need to roam a wider area to integrate sufficient preferred habitat in their home ranges. Alternatively, home range size may be independent of the area of good quality habitat and another mechanism drives spatial use.

The results of this exercise will have applications to bear management and conservation in the area. Recommendations for bear management will be presented.



**Chapter I:**  
**Home range location and space use of black bears (*Ursus americanus*) in and around**  
**Fundy National Park, New Brunswick.**

**Introduction:**

The forest-dwelling American black bear is a habitat and diet generalist. Individuals roam extensive areas particularly in the northern parts of the species' range. It is common throughout New Brunswick. However, in some parts of the Province, concerns have been informally expressed about habitat alterations and hunting pressures facing the bear population. Such influences are present in the Fundy National Park area in the south of the Province. The juxtaposition of a hunted area that is also intensively managed for timber and a protected area provides an opportunity to attempt to assess effects of these pressures on bear behaviour.

Fundy National Park, a 206 km<sup>2</sup> area, was established in 1948. Its managers are mandated to preserve the ecological integrity of the ecosystems within it. It has been left to evolve naturally since its establishment and is composed of a mosaic of relatively old hardwood, softwood and mixedwood stands. The natural disturbance regime is one of gap disturbance (Woodley and Forbes 1997).

The area surrounding the Park is primarily provincial Crown land with some commercial freehold. It has a recent history of industrial forest management typified by a stand-replacing disturbance regime. Even-aged, single-species softwood plantations are a significant landscape component. Harvesting has led to a higher density of accessible roads and a simpler stand geometry than is present in the Park (Woodley and Forbes 1997).

Whether or not bears perceive these differences between the Park and its surroundings and consequentially use the areas differently is at the root of this investigation.

While habitat (specifically the abundance and distribution of foods) is a principal factor in spatial use, it has also been related to factors such as sex, age, reproductive condition, kinship, social rank, and population density (review in Smith and Pelton 1990). Given the limited resources and time available, this study focussed on basic issues of bear spatial use, cross-boundary distribution and disproportionate use of either the Park or the managed area.

### **Methods:**

#### **Field methods:**

Bears were trapped using foot snares (Johnson and Pelton 1980) inside the Park in the spring and early summer of 1993 and both inside and outside the Park during the same period in 1994. Snares were set throughout the area and were not associated with landfill sites. Only females were studied because of their paramount role in bear population dynamics (Kolenosky 1990) and their propensity to roam smaller areas (Hugie 1982, Samson 1995) which facilitates fieldwork. Adult females were fitted with conventional VHF collars. A network of non differentially-corrected GPS-surveyed (Global Positioning System) tracking stations was established along the road network. Bears were tracked on a haphazard schedule and this only during daylight due to logistical constraints.

Bears were chiefly tracked from the ground using handheld yagi antennae. A minimum of three bearings, obtained with no more than a 5 minute interval between each, were taken from different stations and plotted in the field. All tracking information was recorded and suspicious bearings were flagged. To reduce possible bias, two persons did the majority of tracking, with each tracking bears individually. When aircraft were used, locations were estimated and plotted on maps.

### Location estimation (ground-based telemetry only):

Bearing and station data were compiled and verified for transcription errors and concordance of map datum and declination. The program Locate II (Nams 1990) used bearing and station data to estimate the X and Y coordinates of the bear's location and calculate the area of a 95% error ellipse associated with it. The Maximum Length estimator was used as it is an unweighted procedure and estimates a location using 3 bearings rather than the minimum of 5 required by other techniques (Nams 1990). No prior estimate of bearing error was used as it could not be assumed to be constant throughout the study area since topography ranged from flat plateaus to narrow ravines.

The sets of bearings obtained in each tracking event were analysed individually; bearings listed as suspicious in the field were eliminated if they negatively affected the location estimate's precision. Bearings not flagged in the field were not censored unless they grossly affected the error estimate and were obviously erroneous.

### Home range estimation:

A home range (HR) is commonly defined as a restricted area in which an animal moves during the course of its normal activities during a set period (Burt 1943, Mohr 1947, Harris et al. 1990). It can be considered to be the bivariate "utilisation distribution" (UD) of the animal (VanWinkle 1975).

Locations of individual bears were compiled regardless of method of acquisition (visual observation, ground or aerial telemetry) or associated estimation error. The interval between locations was examined and the few (<10) locations occurring within 24 hours of each other were censored out to minimize the risk of serial auto-correlation (White and Garrott 1990). It was observed and thus considered that within 24 hours, the study bears could redistribute themselves within any part of their home ranges.

The program Calhome (Kie et al. 1994) was used to estimate home ranges from the location data. Home ranges were estimated using the minimum convex polygon method (MCP) (Mohr 1947) and the adaptive kernel (AK) method (Worton 1989); a 95% utilisation distribution contour based upon the percentage of points included was calculated using each method. For the adaptive kernel technique, the finest grid available (50 cells) was used for more precise approximation. Bandwidth (or “smoothing parameter” - Worton 1989) was set automatically by Calhome for each estimate after it was observed that iterative alterations did not significantly alter the area or distribution of the home range estimate (J. Baldwin, U.S. Forest Service, Pacific Southwest Forest Research Station, Albany, CA. pers. comm.).

Home ranges were estimated using data pooled across both years of tracking and for the following “seasons”: spring (1994 only: from start of tracking in 1994 to July 15<sup>th</sup>), summer (July 16<sup>th</sup> to September 15<sup>th</sup>), fall (September 16<sup>th</sup> to denning) and “annual” (all dates).

“Number of observation / area” curves (Schooley 1990, Day 1997) were calculated using date-randomized locations for the most located bear to determine the number of locations required to reliably estimate a bear’s home range. The curve’s inflexion point was considered as the “minimum” number of locations needed.

#### Home range selection analysis:

Only bears with park boundary-overlapping annual home ranges were considered. Selection for the Park or “outside” section of these bears’ home ranges was analysed by querying IDRISI GIS (Geographic information System) (Eastman 1997) and comparing the proportion of each bear’s home range within the Park to the proportion of its locations within the Park by means of a  $\chi^2$  goodness of fit test.

The mean home range and location proportions for the sample of boundary-overlapping bears were compared using a t-test.

**Results:**

**Locations and home range estimation:**

Ten adult (age: 3 years or more,  $\bar{x}=5.7$  years, median: 4) female black bears were collared. In 1993, 5 bears (identified as B, C, D, E, F) were captured in the Park and collared. In 1994, another 5 bears were added to the collared sample, 4 of which were trapped in the area surrounding the Park (H, I, J, K; bear A was captured inside the Park). No bears were caught more than 5 km from the Park boundary.

In 1993, bears were tracked from late August to denning (mid-November) and from mid-May to denning in 1994. Six hundred and ten (610) locations were thus obtained. Locations per bear ranged from 36 to 105 ( $\bar{x} = 61$ ,  $SD=23$ ). Fewer locations of bears captured outside the park (1994 only) were obtained than of bears captured in 1993 (or within the Park, in bear A's case). ( $\bar{x}[H, I, J, K]= 39.5$  locations;  $\bar{x}[A, B, C, D, E, F] = 75.3$  locations).

**Table I.1:** Mean home range (HR) areas (km<sup>2</sup>) calculated on a seasonal and annual basis for bears in the Fundy Study Area.

<i>Annual</i>						
<b>n Bears</b>	<b># locations × (SD)</b>	<b>× 95% MCP HR area (SD)</b>	<b>Range</b>	<b>× 95% AK HR area (SD)</b>	<b>Range</b>	<b>× AK Bandwidth (m) (SD)</b>
10	61 (23.3)	62.0 (34.3)	29.7 - 128.4	102.0 (55.4)	42.2 - 209.8	2824.4 (997.5)
<i>Spring</i>						
6	20.5 (5.5)	35.5 (60.7)	12.7 - 92.3	65.9 (39.8)	25.1 - 122.1	2442.3 (1109.9)
<i>Summer</i>						
10	17.9 (4.7)	32.6 (20.9)	8.3 - 65.3	63.9 (48.7)	20.6 - 149.8	2855.6 (1246.7)
<i>Fall</i>						
10	30 (12.9)	33.3 (24.3)	9.3 - 79.6	68.7 (40.2)	27.2 - 134.7	2989.3 (1174.5)

MCP: minimum convex polygon method  
AK: adaptive kernel method

Annually, bears roamed a mean area of 62 km<sup>2</sup> when estimated with the 95% MCP method and 102 km<sup>2</sup> with the AK method (Table I.1). Considering seasonal home ranges, the AK method calculated home ranges of nearly twice the area of the MCP estimates. Seasonal range areas were similar in size regardless of season ( $\approx 34$  km<sup>2</sup> for the MCP method and  $\approx 66$  km<sup>2</sup> for the AK method) and were approximately half the size of annual home ranges.

Annual home range sizes did not differ for bears that used the Park versus those that did not (MCP: overlap bears [A, C, D, E, F], outside [B, H, I, J, K] bears;  $t = -1.15$ , 8df,  $p = 0.28$ ; AK: overlap bears (A, B, C, D, E, F, J), outside bears (H, I, K);  $t = -0.56$ , 8df,  $p = 0.59$ ).

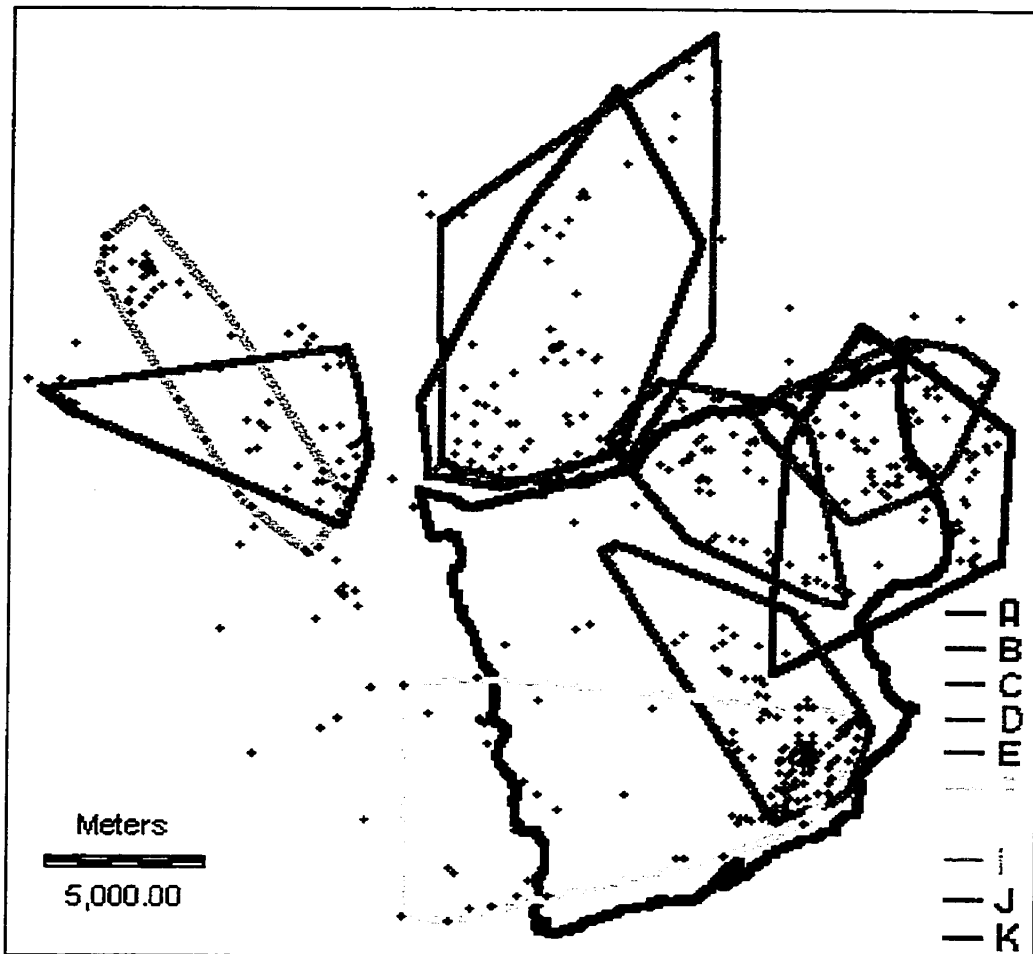
Figures I.1 through I.8 illustrate the size and location of the estimated home ranges relative to the Park boundary. Some bears' home ranges shifted between seasons. For example, bear C's MCP ranges (spring Figure I.3, summer Figure I.5 and fall Figure I.7) remained anchored in the same area yet extended into different zones each season.

Of the bears collared in the first year, bear B maintained most of its annual home range outside the Park though it was captured within it. Other bears collared in 1993 (C, D, F) overlapped the boundary but maintained most of their annual home ranges in the Park. Only bear E was never observed outside the Park.

Bears captured outside the Park in 1994 (H, I, J, K) scarcely included any Park area within their home ranges though their home ranges abutted it. Their annual home ranges were estimated from summer and fall positions only. Bear A was captured in the spring of 1994 inside the Park and maintained roughly half of its home range within it.

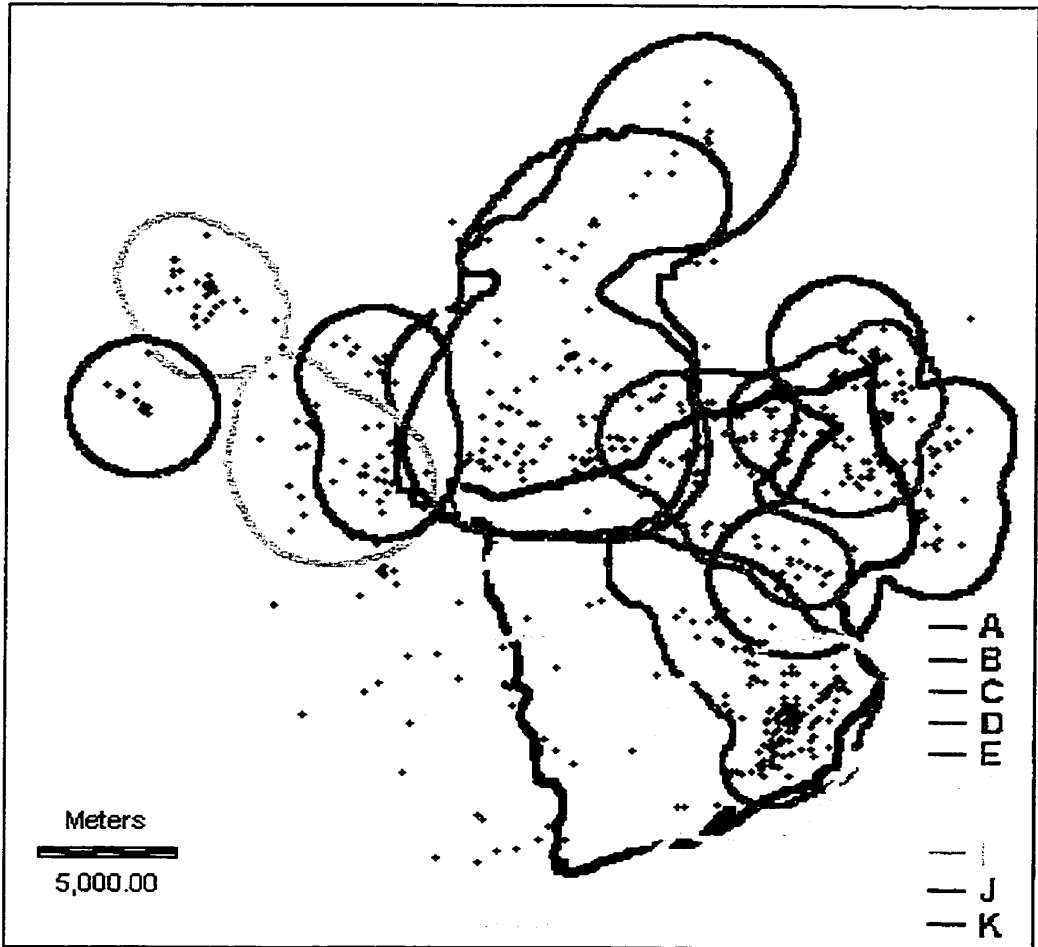
Annual, summer and fall home ranges of different bears overlapped considerably. All outside bears' home ranges show near total overlap with at least one other bear's. Less overlap occurred in spring.

Observation-area curve results suggest that 38 (MCP method) to 48 locations (AK method) were sufficient to accurately assess annual home range area.

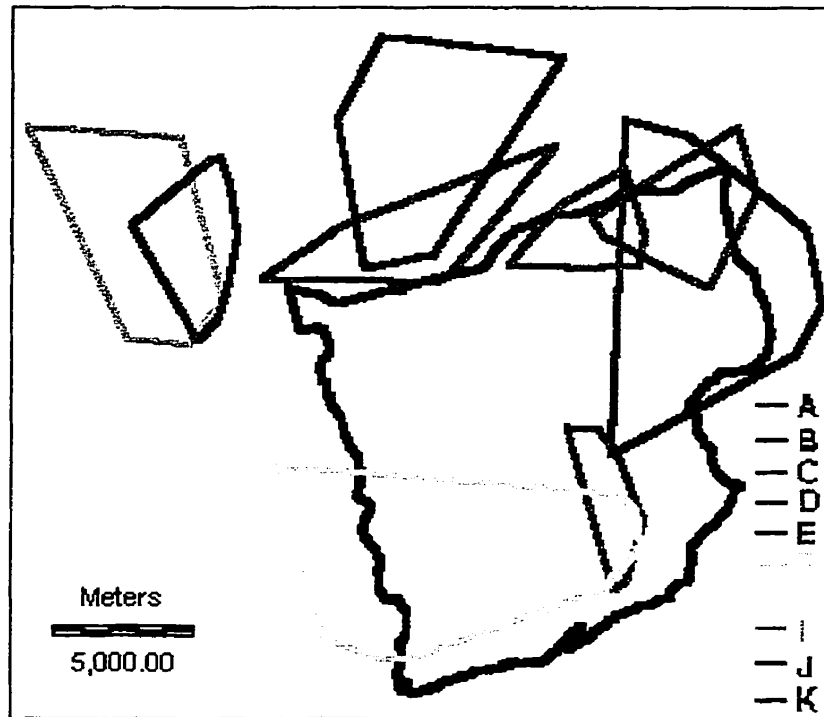


**Figure I.1:** Annual home range estimates of collared bears using the 95% minimum convex polygon method (Mohr 1947). (Park boundary in black).

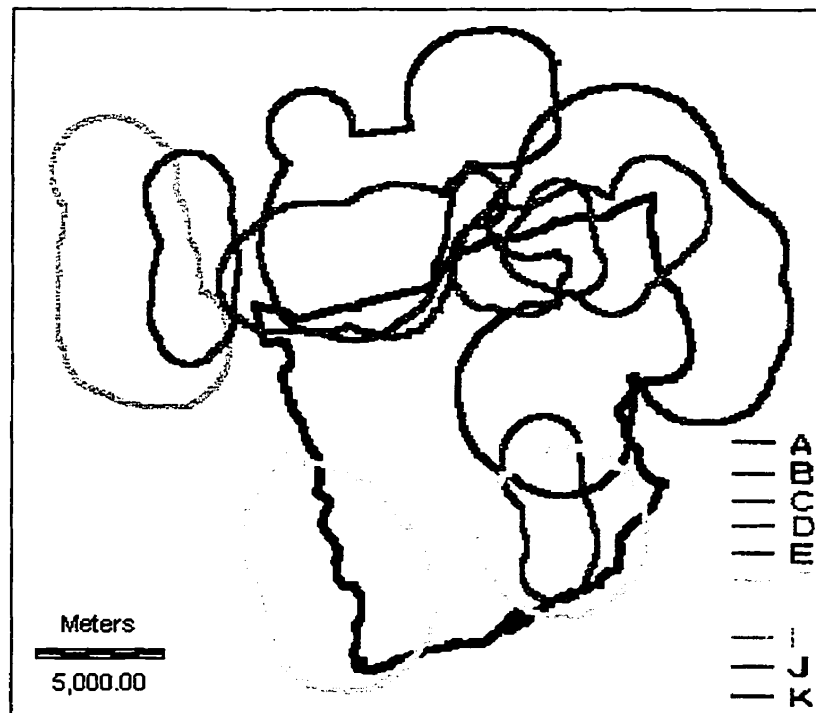




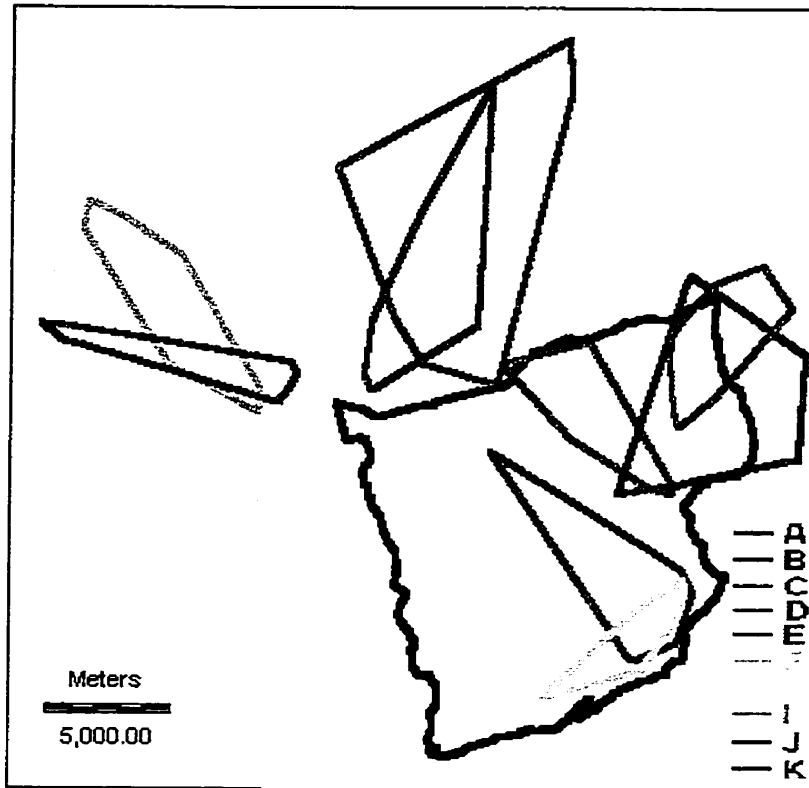
**Figure I.2:** Annual home range estimates of collared bears using the 95% adaptive kernel method (Worton 1989). (Park boundary in black).



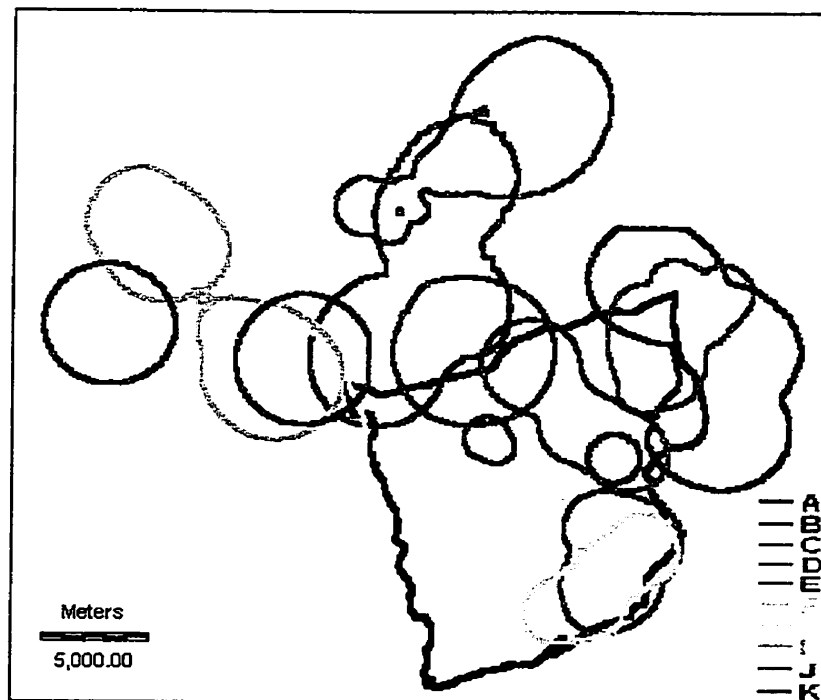
**Figure I.5:** Summer home ranges estimated using the 95% minimum convex polygon method (Mohr 1947). (Park boundary in black).



**Figure I.6:** Summer home ranges estimated using the 95% adaptive kernel method (Worton 1989). (Park boundary in black).



**Figure I.7:** Fall home ranges estimated using the 95% minimum convex polygon method (Mohr 1947). (Park boundary in black).



**Figure I.8:** Fall home ranges estimated using the 95% adaptive kernel method (Worton 1989). (Park boundary in black).

Selection analysis:

The different techniques affected the spatial extent of home range estimates and resultant overlap with the Park boundary. Considering annual MCP home ranges (Figure I.1), 4 bears (A, C, D, F) had boundary-overlapping home ranges; the AK estimation (Figure I.2) showed overlap for 6 bears (A, B, C, D, F, J) (Table I.2). The MCP home range estimates' proportions of home range and locations within the Park are higher than those of the AK home range estimates. Bears used the Park portion of their home ranges as expected by chance: the proportions of home range within the Park and the proportion of locations were not significantly different.

**Table I.2:** Mean proportions of Home Range (HR) and locations contained within Fundy National Park.

HR Method	Boundary bears (n)	$\bar{x}$ %HR inside (SD)	$\bar{x}$ % total locations inside (SD)	t-test
95%MCP	4	68.92 (10.48)	59.52 (23.71)	t=0.73, 6df p=0.5
95% AK	6	44.08 (25.62)	39.99 (34.99)	t=0.23, 10 df p=0.8

Only two bears (a different one from each estimation method) used the Park less than expected by chance (Table I.3).

**Table I.3:** Summary of individual  $\chi^2$  goodness of fit test results for selection for the Park. Results expressed as number of bears showing behaviour.

HR Method	Neutral	Selection shown
MCP	3	1** (avoid)
AK	5	1* (avoid)

\*\* P<0.01( $\chi^2 = 9.61$ ) 1df

\* P<0.05 ( $\chi^2 = 5.87$ ) 1 df

**Discussion:**

The ten adult female bears tracked are a sample of the area's population. The Park was trapped as uniformly as possible; outside the Park, traps were not as evenly distributed and the Park's perimeter was not entirely covered. There are certainly a few more adult females in the Park area. One subadult female was collared in the north-west quarter of the Park but her collar soon failed. The 9 positions yielded showed that it occupied that sector of the Park and overlapped the boundary. Thus, there is no female-free area in the Park. The extensive home range overlap observed supports these assertions.

The number of locations obtained per bear was adequate to delineate annual home ranges according to the "observation-area curve" results (n=38 locations). A sufficient mean number of locations per bear was not obtained in each season to *reliably* estimate seasonal home ranges even though these are typically smaller than annual ranges (Garshelis and Pelton 1981, Hugie 1982, Samson 1995) and thus require fewer locations to estimate.

Estimating annual home ranges using only summer and fall locations is appropriate. The few spring home range estimate obtained all overlapped parts of the summer and fall ranges. Though the limited data obtained did show that the mean area of seasonal home ranges did not differ between seasons, the spring home ranges of bears are generally the smallest and are approximately centered within the annual home range (Samson 1995). The addition of spring locations to the 1994 bears' datasets would probably only increase the precision of the annual estimate and, given the above observations, would probably not result in a major shift in area (accuracy of the estimate).

The difference between the mean AK and MCP estimates is due to the statistical nature of the AK estimation; it considers the dispersion of points and creates a 2 dimensional probability distribution of the population of locations from the sample obtained (Seaman and Powell 1990, Worton 1989). This essentially creates a buffer area

that extends past the sample points. The MCP method is fundamentally graphical in that the “outermost” points of the sample are joined with a zero probability of presence seemingly assigned past these points. The AK method’s probabilistic approach appears to offer a more accurate representation of an animal’s true distribution. This does not imply that either method is superior for home range comparisons.

Regardless of technique, the mean annual home range estimates ( $62 \text{ km}^2 \pm 34.2$  for MCP,  $102 \text{ km}^2$  for AK) are among the largest reported. Of 17 studies in the northern extent of bear range (Table I.4), only 4 reported larger range sizes. The next smaller result (McCutchen 1990) is  $10 \text{ km}^2$  smaller.

This study’s MCP results have a smaller standard deviation ( $34.3 \text{ km}^2$ ) and were derived from more bears than other studies with greater area estimates.

**Table I.4:** Annual home range sizes of female black bears reported in studies conducted in the northern portion of black bear range.

<i>Reference</i>	<i>Location</i>	<i>Size km<sup>2</sup></i>	<i>SD</i>	<i>n (bears)</i>	<i>range</i>	<i>n (loc)</i>	<i>Comments</i>
<i>This study</i>	<i>New Brunswick</i>	62	34.3	10	29.7-128.4	601	95% MCP
Amstrup and Beecham 1976	Idaho	48.9		7	16.6-130.3	494	
Aune 1994	Montana	137.3	96.2	2			ns
Boileau 1993	Quebec	47	23	5	8-65		ns
Costello 1992	New York	31.2	16.2	3	11.1-39.7	391	100%MCP ns
Day 1997	Newfoundland	34.7	14.2	5	17.9-65.1	207	95% MCP ns
Elowe 1984	Massachusetts	28		8			
Hugie 1982	Spectacle Pond, Maine	98.6	43.2	4	72.7-162.7	1342	3 yrs+ HRs for all years' locations combined ns
Hugie 1982	Stacyville, Maine	32.2	13.0	3	23.9-47.2		
Klenner 1987	Manitoba	23.9	5.2	5	19.7-47.8		*
Manville 1983	Michigan	68.9	64	5	17.4-173.7		100%MCP ns
McCutchen 1990	Colorado	52.9	25.2	2	35.1-70.8		ns
Pelchat and Ruff 1986	Alberta	19		12		542	100% MCP abundant berries
Pelchat and Ruff 1986	Alberta	39		14		1349	100% MCP berry failure
Reynolds and Beecham 1980	Idaho	18	5	5	12-26		100% MCP *
Samson 1995 (1991 data)	Quebec	97.9	109.9	10	15.1-369.2		100% MCP ns
Samson 1995 (1992 data)	Quebec	46.9	32	14	14-104.9		100% MCP ns

Only minimum convex polygon results reported. Comments include the results of t-test comparing this study to the others. Asterisk in comment field denotes significance at  $\alpha=0.05$  level; ns denotes non significant when tested.

Due to the small samples involved and the large standard deviations obtained, comparisons of this study's results to others (Table I.4) were rarely significant. Few studies reported sufficient information to allow testing. Few AK method results have been published to date and thus comparisons were limited to MCP method results.

All but one of the studies in Table I.4 used the MCP method at a 100% inclusion level or did not specify. In such cases, it was assumed that they had. This study's results for the 100% inclusion level ( $84.0 \text{ km}^2 \pm 41.8$ ) were much higher than those from the 95% level yet the standard deviation was not much greater. The 95% inclusion level results are reported as they delineate a home range that is more representative of an animal's normal movements. Even using the 95% inclusion level, the mean home range area in Fundy is large compared to that of other studies.

The studies cited in Table I.4 presented home range estimation techniques and results with varying degrees of detail. In some cases, the smaller home range areas reported may result from the absence or the exclusion of excursions to locally abundant food sources. Using another home range estimation technique (thus not reported in Table I.4), Alt et al. (1980) reported the mean total home range and the mean home range exclusive of excursions for a sample of 12 female bears. When excursions were removed, the mean home range area obtained was reduced by 46%.

Such excursions occurred in this study. Bear J established a summer home range on the boundary of the Park (Figure I.6). Figure I.8 shows that fall use of that area was less extensive than it had been previously; however, a new satellite range was established to the north. This new range contains commercial blueberry fields unavailable within the summer range. After spending some time in this "blueberry" range, the bear returned to its "original" range and dened there. Considering that this relatively short excursion ( $\approx 15 \text{ km}$ ) was by far the longest one observed, all such movements were included within the



95% home range estimates. The AK method “recognizes” such trips and creates a separate “sub-range” thus showing only the area truly used. The MCP method includes the area between ranges, even if the animal was never located there.

Perhaps the high mean home range area is related to the young median age (4 years) of the collared bears. This would be inconsistent with other studies that found that young independent females tended to establish small ranges within the home range of their mothers and eventually expanded them into recently vacated neighbouring areas (Rogers 1987).

The area outside the Park hosts a spring and a fall hunt; perhaps this results in a lower population density or in the creation of numerous unoccupied areas into which females can easily expand their ranges. However, the amount of overlap observed is not consistent with a low density situation.

Several studies (e.g. Jonkel and Cowan 1971, Garshelis and Pelton 1981, Young and Ruff 1982, Rogers 1987) have shown that female home range size reflects habitat quality. Thus it is inferred that the study area’s overall habitat quality is low with respect to bears. This can be stated since the home range estimates were based on:

- 1) an adequate number of locations,
- 2) a sample of bears not predisposed to roam vast areas and whose size and composition is comparable to that other studies.
- 3) a defensible method of home range estimation and,
- 4) considerable overlap among bears.

In the most similar study, Hugie (1982) found little evidence of overlap among bears in ecologically-similar Maine, except for the period during which bears foraged on hard mast crops. The mean home range at one study site was one third the size of that reported from an 89 km distant comparison site. The difference in area was attributed to

the poor quality of the second site; specifically to the lack of hard mast producing stands and to the restricted food base found there.

Beech is the only hard mast available in the Fundy study area. However, the local beech have all been severely affected by beech bark disease (a sequential infection by the scale insect *Cryptococcus fagisuga* and the fungus *Nectria coccinea*) which, in infecting trees, dramatically decreases mast production (Costello 1992). Nearly no mast production was observed. This assessment was confirmed by a biologist visiting from La Mauricie National Park (Québec) where the disease is absent (Denis Masse, Parc National de La Mauricie, Shawinigan, QC., pers. comm.). Hugie's (1982) comparison and conclusion supports the assertion of the low habitat quality of the Fundy study area.

The size of the Park relative to home range sizes observed is a concern. Assuming no overlap, the 206 km<sup>2</sup> Park provides scarcely enough area for 3 bears considering the MCP estimate and only 2 bears with the AK estimate. These numbers are based on area alone since bears may access habitats unavailable within the Park. Only one bear (E) never left the Park during the study.

Though mean seasonal home range area was nearly equal across seasons, the seasonal ranges differed in location such that the mean annual home range area was double the seasonal mean. Such a difference is commonly reported (Garshelis and Pelton 1981, Samson 1995).

The 4 bears captured outside (all within 5 km) of the Park boundary were the least-located animals. No spring locations of these bears were obtained due to their late capture date. Approximately twice as many locations were obtained during the fall than during the summer for each. Only one of these bears (J) was located within the Park. Though their home ranges were estimated with less locations than of other bears, their ranges are assumed to be accurate, therefore, it is suspicious that the distribution of these

4 bears falls so neatly outside of the Park. Given their extensive home ranges, it is assumed that they are capable of visiting the Park and probably do so occasionally. However, no use of it was uncovered during the sampling period. The Park's habitats may not have been of use to them during this period.

The analysis indicates no selection with respect to the Park. The AK method results' lower proportions of home range and locations inside the Park are due to the "buffering" properties of the AK method: two additional bears' (B and J) home ranges overlapped the Park boundary. Since these bears had the greatest proportion of their home ranges outside the Park (though observed in the Park, their 95% MCP estimates did not include it), the mean AK proportion for all bears was thus lowered. This is a technical and not a behavioural difference. With either technique, no significant difference was found between the mean proportion of home range and the mean proportion of locations within the Park.

Individually, two bears avoided the Park. The different methods used caused the variation in which individuals exhibited the behaviour. The fact that 3 out of 4 (MCP) or 5 out of 6 bears (AK) showed no selection strongly suggests that the Park is a "random" part of the bears' home ranges. No conclusion regarding selection for or against the Park can be drawn.

### **Conclusion:**

The home ranges of bears in this study area were larger than most reported in studies in similar habitats across the species' range. This suggests low habitat quality or possibly high mortality. The Park is only 2 to 3 times larger than the mean home range area of female bears in the area. No selection behaviour was shown towards the Park. As such, it is unlikely that the Park has more than a minor and local effect on bear populations

in the area possibly through the protection of a few animals that happen to be in the Park during the hunting seasons. The Park was not shown to be preferred or avoided. Thus, it probably does not contribute more ecologically (as opposed to legally) to bear populations in the area than any other area whose boundaries could be arbitrarily traced on a map.

This remains to be explained; locations obtained will be used to evaluate bears' behaviours towards habitats available and thus indirectly gauge the effects of forest management upon them.

**Chapter II:**  
**A multiresource inventory of black bear habitat in southern New Brunswick.**

**Introduction:**

Knowledge of bears' spatial use patterns is important to understanding their ecology; however, it is insufficient to know only where bears are, the reasons for their presence must be understood. A first step towards this is to describe what resources are available to bears in different habitats.

As this may ultimately lead to management applications, the descriptions must be based upon habitat classifications used by natural resource managers and employ easily-measured and potentially manageable habitat features.

Determining which variables to measure at the habitat-type level is challenging. They can be grouped into two broad categories: food plant characteristics and structural characteristics.

The importance of various food characteristics in black bear habitat ecology has been demonstrated by many authors (Hugie 1982, Pelchat 1983, Rogers 1976, Rogers 1987). They have concluded that the abundance and distribution of food are the principal variables driving habitat use. Abundant food is essential; however, a rich and diverse assemblage of food species within different habitats provides alternate food sources. The asynchronous fruiting habits of different plants help ensure food availability throughout the growing season. Species diversity is beneficial during years when dominant food species are scarce due to extreme climatic conditions since some less-abundant alternate food species may thrive under these conditions and provide a compensatory food source (Noyce and Coy 1990, Costello and Sage 1994).

The role of structure in bear habitat use is less understood or recognized. Studies have found that habitat structure can sometimes override food abundance.

The amount of concealment provided by vegetation (referred to as horizontal cover, hiding cover or security cover) is a factor. In Arizona, female black bears avoided using habitats with low concealment even when food was available in these habitats. Higher cover habitats were always significantly preferred (Mollohan and LeCount 1989, Mollohan et al. 1989). In Idaho, Lindzey and Meslow (1977) found that bears selected older cutting units with more concealment even though younger cutting units provided more food. The authors hypothesized that the availability and juxtaposition of food and cover contributed to habitat richness. Also in Idaho, Young and Beecham (1983) reported that bears chose selection cuts significantly more often than other habitats available. This was explained not only by greater food availability in the preferred habitat, but also by the presence of an extremely dense understory. Moreover, the authors suggested that the presence of climbable trees in these habitats added to their security value.

Security is important to all organisms. However, one may wonder what bears may be hiding from. A few authors (LeCount 1986, Rogers 1987: direct observation and description of 8 events communicated to him) have observed bear carcasses in the wild and, using indices found at these sites, have attributed some deaths to bear predation. In Arizona, LeCount (1986) radio-collared 23 black bear cubs to determine their fate. Eleven cubs died and the cause of death was determined for eight. Of these, half (4) had been preyed upon by bears and one quarter (2) of the deaths resulted from felid predation. The bear predation was attributed to infanticide by adult male bears that either wanted to gain an opportunity to mate or wanted to limit future competition from unrelated bears.

Such predation is presumably not limited to Arizona and has likely occurred throughout the species' evolution. It is plausible that hiding from predators in dense habitats with less food can result in a greater fitness gain than obtaining more food in open habitats. However, hiding is not always successful. The means by which bears, especially

cubs, escape predation must be considered.

In a review of bear evolution, Herrero (1972) states that trees are significant to the daily existence of black bears, especially cubs, particularly owing to the security provided by climbing and hiding in them. A cub's principal defence mechanism is tree climbing. Young and Beecham (1983) present evidence of the habitat use consequences of this. They found that females used timbered areas significantly more than did males regardless of whether or not the females were accompanied by cubs. The authors suggested that female black bears had an innate maternal instinct to avoid open areas.

Canopy cover may also be important to bears. Direct relationships between canopy cover and bear habitat use are probably limited to thermoregulation; in habitat management guidelines for brown bears (*Ursus arctos*) in France, stands with >80% canopy cover are considered to offer "thermic protection" (Berducou 1994). In addition, the strong relationship that exists between canopy cover and early-successional food species abundance at a site (Noyce and Coy 1990, Costello and Sage 1994) may have a greater habitat use effect.

Thus, the objectives of this study were:

- to measure the ground cover, richness and diversity of fruit-bearing bear plant food species in each habitat type,
  - to measure the structural characteristics (horizontal cover, escape tree density and canopy cover) of each habitat type,
  - to investigate correlations among these variables, and
  - to determine differences among habitats on a variable by variable basis,
- so as to determine an effective means of habitat evaluation, to quantify habitat variables and therefore enable further examination of bear behaviour.

**Methods:****Map creation:**

A New Brunswick Department of Natural Resources and Energy stand inventory of the area was obtained. Stands were aggregated into 14 habitat types (Table II.1) using a classification (Hugie 1982) that was modified to reflect the management-origin habitats present in the study area. Budworm defoliated areas were added using a 1989 defoliation intensity survey map (Resource Conservation Service, Fundy National Park). Only areas having suffered > 60% defoliation were used as these were clearly recognizable in the field.

**Fieldwork:**

Habitat polygons to be sampled and the sampling point within these were randomly chosen (n=113 sites; eleven sites were not sampled for food-related variables)

Two techniques were used to measure the concealment offered by vegetation. These measurements will be referred to as hiding cover distance and horizontal cover density.

Hiding cover distance was measured using a black plastic silhouette of an average-sized New Brunswick female black bear (n=82 bears >5.5 years of age, from Craig 1991) staked into the ground at 45° from a cardinal direction. The observer walked perpendicularly from the silhouette until 95% of the “bear” was obscured (Mollohan 1987, Mollohan and Lecount 1989, Mollohan et al. 1989, Peyton 1987). This distance was recorded. The measurement was repeated for each 90° interval from the original measurement’s bearing.



**Table II.1.** Bear habitat types, field codes (underlined) and percentages of each within the study area.

<p><b><i>Mature Forest:</i></b> (<u>mat</u>) Stands with crown closure-dominant stratum in development stages I, M and O (immature, mature and overmature)</p> <p><i>Pure Hardwood</i> <u>HW</u> (20.3%) <i>Pure softwood</i> <u>SW</u> (11.5%) <i>Mixedwood, hardwood dominant</i> <u>XHW</u> (9.3%) <i>Mixedwood, softwood dominant</i> <u>XSW</u> (12.4%)</p>
<p><b><i>Young Forest:</i></b> (<u>y</u>) Stands with crown closure-dominant stratum in development stages R, S and Y (regenerating, sapling and young)</p> <p><i>Pure hardwood</i> <u>HW</u> (2.4%) <i>Pure softwood</i> <u>SW</u> (8.6%) <i>Mixedwood</i> <u>XW</u> (7.9%)</p>
<p><b><i>Non Forest:</i></b> Non forested areas in one of two conditions:</p> <p><i>Blueberry fields</i> <u>BB</u> (0.6%): commercial blueberry fields <i>Dry non forest stages</i> <u>DNF</u> (2.8%): Old settlements, old fields reverting to forested conditions, abandoned gravel pits reverting to forested conditions, wasteland, alders and non productive forest.</p>
<p><b><i>Management-Origin Classes:</i></b></p> <p><i>Clearcuts and Plantations</i> <u>CP0-6</u> (3.3%), (all species) up to 6 years old in 1994. (1988-1994) <i>Plantations</i> <u>P7-13</u> (7.1%), (all species) 7 to 13 years old in 1994 (1981 to 1987) (predominantly <i>Picea</i> spp.) <i>Pine Plantations</i> <u>PP14+</u> (0.7%), 14 years and older in 1994 (pre-1981). (<i>Pinus Banksiana</i> exclusively). <i>Spruce plantations</i> <u>SP14+</u> (1.9%), 14 years and older in 1994 (pre-1981).</p>
<p><b><i>Budworm Damage Origin Stands:</i></b></p> <p><u>BUD</u> (11.1%): These stands represent stands that were classified as having suffered from 60 to 100% budworm mortality on a mortality survey map produced by the Park in 1989.</p>

Horizontal cover density between 0 m to 2 m from the ground was measured in each cardinal direction using a cover pole (Griffith and Youtie 1988) viewed from 15 m. At each horizontal cover observation point, canopy cover (overstory density) was measured using a spherical densiometer (Lemmon 1957). The observer then proceeded 2 m to a point 17 m from the cover pole to initiate food abundance measurements. Bear food species present (Table II.2) were inventoried and a visual estimate of each species' percent projected ground cover was recorded for each of the eight 2 m by 2 m quadrats making up the 16 m long transect thus laid out between the observer and the cover pole. Estimated cover categories used were from Noyce and Coy (1990). In each quadrat, the number of trees with a diameter at breast height (dbh) greater than 10 cm was recorded. This is probably the smallest diameter that cubs could climb and obtain sufficient concealment and height. The procedure was repeated in each cardinal direction resulting in an area of 128 m<sup>2</sup> being sampled at each site.

Within each habitat type, food measurements were performed until three sites were successively sampled without new species being recorded. The standard deviation of hiding cover measurements for a habitat type was calculated and plotted with each additional sample. Sampling was terminated when the plot showed a stable trend.

**Table II.2:** Scientific name and common name of bear food plant species encountered.

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<i>Amelanchier spp.</i>	Serviceberry, Amelanchier.
<i>Aralia hispida</i>	Bristly sarsaparilla.
<i>Aralia nudicaulis</i>	Sarsaparilla.
<i>Fagus grandifolia</i>	Beech.
<i>Clintonia borealis</i>	Clintonia.
<i>Cornus alternifolia</i>	Alternate-leaved dogwood.
<i>Cornus canadensis</i>	Bunchberry.
<i>Cornus sericea</i>	Red osier dogwood.
<i>Fragaria virginiana</i>	Wild strawberry.
<i>Lonicera canadensis</i>	Fly honeysuckle.
<i>Lonicera involucrata</i>	Fly honeysuckle.
<i>Maianthemum canadense</i>	Wild lily of the valley.
<i>Sorbus spp.</i>	Mountain ashes.
<i>Nemopanthus mucronatus</i>	Mountain holly.
<i>Polygonatum pubescens</i>	Solomon's seal.
<i>Prunus pennsylvanica</i>	Pin-cherry.
<i>Prunus serotina</i>	Black cherry.
<i>Prunus virginiana</i>	Choke cherry.
<i>Pyrus spp.</i>	Apples and crabapples.
<i>Rhus typhina</i>	Staghorn-sumac.
<i>Ribes glandulosum</i>	Skunk currant.
<i>Ribes hirtellum</i>	Bristly gooseberry.
<i>Ribes lacustre</i>	Bristly currant.
<i>Rosa spp.</i>	Rosehips.
<i>Rubus allegheniensis</i>	Common blackberry.
<i>Rubus flagellaris</i>	Northern dewberry.
<i>Rubus hispidus</i>	Dewberry.
<i>Rubus pubescens</i>	Dwarf blackberry.
<i>Rubus strigosus</i>	Red raspberry.
<i>Sambucus canadensis</i>	Common elder.
<i>Sambucus pubens</i>	Red-berried elder.
<i>Smilacina stellata</i>	False solomon's seal.
<i>Streptopus amplexifolius</i>	Twisted stalk.
<i>Vaccinium angustifolium</i>	Sweet low blueberry
<i>Vaccinium myrtilloides</i>	Velvetleaf blueberry
<i>Vaccinium vitis-idaea</i>	Rock cranberry, partridgeberry
<i>Viburnum alnifolium</i>	Hobblebush
<i>Viburnum cassinoides</i>	Northern wild-raisin

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### Analysis:

Sampling site and habitat-type values for hiding cover, horizontal cover, canopy cover, safety trees, species richness, Simpson's dominance diversity index (Simpson 1949) and percent cover of food species were derived from field data.

Boxplots (Tukey 1977) were plotted to illustrate the abundance levels of each variable for each habitat.

The non-parametric Spearman rank order correlation technique (Rohlf and Sokal 1995) was used since the sample-site data grouped by variable were either not normally distributed or did not have equal variances. The Kolmogorov-Smirnov Test was used to verify the normality of distributions. Equality of variance testing was performed using the Levene Median Test. Both tests were performed using SygmaStat v.1.0 (Jandel Scientific Inc. 1994).

Correlation analysis was performed without the blueberry field data because these sites are commercially managed for high food species ground cover and low diversity. Additionally, due to the low shrub nature of the *Vaccinium* spp. cultivated, the habitat cannot provide horizontal cover, canopy cover, nor safety trees. These managed sites would have clearly been outliers.

To complement the boxplot display, the sampling site results were grouped by habitat and the differences among group means for each variable were investigated by analysis of variance.

To select the proper analysis, the Kolmogorov-Smirnov Test was used to verify the distribution of all groups. Equality of variance testing was performed using the Levene Median Test. Both tests were performed using SygmaStat v.1.0 (Jandel Scientific Inc. 1994). Since many groups failed the normality and equality of variance tests, the non-

parametric Kruskal-Wallis one-way analysis of variance on ranks (Sokal and Rohlf 1995) was used to test for differences among groups.

Multiple comparison tests were then employed to identify which groups were different from each other on the basis of rank. The Tukey-Kramer method was used since it offers the lowest experimentwise error rates (Wilkinson et al. 1996) and it is designed for unequal samples sizes when all pairwise comparisons are executed (Sokal and Rohlf 1995) as was the case in this unplanned analysis of variance. The critical values of Q used for this test were calculated at an experimentwise significance level of  $\alpha=0.05$  level (and  $\alpha=0.2$  for exploratory data analysis, due to the large amount of groups being compared and the consequent reduction in  $\alpha$  for each individual comparison [Sokal and Rohlf 1995]). Winks v4.1c (TexaSoft 1996) was used for both the Kruskal-Wallis and Tukey-Kramer procedures.

### **Results and discussion:**

To reduce repetition, the presentation and discussion of the habitat-type sampling results will be done simultaneously on a variable by variable basis. The analysis of variance results and discussion will follow.

### **Fieldwork:**

One hundred and two (102) sites were sampled for structural and food variables. This represents an average of 7.3 sites (SD=2.3, range: 5-12) for each of the 14 habitat types. An additional 11 sites were sampled for structural characteristics only, and as such, the analysis of structural characteristics is based on a sample of 113 sites.

### Habitat type specific results and discussion

Sampling and correlation analysis results are presented in Tables II.3 and II.4.

**Table II.3:** Results of multi-resource sampling for each habitat type.

Habitat	<i>n</i> <sup>a</sup> ( <i>n</i> <sup>b</sup> )	$\bar{x}$ Hiding cover distance (m) ( <i>SD</i> )	$\bar{x}$ Horiz. cover (%) ( <i>SD</i> )	$\bar{x}$ Canopy cover (%) ( <i>SD</i> )	$\bar{x}$ Safety trees (stems/Ha) ( <i>SD</i> )	$\bar{x}$ food cover per site (%) ( <i>SD</i> )	$\bar{x}$ Food spp. richness per site ( <i>SD</i> )	$\bar{x}$ Food spp. diversity index per site ( <i>SD</i> )
matHW	8 (1)	38.7 (11.2)	29.7 (16.6)	84.1 (17.4)	1259 (495)	19.0 (14.7)	5.5 (2.9)	0.491 (0.276)
matSW	8	28.4 (7.5)	55.3 (22.1)	77.5 (7.5)	1465 (497)	14.6 (11.7)	3.9 (1.8)	0.263 (0.231)
matXHW	5	24.9 (4.6)	53.4 (23.2)	87.2 (11.5)	984 (352)	42.1 (29.2)	7 (1.9)	0.402 (0.135)
matXSW	8 (2)	35.5 (18.8)	38.8 (26.8)	86.7 (6.5)	984 (344)	17.2 (18.5)	4.9 (3.3)	0.256 (0.315)
yHW	5 (4)	21.4 (7.7)	58.0 (27.4)	90.6 (10.2)	703 (537)	29.9 (15.2)	8 (2.2)	0.325 (0.175)
ySW	6	17.6 (7.2)	80.2 (16.5)	88.5 (12.2)	937 (431)	9.6 (6.0)	3.2 (1.0)	0.130 (0.177)
yXW	5	18.0 (5.1)	84.7 (7.3)	93.1 (4.9)	985 (570)	25.9 (19.5)	8.8 (3.1)	0.465 (0.214)
BUD	11	13.5 (5.0)	73.8 (20.8)	67.3 (19.9)	249 (272)	38.1 (23.1)	7.4 (2.2)	0.399 (0.278)
CP0-6	12	32.6 (16.4)	29.4 (10.5)	0	0	57.2 (28.9)	6. (1.5)	0.516 (0.157)
P7-13	9 (1)	16.4 (5.7)	58.7 (22.2)	14.3 (19.7)	47 (148)	56.4 (28.3)	6.5 (2.2)	0.454 (0.094)
PP14+	8	15.9 (3.6)	87.6 (3.7)	93.5 (8.3)	1582 (521)	42.9 (38.2)	8.4 (0.9)	0.521 (0.176)
SP14+	6	10.2 (2.6)	86.9 (6.5)	49.9 (38.5)	312 (349)	44.4 (24.3)	6.2 (2.0)	0.282 (0.118)
BB	4 (2)	124.5 (23.6)	3.1 (0.7)	0	0	68.8 (22.0)	3 (1.4)	0.403 (0.151)
DNF	7 (1)	29.2 (14.2)	38.2 (11.6)	19.7 (33.3)	39 (59)	28.0 (13.1)	7.4 (2.5)	0.671 (0.082)
Total	102 (11)							

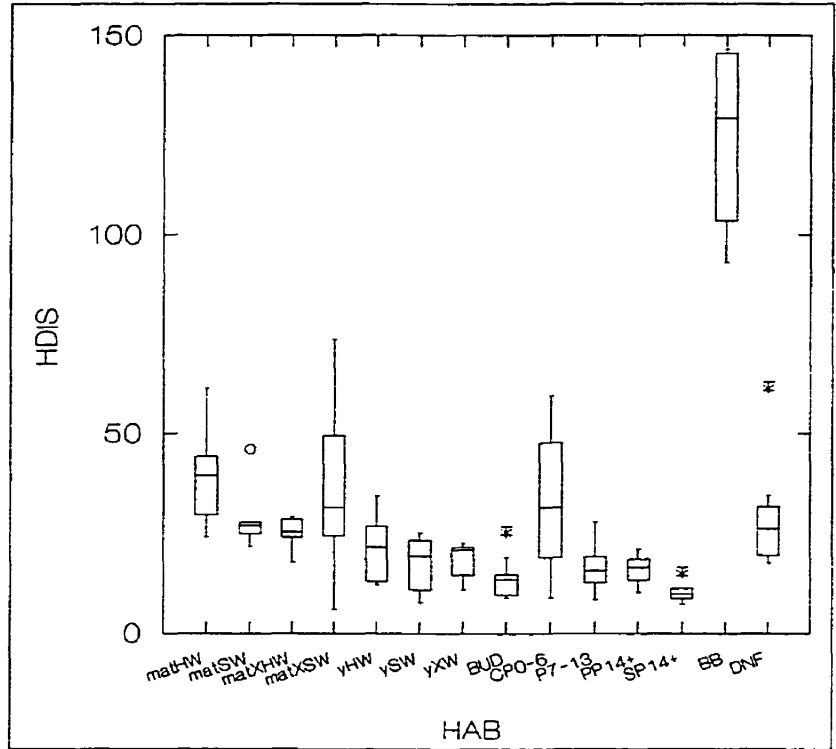
*n*<sup>a</sup>: Sites sampled for all variables.

*n*<sup>b</sup>: additional sites sampled only for hiding cover distance, horizontal cover density, canopy cover and safety trees.





*Hiding cover distance:*



**Figure II.2:** Boxplots of hiding cover distance (m) for different habitats. (Box defines interquartile range, median is represented by line within box).

In terms of hiding cover distance, commercial blueberry fields (BB) are the most striking (Figure II.2 and Table II.3). The median is greater than that of other habitats. The interquartile range is more dispersed than that of other habitats. The management origin of the BB habitat is responsible: there are no trees nor shrubs; thus hiding distance is essentially the distance the observer walked before entering forest.

Mature habitats (mat), CP0-6 and DNF can be grouped, albeit visually, into a “medium” distance group. The remaining habitats (young forest [y], budworm origin and management origin) are all characterized by low distances. This is related to stand maturation: a thick canopy eventually forms resulting in a sparse understory caused by self-thinning of trees, self-pruning of limbs and shade-limited regrowth. The CP0-6 and

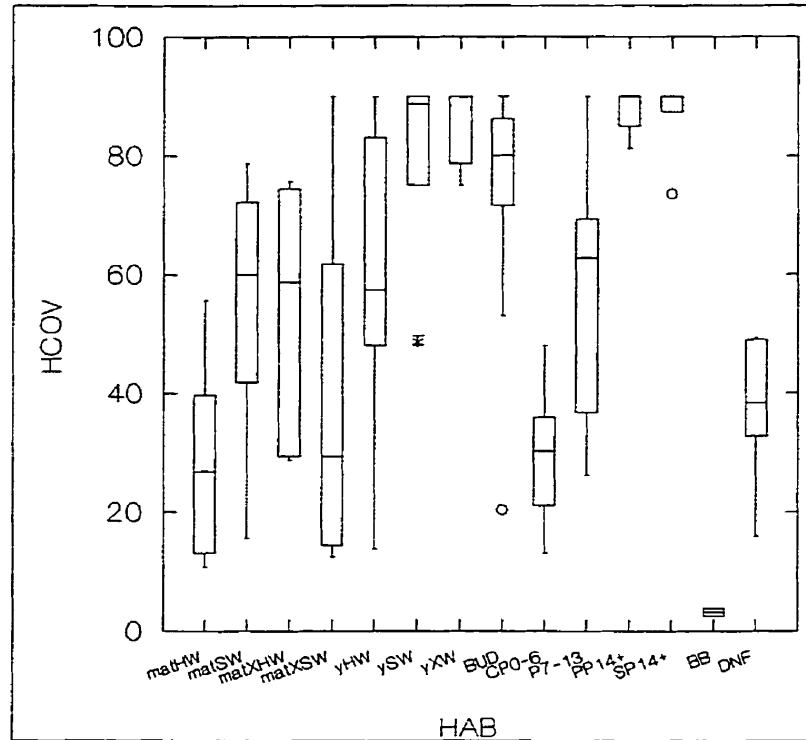
DNF sites do not have enough vegetation to provide cover. The younger stands forming the low distance group afford much understory vegetation.

With regards to hiding cover distance, the correlation analysis (Table II.4) shows the only significant or strong correlation to be with horizontal cover density ( $r=-0.76$ ,  $P<0.01$ ). A correlation with stand age (not measured) probably exists.

The correlation is a technical one; both variables reflect the different concealment measurement techniques. The strong correlation ( $-0.76$ ), its direction and its significance ( $p<0.01$ ) shows an expected orientation. Thus either method provides an adequate measure of concealment. Topography probably explains why the correlation is not stronger. Topography has more influence on hiding cover distance measurements as the distances involved (over 100 m in some cases) are more likely to span terrain features than the 15m from which horizontal cover density is measured.

The cover pole is less subjective. Counting obscured sections of the pole is more repeatable among observers and study areas. The disappearance of the bear may be hard to standardize, especially as there is no "standard" bear. The shorter distances involved in the pole technique make it quicker.

*Horizontal cover density:*



**Figure II.3:** Boxplots of horizontal cover density (%) for different habitats.

Again, blueberry field results (Figure II.3 and Table II.3) stand out in their location and spread. The median and mean ( $\bar{x}=3.1\%$ ), interquartile range and standard deviation ( $SD=0.7\%$ ) are much lower than other habitats'.

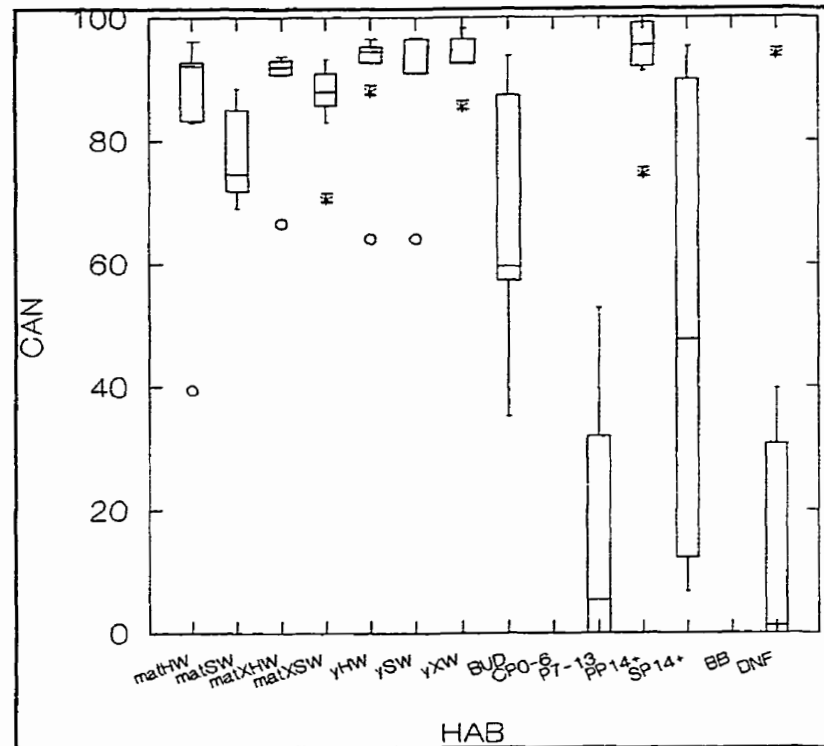
This strengthens the previous section's assertion that the blueberry field habitat's hiding cover distance is related more to the distance from the sampling site to the edge of the field than it is to the concealment offered. Regardless, BB offers the least concealment. Management practices are responsible.

Given the negative correlation between hiding cover distance and horizontal cover density, it is surprising that these boxplots are not inversed images of the previous section's. The younger habitats' results are similar. Most also provide the greatest concealment, with the exception of yHW and P7-13, whose medians are lower (and ranges wider) than those of other young habitats. This differs from the hiding cover distance

results (though CP0-6's relative position was maintained). This could be due to sampling technique. With respect to hiding a bear silhouette, yHW and P7-13 have more cover that is low to the ground. This vegetation cannot conceal the 2 m tall pole's upper sections. The yHW measurements have the greatest spread while the P7-13 group's spread indicates departures from this low ground cover explanation at different sites. Mature softwoods (matSW) and matXHW and yHW and P7-13 are also in the medium density group.

While two habitat groupings were seen when hiding cover distance was considered, three groupings are apparent with horizontal cover density. The low cover group includes: matHW, matXSW, CP0-6 and DNF. The CP0-6 and DNF habitats do not offer much concealment due to their young and regenerating nature, there is not enough vegetation. Lack of understory vegetation in the matHW habitats is characteristic and explains these results. It is harder to explain how the matXSW habitat would be more open than the matXHW habitat; this could be due to low sample size: the few sites sampled may have been very open. The hardwood dominated mix would have been expected to be more open.

As noted, horizontal cover density is correlated with hiding cover distance; it is also weakly, but significantly, positively correlated ( $r=0.35$ ,  $p<0.01$ ) to canopy cover (Table II.4).

*Canopy cover:*

**Figure II.4:** Boxplots of canopy cover (%) for different habitats

The broad range and mid-level median of the SP14+ habitat are interesting (Figure II.4 and Table II.3). The values range from almost 0% to nearly 100% and are normally distributed. This is because stands of this plantation habitat are reaching the age when canopy “closure” occurs; however, some stands in the sample had not yet reached closure. Pine plantations of the same age (PP14+) have closed canopies. The difference between these two habitats is due to factors such as stocking intensity, species growth rate, patchy survival of seedlings, minor age differences and management practices. Some plantations of this age are pre-commercially thinned.

Except for the intermediate SP14+ and BUD, the other habitats can be placed into high and low canopy cover groups according to origin. The unmanaged mature and young habitats have high canopy cover whereas the management-origin habitats are not old

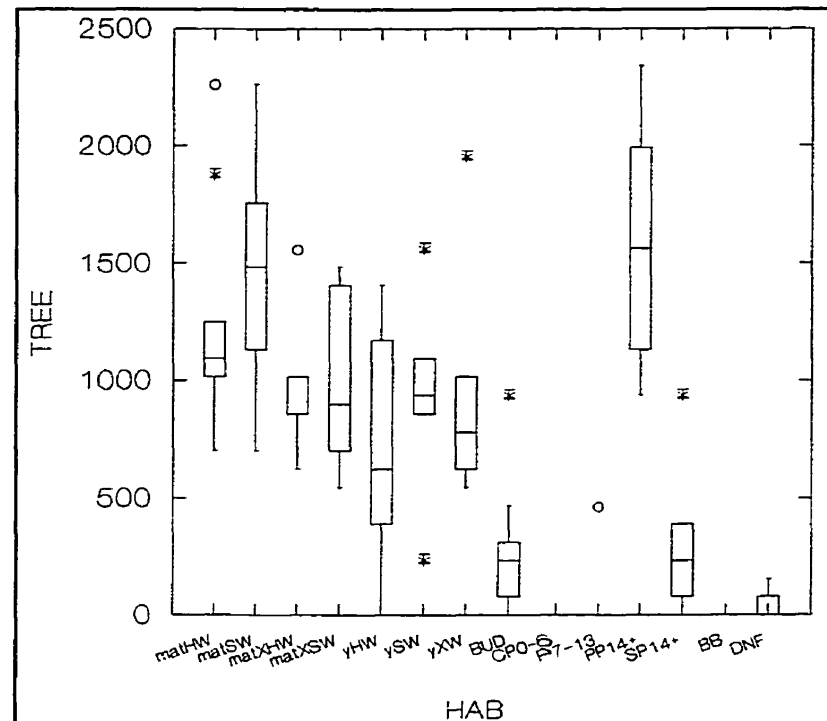
enough or dense enough to provide canopy cover. The BB and DNF habitats have inherently low canopy cover.

The budworm-origin habitat is intermediate due to its patchy nature (typical of the naturally occurring gap-disturbance regime [Woodley and Forbes 1997]). This patchiness results from the presence of mature spruce that survived the budworm outbreak and the presence of various stages of balsam fir regeneration.

In addition to the weak correlation with horizontal cover density mentioned in the last section, there is a strong correlation ( $r=0.72$ ,  $p<0.01$ ) with safety tree density (Table II.4). This makes intuitive sense: when more trees are present, more canopy cover is provided. In future work, perhaps one measurement of concealment would be sufficient.

There is also a moderate negative correlation ( $r=-0.40$ ,  $p<0.01$ ) with food species ground cover and a weak negative correlation with food species diversity ( $r=-0.21$ ,  $p=0.04$ ). These correlations, especially the former, are logical considering that the majority of bear food plants are early successional species such as *Vaccinium* spp. and *Rubus* spp. (Mattson 1990, Noyce and Coy 1990) or, in the case of *Cornus canadensis*, shade-tolerant species that thrive when the canopy is opened (Crane 1989).

*Safety tree density:*



**Figure II.5:** Boxplots of safety tree density (stems/Ha) for different habitats.

Differences in safety tree density among habitats (Figure II.5 and Table II.3) are intuitive. The mature (mat) and young (y) habitats have abundant safety trees whereas the management-origin habitats have few or none. The PP 14+ habitat is an exception to this, as it has the greatest density of safety trees.

It is obvious why mature (mat) habitats would provide abundant safety trees; however, young (y) habitats also provide many owing to the span of development stages included: regenerating, sapling and young. The regenerating stage has few trees greater than 10 cm dbh; once stands attain the sapling or young development stages, the majority of trees are of that size.

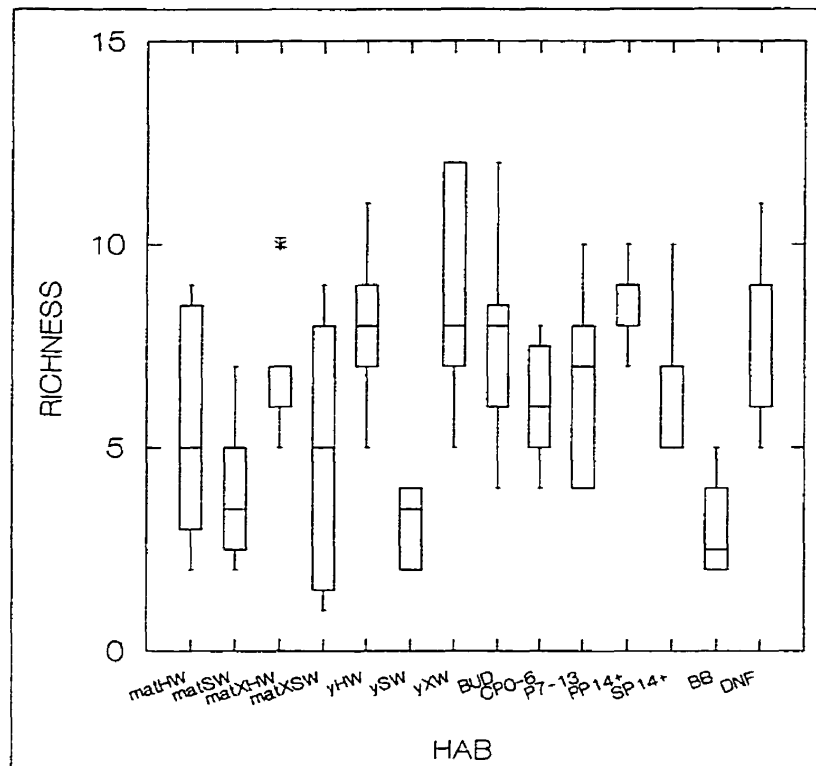
The PP14+ habitat provides the greatest safety tree density due to its high intensity management origin: these pines were selected for rapid growth and stands have received silvicultural treatments; some of these plantations are a few years older than those of the

SP14+ habitat and thus more trees have reached 10 cm dbh. However, most are only 10 cm dbh or slightly larger. There are no truly large trees in the PP14+ habitat. The SP14+ habitat has less safety trees due to the slower growth habits of the species involved. The budworm-origin habitats have a low density of climbable trees, mainly mature birch and spruce that are unaffected by budworm.. Though balsam firs probably remained climbable for some years after death, the majority have now fallen and regrowth is not yet sufficiently large.

As mentioned previously, there is a strong correlation between safety tree density and canopy cover ( $r=0.72$ ;  $p<0.01$ ) (Table II.4). It is therefore not surprising that safety tree density is correlated with food species ground cover ( $r=-0.45$ ,  $p<0.01$ ) and food species diversity ( $r=-0.25$ ,  $p=0.01$ ) given their own correlation with canopy cover. This is logical in light of the relationship between canopy cover, safety tree density and the early successional plant species at the base of bear diets.

The two food variables' correlations with safety tree density are stronger than their own correlations with canopy cover (for food species cover:  $r=0.45$  vs.  $r=0.40$ , both at  $p<0.01$ . For food species diversity:  $r=-0.25$ ,  $p=0.01$  versus  $r=-0.21$ ,  $p=0.04$ ). This is odd since measuring canopy cover directly appears to be superior than counting safety trees, as even 9 cm dbh trees contribute to canopy cover. Perhaps the higher correlation encountered is due to the low number of samples ( $n=98$  sites) or another, unknown, factor.



*Food species richness:*

**Figure II.6:** Boxplots of species richness for different habitats.

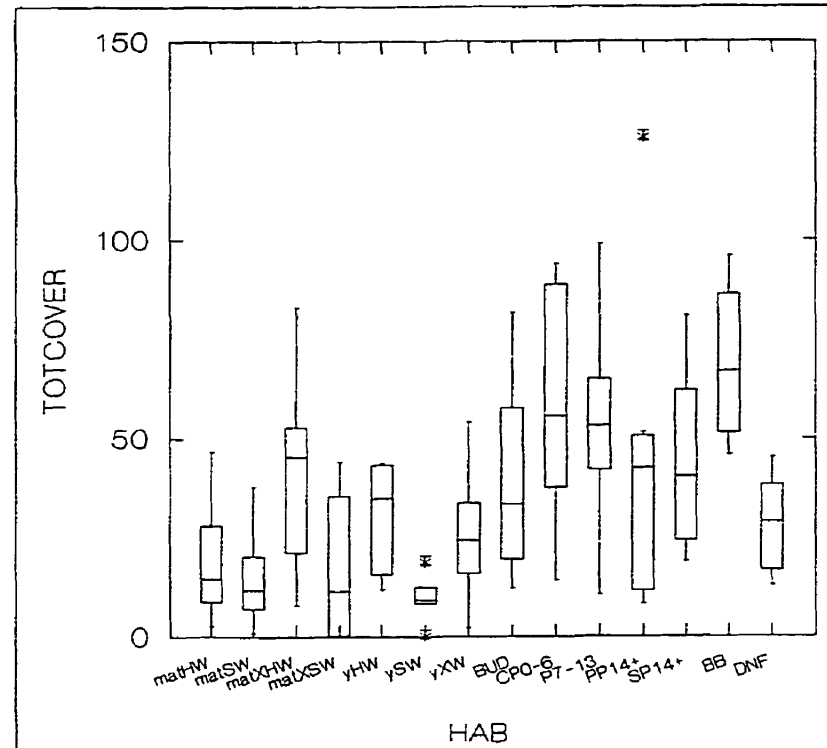
Commercial blueberry fields stand out (Figure II.6 and Table II.3). Their low richness is an artefact of management practices. Only two *Vaccinium* species are cultivated and competing vegetation is controlled. Low richness is not limited to blueberry fields but extends to the mature and young softwood habitats. This is characteristic of softwood habitats (Costello and Sage 1994) and may be related to softwoods having the lowest overall food species ground cover ( $\bar{x}=9.6\%$  and  $\bar{x}=14.6$  respectively). No other interpretation emerges when considering the range of variables measured. The low richness of softwood habitats may relate to an unmeasured variable such as soil fertility or drainage.

The yHW, yXW, BUD and PP14+ habitats show the greatest median richness. The other habitats spread out widely within a similar range. It appears that mature habitats (mat) have slightly lower richness than young (y) or management origin habitats. These

habitats' lower ranges reach the median of the mature habitats with the exception of matXHW. The mature stands may reflect an established ecological community while younger stages are more dynamic and hence richer. The management-origin habitats' high richness may be attributed to the presence of species that survived harvesting of the original stand and are not typically early successional species.

There are moderate correlations with food species cover and diversity ( $r=0.38$  and  $r=0.48$  respectively; both at  $p<0.01$ ) (Table II.4). The latter correlation is expected since richness is integrated into diversity calculations. The ecologically relevant correlation is that with food species cover. With greater food species ground cover, more species can be expected to be present.

*Total ground cover of food species.*



**Figure II.7:** Boxplots of food species ground cover (%) for different habitats.

The ySW sites have the lowest food species cover and the narrowest spread even when outliers are included (Figure II.7 and Table II.3). They do not overlap other young, spruce-dominated softwood types (CP0-6, P7-13 or SP14+) perhaps because of high density natural regeneration. The ySW habitats are dominated by thickets where little light reaches the ground. This is not reflected in safety tree or canopy cover results as the trees are less than 10 cm dbh and the elbow-height spherical densiometer measurements reflect canopy cover and not ground-level light. The other young softwood habitats are of management origin and either age or spacing of trees provides sufficient light penetration for plant establishment and survival. As these plantations replace natural stands that may not have been softwood dominated, some food plants present are possibly remnants of the pre-harvest community not normally found in softwood habitats.

Commercial blueberry fields have the highest median and mean. However, their interquartile range overlaps that of CP0-6 and P7-13 and SP14+. These three habitats are not necessarily as productive as blueberry fields. Edible biomass was not measured, only food species ground cover. There is obviously a strong relationship between ground cover and edible biomass and, as such, these three habitats are indeed quite productive.

However, due to commercial management, blueberry fields likely produce the most edible biomass; however, the majority of this biomass is harvested and not consumed by wildlife.

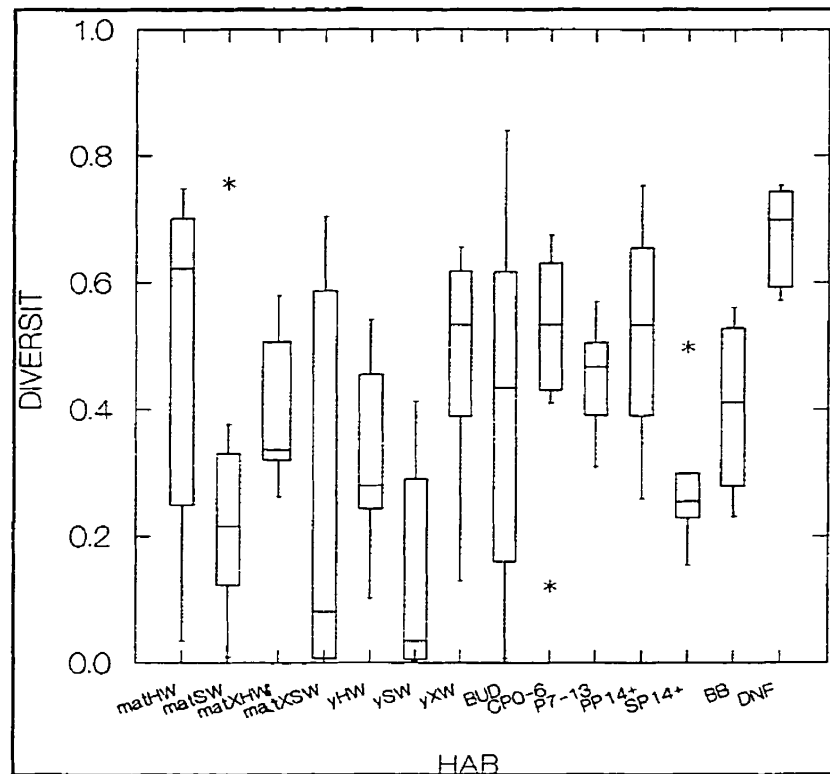
Though slightly overlapping, two groupings can be identified. The matHW, matSW, matXSW and ySW habitats have low food species ground cover whereas all other habitats, including matXHW, are included in the high cover group.

As previously mentioned, the low food cover of natural softwood habitats may relate to canopy density or to their location on less fertile sites. Costello and Sage (1994) and Noyce and Coy (1990) reported that their softwood sites had the lowest quantity of food. Perhaps the low food cover in matHW habitats is because they are climax stages typified by a closed canopies and subsequent paucity of ground-level vegetation. The habitats with higher levels of food cover are younger, more open-canopied habitats and may still have remnants of the pre-harvest community. Costello and Sage (1994) note that the opening of the canopy from selective or shelterwood logging created conditions in managed habitats not found in unmanaged habitats. The increased sunlight encouraged the growth of shade intolerant shrubs. Though no such harvesting techniques were used in the Fundy study area, open canopy habitats clearly had more food species ground cover.

The correlation with food species richness ( $r=0.38$ ,  $p<0.01$ ) (Table II.4) has been mentioned. Moderate negative correlations exist with canopy cover and safety tree density ( $r=-0.40$  and  $r=-0.45$  respectively, both at  $P<0.01$ ). Their orientation and significance is

not surprising but greater strength may have been expected given the emphasis placed upon canopy openness by other authors (Noyce and Coy 1990, Costello and Sage 1994).

*Food species diversity:*



**Figure II.8:** Boxplots of food species diversity for different habitats.

Simpson's "dominance diversity" index (Simpson 1949) was used instead of other indices since it weighs abundant species more than rarer species. Since rare species should vary more between sites of a same habitat, this index should not vary as much from one sample to another. It was assumed that bears would be more attracted to sites with one or two dominant species; such dominance was to be reflected in the index. Such a behaviour may optimize foraging efficiency as opposed to eating small amounts of rare species as they fruit over time.

The diversity results spread out widely (Figure II.8 and Table II.4). The Budworm habitat has a normal distribution with the widest symmetrical interquartile range and total range. This is probably due to its origin: the budworm infestation left remnants of the original forest along with regenerating patches. Given the habitat's inherent patchiness, a wide variety of microsites exist that suit the requirements of different species. A wide

spread results. The DNF habitats show the greatest median diversity yet their small interquartile range suggests that the assemblage of principal species is balanced and stable. They are consistently the most diverse sites.

The matXSW habitat has the largest interquartile range yet it is not normally distributed owing to the influence of 2 sites with one food species and resultant zero diversity. This is probably a sampling anomaly.

The matHW habitats have a high diversity index. This is a reflection of the dominance of beech and *Aralia nudicaulis*. These habitats do not have high food species cover yet are moderately rich.

Perhaps the only trend is that 3 of 4 plantation habitats have great diversity. This may be related to the overwhelming dominance of *Cornus canadensis* and *Rubus strigosus* observed at these sites.

Simpson's "dominance diversity" (Simpson 1949) may reflect a bear's decision-making in its over-representation of dominant species; however, future work should compare the Simpson index to other, more "egalitarian", indices. The results obtained here may be an analysis artefact. For example, a habitat (matHW) with low total food species cover and only moderate species richness rates as the third most diverse habitat. A diversity index for bear management use might consider weighing the cover of each food species more heavily than their relative dominance. In this study, the Simpson's index results do not agree with intuitive expectations of diversity.

All significant correlations with food species diversity were mentioned previously; however, to further the previous point, there is no correlation between food species cover and food species diversity ( $r=-0.03$ ,  $p=0,78$ ) when all results are considered simultaneously (Table II.4). This shows that the Simpson index does over-emphasize the relative dominance of species while overlooking the total cover of food species at a site.

### Analysis of variance and multiple comparisons:

Kruskal-Wallis results (Table II.5) were all highly significant ( $p \leq 0.002$ ). However, this only means that at least one habitat is different from all others. This is illustrated by the Tukey-Kramer multiple comparison tests results (Table II.6): the graphical representations show that, for each variable, at least one habitat was significantly different from another, but the groupings of “non-different” habitats (underlined) were not exclusive. All groupings share common habitats; there are no clear separations between groups of habitats. Though not presented, the results for exploratory testing at  $\alpha=0.2$  are nearly identical and no distinct groupings were shown. This is not surprising given the sampling results. As the boxplots of Figures II.2 to II.8 have shown, the similarity in the medians and the considerable spread in each habitat’s results leads to much overlap. As so much overlap exists between the dispersion measures, the multiple comparison tests cannot exclude the possibility of similarity.

Additional sampling could more precisely define the location and dispersion of each variable’s distribution for each habitat, and perhaps uncover a few more significant differences. However, there are ecological reasons behind such overlap. The habitat types employed are somewhat coarse and encompass much natural variation. A more concise classification scheme could have been used but would have required more categories and consequently, even more sampling.

The variety of foods eaten by bears is another ecological reason why greater differences between habitats were not shown: all habitats had at least 3 or 4 food species present yet never more than 11 per site. Given the narrow range in values present and the small sample obtained, simply comparing the number of food species present was not conducive to uncovering major ecological differences. Increased sampling may have led to the discovery of additional significant differences. It appears that, in New Brunswick at



least, the differences in species richness or other variables between such coarse habitat types are not very large.

**Table II.5:** Results of Kruskal-Wallis testing on habitat variable levels between different habitats based on ranks.

Habitat variable	Kruskal-Wallis H (13 df)	Significance	Conclusion
Hiding cover distance	67.42	$p < 0.001$	Reject $H_0$ <sup>a</sup>
Horizontal cover	70.87	$p < 0.001$	Reject $H_0$ <sup>a</sup>
Canopy cover	82.68	$p < 0.001$	Reject $H_0$ <sup>a</sup>
Safety trees	87.91	$p < 0.001$	Reject $H_0$ <sup>a</sup>
Food species cover	40.99	$p < 0.001$	Reject $H_0$ <sup>a</sup>
Food species richness	40.29	$p < 0.001$	Reject $H_0$ <sup>a</sup>
Food species diversity	32.98	$p = 0.002$	Reject $H_0$ <sup>a</sup>

<sup>a</sup> Therefore accept  $H_1$ : There is a statistically significant difference between habitats.

**Table II.6:** Tukey-Kramer multiple comparison test results at the 0.05 significance level. The ranks of any two groups underscored by the same line are not significantly different.

Hiding cover distance	SP14+	BUD	PP14+	P7-13	ySW	yXW	yHW	mat XHW	DNF	CP0-6	mat SW	mat XSW	mat HW	BB
	-----													
Horizontal cover density	BB	CP0-6	mat HW	mat XSW	DNF	mat XHW	mat SW	yHW	P7-13	BUD	ySW	yXW	SP14+	PP14+
	-----													
Canopy cover	CP0-6	BB	P7-13	DNF	SP14+	BUD	mat SW	mat XSW	mat HW	mat XHW	ySW	yHW	yXW	PP14+
	-----													
Safety trees	CP0-6	BB	P7-13	DNF	BUD	SP14+	yHW	yXW	ySW	mat XHW	mat XSW	mat HW	mat SW	PP14+
	-----													
Food cover	ySW	mat SW	mat XSW	mat HW	yXW	DNF	yHW	PP14+	BUD	mat XHW	SP14+	CP0-6	P7-13	BB
	-----													
Species richness	ySW	BB	mat SW	mat XSW	mat HW	CP0-6	SP14+	P7-13	mat XHW	DNF	BUD	yHW	yXW	PP14+
	-----													
Diversity	ySW	mat SW	SP14+	mat XSW	yHW	BB	mat XHW	BUD	P7-13	yXW	mat HW	CP0-6	PP14+	DNF
	-----													

**Conclusion:****Habitat-type variable specific:**

Both hiding cover distance and horizontal cover measurements represent the amount of concealment provided. However, the use of the cover pole over the silhouette is recommended because of the former's repeatability across observers and its insensitivity to terrain features. Only a 1 m tall pole is required as bears are rarely taller than four feet. However, results from the 2 m pole would be more useful as the data collected could perhaps be applied to other species.

The results obtained generally show that younger habitats provided more concealment to bears than mature habitats did.

Canopy cover and safety tree density showed similar trends: management-origin habitat types had lower canopy cover and safety tree density than natural habitats. This is due to tree spacing for the younger habitats and age for older ones. The variables were strongly and significantly correlated. Since interest lies in the security provided by climbable stems in the habitat, it would be more efficient to only record safety tree density since, at a certain tree density threshold, it can be assumed that canopy cover is provided. Whereas, if only canopy cover was measured, it is not known if the trees providing the cover are climbable.

Food plant species richness varied greatly among habitats. No clear trend emerged but generally, younger habitats were richer than older ones, and natural softwood habitats were the poorest; this was attributed to their correspondingly low ground cover of food species. Poor soil fertility or drainage characteristics at these sites could be the cause.

Ground cover of food species generally followed the same trend as species richness: younger habitats had more food species ground cover than older ones, with

natural softwoods having the least. Food species coverage can be attributed to canopy openness.

Food species diversity was calculated using a perhaps-inappropriate index; future researchers may wish to use an index that does not over-represent some species.

It should be noted that plant species known to be consumed by bears were listed; however, there are likely differences in their electivity. It is conceivable that some abundant species surveyed are not fancied by bears and eaten only as a last resort.

An underlying assumption was that food productivity was roughly proportional to ground coverage. Further work should incorporate food species electivity and translate ground coverage of a species into edible biomass estimates or even caloric availability. Furthermore, no animal food sources were surveyed; inventories of rotten stumps sought as a source of insects could be incorporated in future work.

Due to the wide range of habitats surveyed, there was enough variation within and among the sites that, while ensuring that some sites were significantly different, did not allow for any clear separation of habitats into distinct groups based upon levels of a variable within them.

Future efforts should focus on clarifying the correlations present as there is now a good idea of what variables should be measured.

However, bears' reactions to the variables have yet to be assessed. Selection testing should help identify important variables.

### **Chapter III**

#### **Black bear habitat selection in southern New Brunswick**

##### **Introduction:**

Black bear habitat selection studies have been performed throughout the species' range and have generally been concerned with reactions toward broadly defined habitat types. Few studies have investigated bears' reactions to habitat features such as food species diversity or availability of concealing vegetation.

Presumably, bears base habitat use decisions on the mix of such features available. By describing bear spatial use in Chapter I and the level of potentially influential habitat features within habitat types in Chapter II, the foundations of an examination of bear habitat selection have been laid. Both datasets will now serve to evaluate bears' reactions towards habitat types and habitat features.

In addition, behaviours towards two potentially influential landscape variables: distance from nearest water and area to perimeter ratio of habitat polygons will be examined.

Any relationship between bear location and distance to water is likely to be unrelated to water availability. Water is abundant and widely distributed in the area. Instead, any relationship between distance to water and bear location would probably be linked to watercourse-related topographical features: perhaps bears prefer following stream gullies rather than traversing them. Conversely, bears may avoid using streams because of the thick alders (*Alnus spp.*) that often line them. Or, perhaps bears prefer the cover provided by uncut stream buffer strips that line watercourses through harvested areas and plantations.

Ecotones are generally regarded as richer than either of the habitats that merge to create them (due to "edge effect": Leopold 1933). If these sites support greater food species diversity or abundance, they may be important to bears. Since the quantity of edge

of a polygon of a set area increases with its geometric complexity, more convoluted habitat polygons offer more edge per unit area than those with simpler shapes. Bears were predicted to prefer habitat polygons with greater availability of edge. This is relevant since managed habitat polygons in the area generally have simpler shapes than those of natural habitats.

The objectives of this section were to assess the response of bears to habitat types, habitat type groupings and individual variables. Identifying responses to different levels of habitat variables will help explain why some habitats are used more than others.

## **Methods**

### **Study area**

The study area was defined by the outer limits of the composite home range formed by overlaying the annual 95% adaptive kernel home range estimates of all bears. (Chapter I).

### **Location selection**

Only locations derived from ground-based radio-tracking were used since the error associated with each was known. The area of a 95% probability ellipse (“error ellipse”) surrounding each location was calculated by Locate II (Nams 1991) during position estimation (Chapter I).

The area of the confidence (“error”) ellipse is the best available error measure for radio-triangulation (White and Garrott 1990). The area succinctly summarizes the three main independent factors affecting a location estimate’s precision (Saltz and Alkon 1985): variance around the bearing, distance from the receiving site to the animal and intersection angle of the bearings.

The intent was to select a mean error ellipse area smaller or equal to that of the mean area of habitat polygons. Each habitat polygon's area was measured. The mean, standard deviation and median of polygon area were derived using IDRISI GIS. In keeping with guidelines (Saltz and White 1990, Saltz 1994), the locations used in habitat use analyses were selected by using an error ellipse area upper limit; this maximum size was determined iteratively by considering the resultant mean error ellipse area of all locations with a error ellipse smaller than the cut-off.

All bear locations were pooled since there were insufficient locations for each animal to allow individual analysis of behaviour. Consequently, it had to be assumed that all bears in the sample behaved similarly.

### Season

Only summer and fall data (July 6 to early November) were used. There were insufficient usable locations (n=73 from six bears) to analyse spring habitat use. Including these spring locations with the summer and fall sample was inappropriate as one principal variable associated with bear habitat use - plant-origin food - (Jonkel and Cowan 1971, Reynolds and Beecham 1980, Garshelis and Pelton 1981, Rogers 1987) is essentially absent during the spring. Locations from the summer and fall were pooled due to the small sample (n=417 from 10 bears) of usable locations from this period. No nighttime locations were obtained.

### Analysis map creation

#### *Landscape variables*

Since the few aerial relocations obtained were excluded and owing to the nature of home range estimation, the study area included large areas without bear locations. These were primarily areas distant from roads.

Including these “bearless” areas in analyses would cause the areas to be considered as available to bears yet not used by them. However, the lack of bear locations does not mean that these areas were unsuitable to or unused by bears; it is an artefact of the tracking technique. It was impossible to detect bears there. Considerable bias would result if such areas were included without being able to detect bears within them.

The distance from a road within which bears could be confidently located was calculated and used to remove (mask) all areas beyond it. This road buffer mask was subsequently applied to all analysis maps.

IDRISI GIS was used to create raster maps of both distance from roads and from streams. Each 10 m map cell (pixel) was assigned a value corresponding to its distance from the nearest feature of interest.

Each habitat polygon’s area to perimeter ratio was calculated and represented in a map where each 20 m map cell was assigned the value of the perimeter to area ratio of the polygon to which it belonged.

#### *Categorical variables (Bear habitat type maps and variants)*

The habitat map derived from the stand inventory (Chapter II) was masked (cut out) with both the 95% adaptive kernel composite home range and the distance from road mask. The resultant map (Figure III.1) served as the base for all categorical variable maps. Maps of forest type (hardwood, softwood, mixedwood, managed and non-forest), development stage (mature, immature and non-forest) and management regime (natural, managed and non-forest) were created by grouping habitat types according to the variable of interest (see Table II.1).

Habitat type multi-resource descriptions (Chapter II) were linked to bear locations by creating “distribution” maps of the features measured. Each habitat polygon’s category label could have been replaced with the habitat type’s mean surveyed value for the variable



of interest. However, this would amount to replacing a categorical label with a numerical one and would not change the proportions of each habitat available to a bear within the landscape. In addition, though values differ among habitats, bears may not perceive or react to minute differences. For example, mean hiding cover distances for mature softwood and dry non-forest habitat types were 28.4m and 29.2 m respectively.

The intent was not to re-label the map, but rather to create independent maps of each variable by grouping habitats together based solely upon their levels of a variable.

However, multiple comparison tests (Chapter II) did not clearly separate out independent groupings of habitat types: in all cases groups overlapped.

Groupings of habitats were thus created for each variable by using box and whisker plots (Figures II.2 to II.8) and bar graphs. Though habitat groupings were determined visually, the difference between the mean of the habitat at the upper limit of one abundance group and that of the habitat with the next highest mean (the lower limit of the next group) was greater than the difference between means of the next highest (or lowest) habitat within each habitat's respective group.

The field data were then grouped according to this scheme. Kruskal-Wallis one way analysis of variance on ranks tests and Tukey-Kramer multiple comparison tests on ranks were used to verify that the new grouping scheme resulted in independent habitat groups.

The new groups consisted of high, medium and low abundance categories. (A habitat's membership in a category was not constant, it varied with the variable considered). The grouping schemes were then applied to the GIS database to create maps reflecting the each variable's abundance. The groupings based on levels of a given variable were treated as "classical" habitats from this point on.

Habitat selection analysis:

*Analysis of landscape variable selection:*

Bear locations were overlaid on the landscape variable maps. The map cells where bears had been located were compared to the set of map cells composing the remainder of the map by means of a t-test to detect whether or not the samples reflected the population.

*Analysis of habitat-type variable selection:*

The use versus availability habitat selection analysis technique of Neu et al. (1974) (Byers et al. 1984) was used. The study area's habitat proportions were used to calculate the bears' expected use (amount of locations) of each habitat assuming that use was random and thus proportionate to its availability.

Each habitat's expected use was then compared to its observed use and a  $\chi^2$  value calculated. The  $\chi^2$  values derived for each habitat were then summed. The sum was checked for significance against the  $\chi^2$  distribution (with  $n = [\text{number of habitat types} - 1]$  degrees of freedom) to accept or reject the hypothesis of no selection considering all habitats simultaneously.

If the hypothesis was rejected, selection was occurring for at least one habitat considered. The habitat(s) selected (and selection orientation [+/-]) needed to be identified. For each habitat, Bonferroni confidence intervals were calculated from selection data and compared to the availability proportion. If the intervals did not overlap the availability proportion, the hypothesis of significant selection was accepted and the direction was identified.

The Bonferroni multiple comparison confidence intervals ensure that the experimentwise selection conclusions are significant at the desired confidence level (i.e. the "family" of confidence intervals derived for each habitat is significant at  $\alpha=0.05$ ). When conclusions for each habitat are considered individually based on each's  $\chi^2$  test

result, the overall probability of type I error is additive. For example: if individual  $\chi^2$  test results revealed that three habitats out of seven were subjected to significant ( $p=0.05$ ) selection, the overall conclusion for all habitats considered would only be significant at the 0.15 level. When the number of habitat categories is very large, the -experimentwise- confidence level for each habitat's conclusion is roughly equal to the overall confidence level divided by twice the number of habitats considered ( $\alpha/2k$ ), in this case  $0.05 \div 14$  (habitat types) = 0.0017 (Byers et al. 1984).

While this ensures that the probability of experimentwise Type I error remains low, given the number of locations obtained and the number of habitats being compared, it sets an almost unattainable significance threshold. Thus, habitats with individually significant  $\chi^2$  selection results were also noted. However, doing this is only truly justified if a habitat was hypothesized to be selected a priori and if overall selection had been shown.

## **Results:**

### Locations used:

Six hundred and ten (610) locations were obtained for the 10 bears. Of these, 506 were obtained via ground telemetry.

The habitat map, as delineated by the composite 95% adaptive kernel home range, was composed of 6657 polygons no smaller than 50 m by 50 m. The mean size of these was 9.85 ha (SD= 46.95 ha) with a median of 2.25 ha. Through an iterative process, the upper limit of the error ellipses of the locations to be included in further analyses was set at 30 ha. The 417 locations that satisfied this condition had a mean error ellipse of 7.39 ha (SD = 8.23) and a median of 3.77 ha. This ensured that the mean error ellipse for the locations used would be encompassed within the mean size of the habitat polygons. Analyses were performed using 307 locations because 73 of the 417 usable locations were

collected in spring. The 37 other censored locations occurred outside the analysis area (either 95% composite home range or the distance to road buffer).

Habitat selection:

*Landscape variables:*

**Distance to road:**

The detectability of a bear seemed to be inversely related to the distance that it was from a road. All usable bear locations were within 2700 m of a road and 95% were within 1319 m.

The latter distance served as a detectability mask for all other analyses. Equal detectability was assumed within this 1319 m band; all areas past it were disregarded.

**Distance to stream:**

On average, bears were 349 m away from streams (SD= 286.2, n=307) whereas the population of map cells making up the study area was 351 m away from streams (SD=373.7, n= 5 750 350). There was no significant difference ( $t=-0.109$ , 5 750 655 df,  $p=0.91$ ).

**Perimeter to area ratio:**

The mean perimeter to area ratio of polygons encompassing the map cells occupied by bears was 0.021 (SD=0.013, n=307) whereas the mean perimeter to area ratio of the cells of other habitat polygons in the study area was 0.020 (SD=0.013, n= 1 430 979). There was no significant difference ( $t=1.16$ , 1 431 285 df,  $p=0.25$ ).

*Habitat-type variables:*

**Habitat type maps and variants:**

A 546.7 km<sup>2</sup> area remained (Figure III.1) once the areas not covered by the composite home-range or further than 1319 m from a road had been excluded.

The habitats were grouped (Table III.1) using the multi-resource sampling results (Chapter II). Table III.2 shows the boundaries and mean values of each variable's groupings. Using the sampling site data, Kruskal-Wallis nonparametric analysis of variance tests showed a significant difference ( $p < 0.0001$  in all cases) between the groupings of each variable. Tukey-Kramer multiple comparison tests confirmed that all groups (of each variable) were significantly different from each other ( $\alpha = 0.05$ ).

*For clarity, habitat type and habitat variable selection tests results and discussion will be presented jointly.*

**Table III.1: Habitat type groupings used (habitat type abbreviations in Table II.1).**

Variable	Group	Habitat types included
Hiding cover	Low	BB
	Medium	matHW, matSW, matXHW, matXSW, CP0-6, DNF
	High	yHW, ySW, YXW, BUD, P7-13, PP14+, SP14+
Horizontal cover density	Low	matHW, matXSW, CP0-6, BB, DNF
	Medium	matSW, matXHW, yHW, P7-13
	High	ySW, yXW, BUD, PP14+, SP14+
Canopy cover	Low (& none)	CP0-6, BB
	Medium	BUD, P7-13, SP14+,
	High	matHW, matSW, matXHW, matXSW, yHW, ySW, yXW, PP14+
Safety trees	Low	BUD, CP0-6, P7-13, SP14+, BB, DNF
	Medium	matXHW, matXSW, yHW, ySW, yXW
	High	matHW, matSW, PP14+
Food species ground cover	Low	matHW, matSW, matXSW, ySW
	Medium	matXHW, yHW, yXW, BUD, PP14+, SP14+, DNF
	High	CP0-6, P7-13, BB
Food species richness	Low	matSW, ySW, BB
	Medium	matHW, matXSW, CP0-6, P7-13, SP14+
	High	matXHW, yHW, yXW, BUD, PP14+, DNF
Food species diversity index	Low	matSW, matXSW, yHW, ySW, SP14+
	Medium	matHW, matXHW, yXW, BUD, CP0-6, P7-13, PP14+, BB
	High	DNF

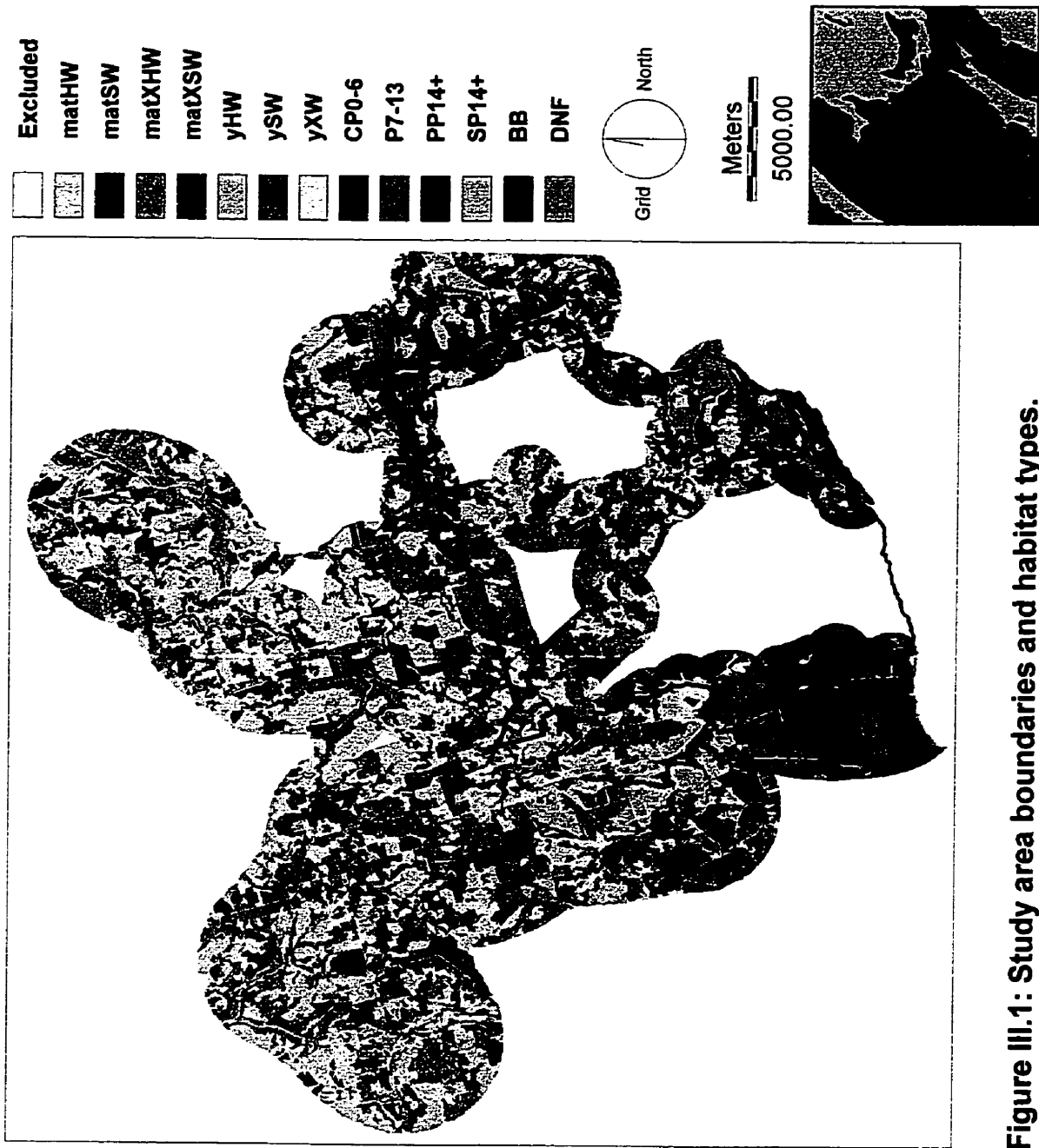


Figure III.1: Study area boundaries and habitat types.

**Table III.2: Characteristics of habitat type groupings used.**

Variable	Low abundance (or none)			group boundary <sup>a</sup>	Medium abundance			group boundary <sup>a</sup>	High abundance			Kruskal - Wallis H	Significance
	$\bar{x}$	(SD)	n		$\bar{x}$	(SD)	n		$\bar{x}$	(SD)	n		
Hiding cover distance (m)	124.4	23.6	6	81.6	32.3	14.0	52	23.15	16.2	6.2	55	58.57	P<0.0001
Horizontal cover density (%)	29.6	19.3	45	46.1	56.8	22.8	32	66.25	81.6	14.6	36	62.52	P<0.0001
Canopy cover (%)	0	0	18	7.15	38.3	34.8	35	72.4	87.3	11.1	60	68.68	P<0.0001
Safety trees (stems/Ha)	101.7	211.5	53	507.5	904.0	440.4	35	1122	1428.1	502.0	25	79.73	P<0.0001
Food species ground cover (%)	15.5	13.6	30	22.45	36.5	24.5	47	50.4	58.8	27.0	25	37.39	P<0.0001
Food species richness (# spp.)	3.4	1.5	18	4.4	5.8	2.4	43	6.75	7.8	2.1	41	36.59	P<0.0001
food species diversity index	0.25	0.22	33	0.362	0.46	0.20	62	0.596	0.67	0.08	7	28.32	P<0.0001

<sup>a</sup> Limits were defined as the midpoint between the means of the habitats forming the upper extremes and lower extremes of adjacent groupings.



## **Discussion:**

### **Landscape variables:**

#### *Distance to stream:*

Once distance from road detectability was taken into account, it was defensible to study bears' distances from streams especially given that roads were not laid out in relationship to stream courses.

No selection was shown. Perhaps this is due to the abundance of watercourses in the area. On average, any point was within 351m of water. As water would be encountered with most any movement, bears need not consider it a factor. Lack of selection also shows there is no advantage to following streams versus pursuing a cross-country course in this gentle terrain.

#### *Perimeter to area ratio of habitat polygons:*

Bears do not appear to be influenced by this variable.

Yet the p value of 0.25 is much smaller than stream selection's ( $p=0.91$ ) suggesting that polygon geometry may exert some influence. As twenty metre square map cells were used, the analysis is insensitive to any "edge" patterns smaller than 20 m and cannot incorporate ratios greater than 0.2 (80 m/400 m<sup>2</sup>). Perhaps effects may be more pronounced at a smaller scale. Additional work should be performed to determine this. Habitat type boundaries were of interest here, however, selection may have been shown towards stand type boundaries or a different habitat type definition.

Habitat type variables:

*Groupings:*

The Kruskal-Wallis and Tukey-Kramer tests showed that the groupings created were significantly different.

The aggregation of habitat types by level of abundance sometimes created unbalanced groupings. For example, the low hiding cover group includes only commercial blueberry fields (BB). Therefore, that category's results also reflect bear behaviour towards blueberry fields and not exclusively their response to low hiding cover.

*Habitat type selection: results and discussion*

**Table III.3:** Habitat selection test results. Only points with error ellipses smaller than 30 ha taken during the summer and fall were considered.

Habitat	Expected locations	Observed locations	$\chi^2$ value (significance <sup>a</sup> )	Bonferroni confidence interval conclusions ( $\alpha=0.05$ )
matHW	66	31	18.56**	<i>avoid</i>
matSW	32	33	0.03	no selection
matXHW	26	25	0.04	no selection
matXSW	31	39	2.06	no selection
yHW	8	8	0	no selection
ySW	29	43	6.76**	no selection
yXW	28	28	0	no selection
BUD	29	39	3.45 <sup>^</sup>	no selection
CP0-6	12	6	3.00 <sup>^</sup>	no selection
P7-13	25	28	0.36	no selection
PP14+	2	1	0.50	no selection
SP14+	7	8	0.14	no selection
BB	2	3	0.50	no selection
DNF	10	15	2.50	no selection
<b>Sum</b>	307 ( <i>n=10 bears</i> )	307	37.90	<b>Selection is occurring</b> <b>P&lt;0.001 (<math>\chi^2_{tab}=34.57</math>)</b>

<sup>a</sup> Denotes the significance of the  $\chi^2$  test if it were to be considered individually. Since it is not, this is only an indication of possible behaviours that did not prove to be significant when all habitat types were considered simultaneously.

<sup>^</sup> significant at the 0.1 level  $\chi^2_{tab}$  1 df=2.70

<sup>\*\*</sup> significant at the 0.01 level  $\chi^2_{tab}$  1 df=6.63

Significant overall selection did occur ( $\chi^2_{sum}=37.90$ ,  $\chi^2_{tab, 13df, \alpha=0.001}=34.57$ ).

However, experimentwise selection was limited to an avoidance of the mature hardwood habitats ( $\alpha=0.05$ ).

Disregarding experimentwise significance (Bonferroni conclusions), habitats other than matHW had individually-significant  $\chi^2$  selection results. Considered independently,

the ySW habitat received more use than expected (43 observations vs. 29 predicted,  $\alpha=0.01$ ). Budworm habitats also received more use than expected (39 observations vs. 29 predicted,  $\alpha=0.1$ ). Clearcuts and plantations of 0 to 6 years of age were used less than expected (6 observations vs. 12 predicted,  $\alpha=0.1$ ).

The significance of the mature hardwoods (matHW) results is notable considering that 14 different habitats were compared at an experimentwise significance of 0.05. Considered independently, the difference is significant at  $p=0.00002$  (31 obs. vs. 66 exp;  $\chi^2=18.56$ , 1 df).

This strong avoidance is probably because mature hardwoods offered the second lowest amount of concealment and the fourth lowest food species ground cover (Table II.3). Food availability may be even lower since beech cover may not be proportional to beechnut productivity given the devastating effects of beech bark disease (Chapter I).

Mature hardwoods offered at least average quantities of all other habitat variables (Table II.3). They only lacked concealment and food. The strong avoidance of these habitats, of which beech are a principal component, strongly suggests that beechnut production had been reduced by beech bark disease. In all other studies in similar habitats, hardwood stands were used significantly more than expected (Hugie 1982, Samson 1995, Costello and Sage 1994), at least in the fall.

During a poor hard mast-crop year, female bears in Quebec avoided mature hardwoods during summer and fall. In good years, they only avoided these habitats in summer. The selection observed here suggests that sarsaparilla and hobblebush, the second and third most abundant food in such habitats (from data collected), do not significantly compensate for the lack of hard mast.

In New York, Costello (1992) found that hardwoods were used according to availability in summer and more than expected in fall as beechnuts ripened. It appears that

beechnut production in Fundy is insufficient to attract bears. As the infection had recently begun in the Adirondacks, some nuts were still produced.

So many habitats were compared that the experimentwise significance threshold is almost unattainable for habitats with use and availability differences smaller than mature hardwood's (n=35 observations). Habitats with significant individual  $\chi^2$  test results are also reported as this provides additional insight into bear behaviour.

The strong preference for young softwoods in individual testing ( $\chi^2=6.76$ , 1df,  $p<0.01$ ) was surprising since they had the lowest mean ground cover of food of all habitats (9.6%) and the second lowest food species richness (3.2 spp.). However, bears had access to many climbable trees (937 stems/Ha) and were well hidden in these sites.

The preference for budworm-defoliated habitats ( $\chi^2=3.45$ , 1df,  $p<0.1$ ) was less surprising: they had an abundant (38.1%) and rich (7.4 spp.) food source and some climbable trees (249/Ha - about one in every 6 m x 6 m square on average).

The avoidance ( $\chi^2=3.00$ , 1 df,  $p<0.1$ ) of zero to six year old plantation (CP0-6) habitats was also surprising. They had the greatest ground cover of food species of all forested habitats (only BB was higher with 68.8%) but had no climbable trees or canopy cover, low horizontal cover density (29%) and medium hiding cover distance (32.6 m). This strongly suggests that escape and concealment are more important to female black bears than food availability alone.

Had the areas that became CP0-6 habitats been harvested while maintaining sufficient climbable trees (BUD was preferred and only had 249 safety trees per hectare) and more concealment (to which climbable trees contribute) they would have probably become preferred rather than avoided habitats.

It is also surprising that some habitats were only used as much as expected. The best example is the seven to 13 year old plantation (P7-13) habitat. It had abundant food

species ground cover (56.4%, third highest) and perhaps, as a consequence, medium species richness (6.5 spp.). It also had high hiding cover distance (16.4m), medium horizontal cover density (58.7%) yet low levels of safety trees (47/Ha) and medium canopy cover (14.3%). Given its abundance of food and concealment, this habitat was probably not used more than expected because of its lack of safety trees. The food and cover available perhaps entices female bears into the habitat often enough that it is used as expected; whereas if sufficient escape trees were present, it might be preferred.

As very young plantations habitats (CP0-6 and P7-13) are avoided or “neutral”, it appears that they are not ecological replacements to their natural counterparts: young softwoods and budworm-defoliated habitats.

It is not exactly known which females were accompanied by cubs during the study, and limited field observations would suggest that most were not. Regardless, the results support Young and Beecham’s (1983) contention that females (whether with or without cubs) have an innate maternal instinct to avoid open areas. “Where cubs have no means of escape” could even be added. It would be interesting to see if male bears used open habitats more than expected given that escape trees are probably superfluous to them.

In Quebec (Samson 1995), early successional habitats were preferred in summer. In autumns with good beechnut crops these habitats were avoided since bears had moved to hardwood stands. Had both seasons been combined as was done here, perhaps these early successional sites would also have been “neutral.” However, the strong avoidance of mature hardwoods observed here clearly shows that bears do not use hardwood habitats in the fall. Bears probably forage in early successional habitats as long as they can find food there and den-up afterwards or, instead, they may search for any remaining abundant point sources of food such as abandoned orchards or hunting baits. However, it is conceivable

that for some habitats, summer preference caused by the presence of food may be masked by fall avoidance and result in “neutral” selection for the combined summer-fall season.

The lack of selection for mature mixed hardwood habitats (matXHW) was unexpected given their above-average food ground cover (42.1%) and medium levels of concealment and safety trees. This cannot be attributed to beech bark disease since beech cover 1.6% of the ground in these stands (from data collected). Since this habitat is average in all aspects except food, it only receives average use. In Hugie’s (1982) food-poor Spectacle pond study area, these habitats were avoided.

This “average habitat - average selection” explanation can be invoked to explain the lack of selection for mature softwoods (matSW). These habitats were average except for their lesser food species ground cover and greater density of safety trees. These habitats were avoided in the Spectacle pond area in Maine (Hugie 1982).

Mature mixed-softwoods (matXSW) were used in proportion to their availability in Maine, as they were in this study. The habitat was generally comparable to mature softwoods; it only differs in its slightly greater level of food species ground cover and its lesser amount of safety trees.

Young mixedwood stands (YXW) were avoided in the Spectacle pond area (Hugie 1982) yet were used as expected here. They provided good concealment, a moderate amount of safety trees and moderate amounts of food of great richness yet medium diversity. Again, this is an average habitat; it receives average use. The same can be said of young hardwoods (yHW) here though these were preferred in Maine.

The remaining habitats (PP14+, SP14+, BB, DNF) did not account for more than 2.8% of the study area each; thus, a very low number of locations was expected in each given the number of locations analysed (n=307 usable locations). It would have been interesting to see if the greater safety tree density and food species richness of the PP14+

habitats would have led them to be preferred over the SP14+ habitats. The dry, non forested habitats (DNF), if viewed independently, were almost preferred (15 observations vs. 10 expected.  $\chi^2$  value is short of being significant at the 0.1 level).

Commercial blueberry fields covered 0.6% of the study area; 2 locations were expected, the 3 observed are not significant. However, bears were clearly influenced by blueberry fields. Bears moved to areas surrounding blueberry fields when berries ripened in late summer. These were not random long-distance excursions: some bears repeated them both years. An analysis of late summer movements and proximity to blueberry fields (and DNF habitats also) would probably show that bears migrated to these sites and were more likely to be found closer to these habitats than further away from them when berries were available within them. Anecdotal observations of the quantity and composition of scat found in these sites in autumn suggests a strong attraction.

Bears were not tracked at night. Diurnal activity was assumed as it is observed elsewhere with non-habituated bears, (Amstrup and Beecham 1976, Garshelis and Pelton 1980, Larivière et al. 1994). Therefore, it would be unexpected to observe significant nocturnal use of food-rich habitats with low cover and escape that were not used in daytime (eg. CP0-6). Additional study with different experimental groups (males, solitary females, females with cubs) would perhaps also relate some avoidance of these habitats to the lack of thermal cover provided. Such habitats may be used during cooler periods but it remains that they provide little security to cub-accompanied females.



*Forest type selection: results and discussion*

**Table III.4:** Forest type selection results.

Forest type	Expected locations	Observed locations	$\chi^2$ value (significance <sup>a</sup> )	Bonferroni confidence interval conclusions ( $\alpha=0.05$ )
Hardwood	74	39	16.55**	<i>avoid</i>
Softwood	62	76	3.16 <sup>^</sup>	no selection
Mixedwood	114	131	2.53	no selection
Managed	45	43	0.08	no selection
Non-forest	12	18	3.00 <sup>^</sup>	no selection
<b>Sum</b>	307	307 ( <i>n</i> =10 bears)	25.34	Selection <i>is</i> occurring P<0.001 ( $\chi^2_{tab}$ =18.47)

<sup>a</sup>Denotes the significance of the  $\chi^2$  test if it were to be considered individually. Since it is not, this is only an indication of possible behaviours that did not prove to be significant when all habitat types were considered simultaneously.

<sup>^</sup>significant at the 0.1 level  $\chi^2_{tab}$ , 1df=2.70

\*\* significant at the 0.01 level  $\chi^2_{tab}$ , 1df=6.63

Hardwoods were again used less than expected (Table III.4). The addition of the neutral-selection young hardwoods did not alter the avoidance observed previously.

There are 76 observations versus the 62 expected for softwoods and thus no experimentwise significance. However, considered independently, there is a preference for softwood habitats during the combined summer and fall season. In the Adirondacks, softwood use was proportional to its availability during both seasons (Costello and Sage 1994). Since the mature softwood habitat type was used in proportion to its availability (33 observations vs. 32 expected), selection towards softwoods as a group is derived from young softwood's contribution (43 observations vs. 29 expected).

The non-forested group (DNF and BB) was not significantly selected overall, but its individual  $\chi^2$  value suggests preference.

The most relevant result is that management-origin habitats were neutral: they are not significantly better or worse than "average" overall.

*Development stage selection: results and discussion*

**Table III.5:** Development stage selection results.

Development stage	Expected locations	Observed locations	$\chi^2$ value (significance <sup>a</sup> )	Bonferroni confidence interval conclusions ( $\alpha=0.05$ )
Mature	155	128	4.70 <sup>*</sup>	<i>avoid</i>
Immature	140	161	3.15 <sup>^</sup>	<i>prefer</i>
Non-forest	12	18	3.00 <sup>^</sup>	no selection
Sum	307	307 (n=10 bears)	10.85	Selection <i>is</i> occurring P<0.01 ( $\chi^2_{tab}=9.21$ )

<sup>\*</sup> Denotes the significance of the  $\chi^2$  test if it were to be considered individually. Since it is not, this is only an indication of possible behaviours that did not prove to be significant when all habitat types were considered simultaneously.

<sup>^</sup> significant at the 0.1 level  $\chi^2_{tab}$  1df=2.70

<sup>\*</sup> significant at the 0.05 level  $\chi^2_{tab}$  1df=3.84

These results are not unexpected. Mature (all “mat” habitats) habitats were used less than expected while immature (BUD, all plantations and all “y” habitats) habitats were preferred (Table III.5). This is consistent with other studies, especially if fall mast crops are ignored or only summer data are considered (Hugie 1982, Costello 1992, Samson 1995).

Immature habitats generally had more food species ground cover and concealment than mature habitats yet fewer safety trees. However, when all immature habitats were grouped, the lower mean level of safety trees was apparently compensated for and bears preferred these habitats.

*Management regime selection: results and discussion*

**Table III.6:** Management regime selection results.

Mgt. regime	Expected locations	Observed locations	$\chi^2$ value (significance <sup>*</sup> )	
Natural	250	246	0.06	
Managed	45	43	0.09	
Non-forest	12	18	3.00 <sup>^</sup>	
<b>Sum</b>	307 ( <i>n=10 bears</i> )	307	3.15	Selection <i>is not</i> occurring ( $\chi^2_{tab,0.1, 2df}=4.6$ )

<sup>\*</sup> Denotes the significance of the  $\chi^2$  test if it were to be considered individually. Since it is not, this is only an indication of possible behaviours that did not prove to be significant when all habitat types were considered simultaneously.

<sup>^</sup> significant at the 0.1 level  $\chi^2_{tab, 1df}=2.70$

No experimentwise selection was shown. Bears apparently do not distinguish or consider stand origin (Table III.6).

Habitat variables: results and discussion

**Table III.7:** Results of use versus availability goodness of fit tests for habitat variables. Note: The high, medium and low categories do not regroup the same habitat types for each variable.

Habitat Variable	Category	Expected locations	Observed locations	$\chi^2$ value (significance <sup>a</sup> )	Bonferroni confidence interval conclusions ( $\alpha=0.05$ )
Hiding Cover	Low	2	3	0.5	no selection
	Med.	177	149	4.43 <sup>*</sup>	<i>avoid</i>
	High	128	155	5.70 <sup>*</sup>	<i>prefer</i>
	Sum	307	307 (n=10 bears)	10.62	Selection is occurring P<0.01 ( $\chi^2_{tab}=9.21$ )
Horizontal Cover	Low	120	94	5.63 <sup>*</sup>	<i>avoid</i>
	Med.	91	94	0.10	no selection
	High	95	119	6.06 <sup>*</sup>	<i>prefer</i>
	Sum	307	307 (n=10 bears)	11.79	Selection is occurring P<0.01 ( $\chi^2_{tab}=9.21$ )
Canopy Cover	Low	223	208	1.01	no selection
	Med.	71	90	5.08 <sup>*</sup>	<i>prefer</i>
	High	14	9	1.78	no selection
	Sum	307	307 (n=10 bears)	7.88	Selection is occurring P<0.05 ( $\chi^2_{tab}=5.99$ )
Safety Tree Abundance	Low	84	99	2.68	no selection
	Med.	122	143	3.61 <sup>^</sup>	<i>prefer</i>
	High	101	65	12.83 <sup>**</sup>	<i>avoid</i>
	Sum	307	307 (n=10 bears)	19.12	Selection is occurring P<0.001 ( $\chi^2_{tab}=13.81$ )

Table III.7 (Continued)

Habitat Variable	Category	Expected locations	Observed locations	$\chi^2$ value (significance <sup>a</sup> )	Bonferroni confidence interval conclusions ( $\alpha=0.05$ )
Food Species Cover	Low	196	186	0.51	
	Med.	137	153	1.87	
	High	47	41	0.77	
	Sum	307	307 (n=10 bears)	3.14	Selection is not occurring ( $\chi^2_{tab,0.1,2df}=4.6$ )
Food Species Richness	Low	64	79	3.52 <sup>^</sup>	no selection
	Medium	140	112	5.60 <sup>*</sup>	<i>avoid</i>
	High	104	116	1.38	no selection
	Sum	307	307 (n=10 bears)	10.50	Selection is occurring P<0.01 ( $\chi^2_{tab}=9.21$ )
Food species diversity	Low	108	131	4.90 <sup>*</sup>	<i>prefer</i>
	Medium	189	161	4.15 <sup>*</sup>	<i>avoid</i>
	High	10	15	2.50	no selection
	Sum	307	307 (n=10 bears)	11.54	Selection is occurring P<0.01 ( $\chi^2_{tab}=9.21$ )

<sup>a</sup>Denotes the significance of the  $\chi^2$  test if it were to be considered individually. Since it is not, this is only an indication of possible behaviours that did not prove to be significant when all habitat types were considered simultaneously.

<sup>^</sup> significant at the 0.1 level  $\chi^2_{tab}$  1df=2.70

\* significant at the 0.05 level  $\chi^2_{tab}$  1df=3.84

\*\* significant at the 0.01 level  $\chi^2_{tab}$  1df=6.63

#### *Hiding cover distance selection:*

The low hiding cover (greater distance) group's result was influenced by the classification scheme. Blueberry fields were the only habitat in the category since their sampling results were outliers to the other groups'. The BB's minute proportion of the study area and technical constraints meant that few bears were observed in these sites (n=3). These results represent only selection for BB habitats and not truly those of a low hiding cover grouping (Table III.7).

The medium hiding cover group was avoided whereas the high cover (small distances) group was preferred. The medium classification is a misnomer. Blueberry fields (the high cover group) could be ignored and the “medium group” would become the “lower” cover group, thus lower cover would be avoided and higher cover preferred.

Given the suggested importance of horizontal cover to female bears (Mollohan and Lecount 1989, Mollohan et al. 1989, Lindzey and Meslow 1977 and Young and Beecham 1983), this result was expected and further supports the assertion that female black bears prefer habitats with good concealment.

*Horizontal cover density selection:*

Low horizontal cover density habitats were avoided, no selection was seen for habitats with medium levels of horizontal cover and high cover habitats were preferred (Table III.7). These results are the clearest and strongest confirmation of the importance of horizontal cover to bears. They reflect the hypothesis presented by the authors listed above. As opposed to hiding cover distance, the boundaries selected for the groupings led to the formation of nearly balanced groups (120, 91 and 95 expected locations).

Horizontal cover is clearly an important variable: female bears react to it as expected if they were seeking the security of concealment.

*Canopy cover selection:*

The canopy cover selection results are not as intuitive (Table III.7). Sites with medium canopy cover were preferred whereas sites with low or high canopy cover were used in proportion to their availability. Perhaps the medium level is “just right.” However, the unbalanced groupings (223 locations expected in the low canopy cover group vs. 14 in

the high) make the detection of differences more difficult as greater deviations (in absolute terms) from the expected are required to show significance in the low group.

Nevertheless, it is plausible that bears prefer sites with medium canopy cover and are neutral to other levels. The correlations between canopy cover and safety trees ( $r=0.72$ ,  $p<0.01$ )(since large trees contribute to canopy cover) and with food species ground cover ( $r=-0.40$ ,  $p<0.01$ ) suggest that independently assessing each habitat variable using habitat groupings may be impractical. Open canopy habitats may have more food but insufficient safety trees whereas densely canopied habitats may have abundant trees but limited food; in either case one factor may compensate for the other and bears may appear neutral towards these habitats

*Safety tree density selection:*

Bears avoided habitat types with high densities of trees, preferred medium levels and showed no selection for low densities (Table III.7). These results are possibly also an expression of the correlations between canopy cover, food species ground cover and safety tree abundance. However, the number of locations in each group was essentially balanced and the overall results highly significant. An explanation based solely upon the presumption that bears need safety trees is perhaps inappropriate since bears should not then avoid habitats with higher densities of safety trees than required and would probably avoid areas with low tree density. The “correlation compensation” discussed in the last section probably also affects these results. Areas with abundant safety trees may provide security but not food. In addition, past a certain density, additional trees are perhaps superfluous since security needs have been met. The difference in habitat types included in the high canopy cover and high safety tree groups may be responsible for the different

reactions to these variables (high cover was neutral whereas high tree density was avoided)

The lack of selection towards low safety tree density habitats is perhaps also explained by such “correlation compensation”. Or perhaps solitary females used the habitat whereas those with offspring avoided it resulting in neutral selection.

The arbitrary definition of safety tree diameter is debatable and may have had consequences on the grouping exercise and subsequent testing that could explain the results observed. In future work, tree diameter should be recorded to allow the investigation of different “safety diameter” thresholds.

*Food species ground cover selection:*

The lack of selection towards this variable is the most surprising result given the widespread opinion (Jonkel and Cowan 1971, Reynolds and Beecham 1980, Garshelis and Pelton 1981, Rogers 1987) that bear habitat use is driven mainly by food abundance in a habitat (Table III.7). Available edible biomass was not measured: only ground cover of food species was. However, the relationship between cover and biomass cannot be so subtle that no selection results. The inclusion of the abundant bunchberry is perhaps debatable; regardless, food abundance rankings would remain virtually unchanged if bunchberry were removed (from field data).

No relationship between habitat use and food species ground cover was shown.

*Food species richness selection:*

Again, the results are not intuitive (Table III.7). What benefits would be obtained by bears avoiding medium richness sites? Why would they be neutral towards high and low richness sites? (Individual results hint at a preference for low richness sites). A



significant positive correlation exists between richness and food species ground cover ( $r=0.38$ ;  $p<0.01$ ). As food species ground cover was not shown to elicit a selection response, this correlation could illuminate some of the richness results. Perhaps the preference for medium sites is not a methodological artefact -such as a correlation “compensation” discussed previously- but involves a relationship between richness and available biomass. High richness sites may produce only small quantities of food at a time but production may be spread over the season prompting regular visits. Sites with medium richness may only provide a small quantity of food once a year and any temporary preference for the habitat may not be detectable over a season. Low richness sites could be typified by such abundant production of one species that a significant behaviour is shown. This should be examined.

*Food species diversity index selection:*

The Simpson dominance diversity index (Simpson 1949) assigns greater importance to the most dominant (proportionately) species in a sample. As such, the index assigned to habitats with an abundance of one or two food species will be greater than that calculated for habitats with many food species but no truly dominant ones. This index was chosen under the assumption that bears would be more attracted to sites with one or two abundant -and dominant- species as it seemed more efficient to forage on a few dominant species than to eat trace quantities of many rarer species. As mentioned in Chapter II, the diversity index obtained is not intuitively “correct” if the richness and ground cover of food species of each habitat are considered. However, the selection results validate the adoption of the Simpson index. The low diversity habitats (dominated by a few abundant species) are preferred whereas the medium diversity ones are avoided (Table III.7). The high diversity category consists of the dry non-forested habitat type only; as such, the

results reflect bears' reactions towards this habitat and not food species diversity *per se*. As the high group comprises one habitat, it could be combined with the medium group. This would result in no selection ( $\chi^2=2.65$ , 1 df,  $P>0.1$ ) for the new group and a preference for the low diversity group.

The preference for the low diversity group is dependent on its inclusion of the ySW and matXSW habitats. Considering habitat type selection (Table III.3), there are 14 more observations than predicted in ySW. The matXSW results show eight more observations than expected. Thus, the 23 observation difference causing preference of the low diversity category is nearly fully attributable to two out of five habitats in the group. The three other habitats were essentially unselected.

When the medium diversity group results are considered similarly, the habitat selection inequalities are more balanced. The matHW habitat has an observation "deficit" of 25 observations, whereas BUD has a "surplus" of 10, CP0-6 has a six observation "surplus" and so on. This suggests that avoidance of these habitats is not a methodological artefact.

Bears react to species diversity calculated using the Simpson index and seem to prefer low diversity habitats.

### **Conclusion:**

The bears' reactions to landscape variables were examined. Ground-based radio-tracking was unsuitable for the study of behaviour towards roads since detectability decreased as distance from the -road based- observer increased. This was not calibrated. Thus, the matter could not be examined further. Road-related behaviour should be the subject of an aerial or GPS-collar-based study.

Bears' behaviours towards water were neutral. Water is probably abundant enough in the area that bears need not consider it; streams are not an aid nor an impediment to travel.

The perimeter to area ratio selection results were not significant either. The 20 m map cells used were perhaps too coarse to detect an effect. The definition of scale is important, as is the definition of what constitutes a boundary. Further research should verify this by using smaller cells and/or stand boundaries.

The reaction of bears to habitat types and habitat variables was the focus of this chapter. It must be restated that stands were aggregated into locally-defined habitat types. For habitat variables, field sampling results were used to aggregate habitat types into categorical groups reflecting abundance levels.

Single habitat "groups" should not be used. The selection exhibited towards them reflected bears' reactions to the habitat (and its unique combination of variables) and not specifically the abundance level of the variable *per se*.

The results of selection analyses on habitat types showed the importance of concealment and escape in bear behaviour.

Mature hardwoods were strongly avoided as they offered little concealment or food. This latter deficiency is likely due to a beechnut production decrease resulting from beech-bark disease. The preference for young softwoods was surprising: they had the lowest coverage of food species but abundant concealment and escape trees. This illustrates the importance of cover and escape over food; as additional evidence, zero to six year old plantations were avoided though they had the highest level of food species ground cover. However, they lacked concealment and safety trees.

Selection for forest type also showed an avoidance of hardwoods; all other types were again used according to their availability. When development stage was considered,

results were consistent with expectations: mature habitats were avoided, immature habitats preferred and no selection shown towards non-forest habitats.

No selection was shown towards management regime. Any differences between natural and managed habitats apparently do not influence bear behaviour.

These results reflect behaviour towards the different grouping schemes but they are not truly independent. In each of the previous three cases, the non-forested group consisted of blueberry fields and dry non-forest habitats only. The technique did not always allow for an independent evaluation of bear behaviours with respect to each theme.

Similar independence issues appeared when considering bear behaviour towards the habitat variables. Habitat variable results (Table III.8) should be used as forest management guidelines.

These results reflect bear behaviour observed; however, some do not reflect other author's findings. In addition, the results were not always predictable if it was assumed that bears were optimizing their behaviour while considering only the variables examined.

Though habitat groupings for each variable were independently derived, bears' selection towards each group could not be independently examined due to correlations. All variables should be examined simultaneously to examine each's contribution to bear behaviour. In some cases, it was unclear whether the bears were reacting to the variable in question or a group containing a few habitat types that were strongly selected for because of an abundance or paucity of another variable.

Which variables directly influence behaviour and which ones are simply correlates cannot yet be identified with certainty. Without having simultaneously considered all variables and compared the strength of bears' reactions towards each, the results are simply too disparate for an overall conclusion. The next chapter will attempt to resolve

this. However, it can be stated safely that bears were not influenced by the ground cover of food in a habitat.

**Table III.8:** Summary of bear selection behaviours shown towards variables considered.

<b>Behaviour</b>	<b>Level</b>	<b>Variable</b>	<b>Value</b>
<b><i>Prefer</i></b>	High	Hiding cover	<23.15m
	High	Horizontal cover	>66.25%
	Medium	Canopy cover	7.15 - 72.4%
	Medium	Safety trees	507.5 - 1122trees/Ha
	Low	Food spp. diversity	<0.362
<b><i>Avoid</i></b>	Medium	Hiding cover	23.15-81.6m
	Low	Horizontal cover	<46.1%
	High	Safety trees	>1122 trees/Ha
	Medium	Food spp. richness	4.4 - 6.75spp.
	Medium	Food spp. diversity	0.362 - 0.596
<b><i>Used according to availability</i></b>	Low	Hiding cover	>81.26m
	Medium	Horizontal cover	46.1 - 66.25%
	Low and High	Canopy cover	<7.15% and > 72.4%
	Low	Safety trees	>507.5trees/Ha
	All levels	Food spp. ground cover	0-100%
	Low and High	Food spp. richness	>4.4 and >7.8 spp.
	High	Food spp. diversity	>0.596

The stepwise creation of a statistical model predicting the presence or absence of a bear at a site using logistic regression would have been superior but was unfeasible given the manner in which the data were collected. The simultaneous consideration of all variables and the discrimination of each's influence in such a model would have identified the importance of each variable's contribution to bear habitat use behaviour. The capability to integrate landscape variables in such an analysis is beneficial. However, since bears were neutral towards these, they would not have been considered.

The habitat variable maps could have been queried for the attributes of each bear location and at random sites. However, this would not have been appropriate either since the mean values of each habitat type were used to create these maps.

A determination of the influence of each variable on bear use of a site will be attempted through the construction of a cartographic model in the next chapter.

Since each habitat type (and more appropriately, stand type) is an expression of the unique mixture of variables that define it, it is tempting to conclude that the reductionist, variable by variable approach used may have only confused matters. The use of habitat type inventory data to anecdotally explain the behaviours shown towards habitat types was perhaps the best approach. Though this does not prove a significant relationship, it provides a strong basis upon which to hypothesize an explanation for the behaviours observed.

## **Chapter IV**

### **A cartographic modelling approach to determining fragmentation effects of forest management activities on black bear habitat in southern New Brunswick.**

#### **Introduction:**

The home range area differences observed in Chapter I lead to questions concerning why similar adult female bears maintained different-sized home ranges. The replacement of natural forest stands by monoculture plantations could cause a fragmentation effect (Harris 1984) in the area (Woodley and Forbes 1997). However, in Chapter III, management-origin habitats as a whole were neither preferred nor avoided. However, the natural habitats they replaced may have been either. For example, the dominant habitat type, natural-origin mature hardwoods, is avoided by bears.

It is plausible that bears need a minimum amount of “high quality” (preferred) or at least suitable (neutral) habitat for their survival. Unsuitable habitat types are superfluous and traversing or avoiding these is an unproductive expense that should be minimized assuming that bears forage optimally (MacArthur and Pianka 1966, Krebs 1978). In keeping with this, bears should not occupy any larger an area than that needed to meet all of their requirements.

The hypothesis that variation in home range size is determined by the amount of unsuitable habitat within it will be tested. The prediction that unsuitable habitat is diluting the concentration of suitable habitat in the landscape follows. Bears must therefore roam a larger area to integrate sufficient suitable habitat into their home range to ensure a productive existence.

The hypothesis and prediction are summarized as:

“If home range size variations are determined by the variation in the area of unsuitable habitat within them, then home ranges of comparable bears will have the same area of suitable habitat.”

In other words, comparable bears should incorporate the same area of suitable habitat within their different-sized home ranges. This result would show that the presence of unsuitable habitats is significant enough that it causes bears to behave as if their landscape was “diluted”.

The objective of this chapter is to determine if the presence of unsuitable habitat produces a landscape “dilution” effect (fragmentation). To do this, other objectives must be met:

- identification of the principal variables responsible for habitat selection behaviour, and,
- comparison of the results of the habitat type selection analysis with those of the variable by variable approach.

### **Methods:**

#### **Overview:**

To test the hypothesis, the independent habitat variables’ selection results were integrated to produce a map of the study area’s habitat suitability. The area of each home range and the area of suitable habitat in each were measured. According to the prediction, the latter amount should be equal in all cases. Thus a linear regression of the area of suitable habitat on home range area should result in a slope of zero, showing the impossibility of predicting home range size from the area of suitable habitat and therefore, that fragmentation in the form of “landscape dilution” is occurring.

#### **Assumptions:**

It was assumed that the sample bears were comparable as all were adult females; however, some were accompanied by cubs during part of the tracking period. Furthermore, female bears were assumed not to exhibit intraspecific or intrasexual



territoriality. This agrees with reports from locales with abundant food (Amstrup and Beecham 1976, Lindzey and Meslow 1977, Garshelis and Pelton 1981, Reynolds and Beecham 1980, Samson 1995). Nothing was observed in this study's results (Figures I.1 to I.8) to challenge this claim.

#### Cartographic model:

Cartographic modelling (Tomlin 1990) is a technique in which maps representing the geographic extent of levels of different variables are overlaid. The result is a composite map in which each individual map cell's associated value represents the sum of the values encountered in each layer at that location. The choice of maps to incorporate in the model is crucial. Including correlated variables would bias results.

The results of selection tests on habitat types or derivatives were not included in the model. A bear's behaviour towards a habitat type is a reaction to its unique combination of variables. Therefore, layers showing the results of selection towards habitat types should not be included with variable-specific layers. However, the behaviours towards habitat types can be compared to the results of the model.

A preliminary analysis showed that including commercial blueberry field measurements would bias the data. Due to commercial management, the 4 blueberry field sites (out of 102 sites surveyed) had the greatest food species coverage and virtually no canopy cover, horizontal cover or hiding cover; the sites were excluded from the analysis. The total cover of food species variable was also excluded from the model since it had not elicited selection (Chapter III).

Correlations were appraised to ensure that only independent habitat variables were included in the model. Some measurements were different expressions of a same habitat component. For example, hiding cover distance and horizontal cover density both reflect

concealment offered by vegetation. Other variables were possibly ecological correlates (i.e., ground cover of food species and canopy cover).

Since the data were non-normally distributed, a non-parametric Spearman rank order correlation analysis was used.

Correlated pairs were scrutinized to determine which variable should be used in the model. Variables selected for the model had the greatest total  $\chi^2$  value associated with them (as calculated by the Neu et al. (1974) method in Chapter III) in each correlated pair. This value indicates the strength of the bears' behaviour towards the variable and was comparable since all testing was done with 2 degrees of freedom.

Once the independent variables were identified, the cartographic model was created by taking each's map and reclassifying their high, medium and low abundance categories to correspond to the selection results obtained in Chapter III. Suitability values of -1 were assigned to map cells of avoided categories, 0 (zero) to map cells of categories used according to availability and +1 to map cells of preferred categories. For example, the low horizontal cover density category was avoided (Table III.7); therefore, all map cells representing it (those originally belonging to: matHW, matXSW, CP0-6, BB and DNF) were assigned a value of -1. This was repeated for each independent variable. All maps were then additively overlaid to produce the suitability map (the cartographic model). IDRISI GIS (Eastman 1997) was used.

The road distance mask (Chapter III) was not applied since selection had been examined only within the detection area; results were thus applicable to the area outside the masked area.

Since bears showed no selection towards distance to stream or area to perimeter ratio of habitat polygons, the production of the cartographic model map became less relevant. These continuous variables were spatially independent of the habitat polygon

boundaries yet could have been integrated into the model. Had selection been shown, the maps illustrating the results would have been based on distance to stream or on polygon boundaries (independent of polygon habitat type).

The inclusion of these landscape variables in the model would have produced a suitability map whose polygon boundaries were based upon the intersection of habitat polygon boundaries and distances from streams. However, as there was no selection for landscape variables, the model can be summarized without a map by tallying which abundance grouping a habitat type was assigned to for each variable (Table III.1) and summing the selection responses (Table III.7) for each habitat. A table of the model outcome for each original habitat type was produced. The modelled suitability of each habitat type was then compared to habitat type selection test results.

#### Regression analysis:

Combined summer and fall “season” (July 6 to early November) home ranges (Adaptive Kernel [Worton 1989] and Minimum Convex Polygon [Mohr 1947]) were estimated at the 95% point inclusion level for each bear, overlaid on the cartographic model map and queried for area and composition.

Simple linear regression was used to examine the hypothesis that variation in home range size was determined by the variation in the area of unsuitable habitats within them. The prediction that all bears will use a “standard” area of suitable habitat follows and therefore the regression should have a slope of zero (home range size not predictable from area of suitable habitat).

The area of suitable habitat was regressed against total home range area. Since the definition of the minimum suitability of a habitat was arbitrary, the analysis was initiated using only the area of highest suitability habitat and repeated including the next lower

quality habitat until all habitats up to the 0 (zero) category (no selection) had been incorporated. The slope and significance were examined to verify the hypothesis.

### **Results:**

#### **Selection of independent variables for inclusion in model:**

The Spearman rank order correlation analysis of data collected in all habitats except commercial blueberry fields (Table IV.1) yielded four pairings with significant ( $p < 0.01$ ) and “sufficiently” strong (arbitrarily set at  $|r| > 0.35$ ) correlation. These four pairs included all six variables considered: no variables were completely independent.

**Table IV.1:** Spearman rank order correlation analysis results. Shaded pairings were strongly (arbitrarily set at  $|r| > 0.35$ ) and significantly correlated. (Commercial blueberry fields excluded)

<i>Correlation coefficient (r)</i> <i>Significance (p)</i>	Horizontal cover density	Canopy cover density	Safety tree density	Food spp. richness	Food spp. diversity
Hiding distance	-0.76 0.00	-0.08 0.42	0.18 0.08	-0.12 0.23	0.13 0.21
Horizontal cover density		0.35 0.00	0.15 0.13	0.17 0.09	-0.14 0.16
Canopy cover density			0.72 0.00	-0.002 0.98	-0.21 0.04
Safety tree density				-0.13 0.21	-0.25 0.01
Food species richness					0.48 0.00

The variables selected for use in the cartographic model were (Table IV.2): horizontal cover density (cover pole), safety tree density, and food species diversity. Among the habitat variables considered, these appear to drive bear behaviour. Using the  $\chi^2$  value as a gauge, safety tree density elicited the strongest behaviour, followed by horizontal cover density and food species diversity which were nearly equally important.

**Table IV.2:** Selection of variables for inclusion in the cartographic model using largest  $\chi^2$  value as criteria for selecting only one of two correlated variables. Shaded cells show variables included.

	Variable	Correlation coefficient ( <i>r</i> ) Significance ( <i>p</i> )	Variable
	Hiding distance	-0.76 p<0.01	Horizontal cover
$\chi^2$	10.62		11.79
	Horizontal cover	0.35 p<0.01	Canopy cover
$\chi^2$	11.79		7.88
	Canopy cover	0.72 p<0.01	Safety trees
$\chi^2$	7.88		19.12
	Food spp. richness	0.48 p<0.01	Food spp. diversity
$\chi^2$	10.50		11.54

### Cartographic model results:

Once the variables to be included were identified, the cartographic model map (Figure IV.1) was created. Since three variables were retained, map cell values ranged from -3 to +3. The selection behaviours were linked to the original habitat types used and summarized (Table IV.3). The sum of ratings was considered to be the habitat's suitability.

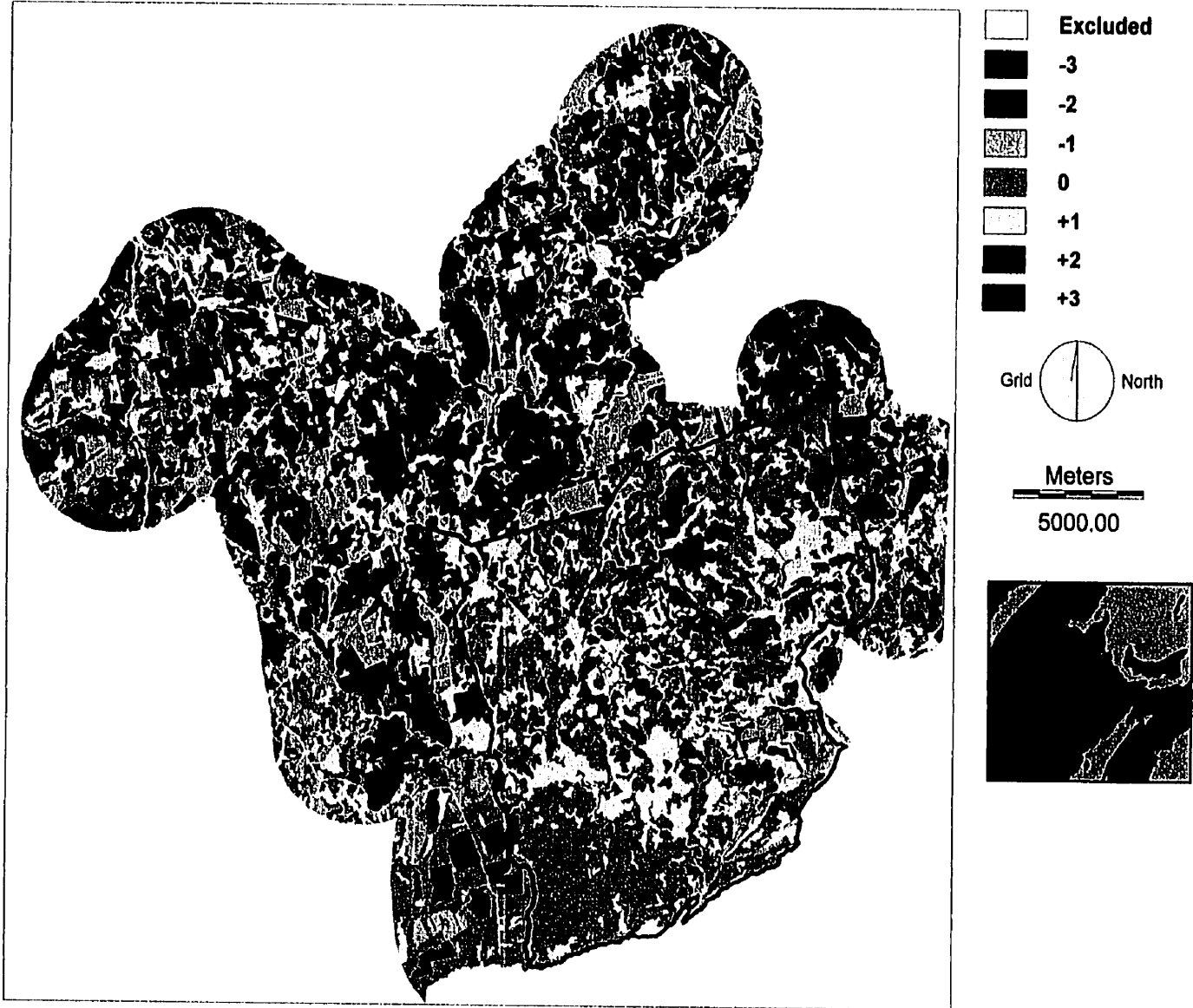
**Table IV.3:** Summary of selection results for each habitat and resultant cartographic model suitability rating. (∅ : neutral; + : suitable; - : unsuitable)

Habitat type	Horizontal cover density selection	Safety tree selection	Food species diversity selection	Cartographic model suitability rating
matHW	-	-	-	-3
matSW	∅	-	+	0
matXHW	∅	+	-	0
matXSW	-	+	+	+1
yHW	∅	+	+	+2
ySW	+	+	+	+3
yXW	+	+	-	+1
BUD	+	∅	-	0
CP0-6	-	∅	-	-2
P7-13	∅	∅	-	-1
PP14+	+	-	-	-1
SP14+	+	∅	+	+2
BB	-	∅	-	-2
DNF	-	∅	∅	-1

Mature hardwoods (matHW) were rated as the least suitable (-3) of all habitats (Table IV.3) and were the only unsuitable natural forest habitat type. Mature softwoods (matSW), mature mixed hardwoods (matXHW) and budworm defoliated habitats (BUD) were neutral (0). All other natural forest habitats were considered suitable: mature mixed softwoods (matXSW) and young mixedwoods (yXW) received a +1 rating, young hardwoods (yHW) a +2 rating. Young softwoods (ySW) were the best habitat type receiving the only +3 suitability rating.

Overall, management-origin forest habitats were unsuitable. Zero to six-year-old cuts and plantations (CP0-6) were the least suitable managed habitat at -2. Seven to 13-year-old plantations (P7-13) and 14-year-old or older pine (PP14+) plantations received a -1 rating whereas 14-year-old or older spruce plantations (SP14+) received the only suitable rating: +2. No management-origin forested habitats were neutral.

Both non-forested habitats were unsuitable. Dry non-forest (DNF) habitats were rated as slightly unsuitable (-1) whereas commercial blueberry fields (BB) received a -2 rating.



**Figure IV.1: Cartographic model - habitat suitability**



The modelled suitability was compared to the results of habitat type selection testing (Table IV.4). The direction of selection test results towards habitat types was determined by considering observed to expected locations.

**Table IV.4:** Comparison of selection results and cartographic model suitability rating for each habitat type. (Though habitats with  $\chi^2$  values below 2.70 were not significantly selected ( $p>0.1$ ), selection trend was indicated if the  $\chi^2$  value was greater than 1.97 ( $p=0.16$ )).

Habitat type	Experimentwise conclusions	$\chi^2$ value (significance <sup>a</sup> )	direction	Cartographic model suitability	agreement
matHW	<i>avoid</i>	18.56**	-	-3	yes
matSW	no selection	0.03	∅	0	yes
matXHW	no selection	0.04	∅	0	yes
matXSW	no selection	2.06≈	+	+1	yes
yHW	no selection	0	∅	+2	no
ySW	no selection	6.76**	+	+3	yes
yXW	no selection	0	∅	+1	no
BUD	no selection	3.45 <sup>^</sup>	+	0	no
CP0-6	no selection	3.00 <sup>^</sup>	-	-2	yes
P7-13	no selection	0.36	∅	-1	no
PP14+	no selection	0.50	∅	-1	no
SP14+	no selection	0.14	∅	+2	no
BB	no selection	0.50	∅	-2	no
DNF	no selection	2.50≈	+	-1	no

<sup>a</sup>Denotes the significance of the  $\chi^2$  test if it were to be considered individually.

<sup>^</sup> significant at the 0.1 level  $\chi^2_{\text{tab}}$  1df=2.70

\*\* significant at the 0.01 level  $\chi^2_{\text{tab}}$  1df=6.63

≈ approaching significance. 0.16 level  $\chi^2_{\text{tab}}$  1df=1.97

The results of habitat type selection testing agreed with the cartographic model's suitability ratings 6 times out of 14 (43%). In most cases (8 out of 14; 57%) conclusions differed.

The model agreed with the direction and strength of the highly significant results of individual  $\chi^2$  goodness of fit tests. Both mature hardwood and young softwood's results were significant at the 0.01 level and both were assigned the highest possible classification in the model (-3 and +3 respectively).

No further relationships appear between  $\chi^2$  value, selection test "preference/avoidance" and modelled suitability. For example, budworm defoliated

habitats were significantly ( $\chi^2=3.45$ ,  $p<0.1$ ) preferred in individual  $\chi^2$  testing yet were classified as neutral by the model. Conversely, selection towards zero to six-year-old plantations (CP0-6) was not as strong ( $\chi^2=3.00$ ,  $p<0.1$ ) as that shown for budworm yet the CP0-6 model rating (-2) agreed with the selection result.

Similarly discordant situations occurred with the other findings. The results of some marginally significant habitats were in agreement whereas others were contradictory. Habitats rated neutral in the use versus availability analysis received ratings as high as |2|.

Though the two strongest conclusions were identical, there was no trend in agreement between the selection analysis and the model's suitability predictions.

#### Hypothesis testing:

The area of each suitability category in each bear's "summer/fall" home range are reported in Appendix I. The mean adaptive kernel home range size was 94.77 km<sup>2</sup> (SD=54.58 km<sup>2</sup>, range: 39.1 km<sup>2</sup> to 205.6 km<sup>2</sup>). Using the minimum convex polygon method, mean home range size was 55.42 km<sup>2</sup> (SD=36.57 km<sup>2</sup>, range: 21.8 km<sup>2</sup> to 139.2 km<sup>2</sup>).

Simple linear regression using the area of map cells with a suitability of +3 produced the following equations:

Adaptive kernel home range (AK HR):

$$\text{area of +3} = -0.511 + (0.106 * \text{AK HR area})$$

$$r^2=0.717, P=0.0020, n=10$$

Minimum convex polygon home range (MCP HR):

$$\text{area of +3} = -0.603 + (0.111 * \text{MCP HR area})$$

$$r^2=0.752, P=0.0012, n=10$$

In both cases the slope was significantly different from zero (AK slope=0.106, P=0.0020; MCP slope=0.111, P=0.0012). Thus, each bear used a significantly different area of sites with a +3 suitability rating.

Considering the area of map cells with a suitability of +2 and +3 jointly, the following equations were obtained:

Adaptive kernel home range (AK HR):

$$\text{area of +2+3} = -3.36 + (0.180 * \text{AK HR area})$$

$$r^2=0.750, P=0.0012, n=10$$

Minimum convex polygon home range (MCP HR):

$$\text{area of +2+3} = -2.91 + (0.195 * \text{MCP HR area})$$

$$r^2=0.798, P=0.0005, n=10$$

In both cases the slope was significantly different from zero (AK slope=0.180, P=0.0012; MCP slope=0.195, P=0.0005). Thus, each bear used a significantly different area of sites with +2 and +3 suitability ratings.

Considering the area of all suitable (+1, +2 and +3) map cells jointly, the following equations were obtained:

Adaptive kernel home range (AK HR):

$$\text{area of +1+2+3} = 0.635 + (0.334 * \text{AK HR area})$$

$$r^2=0.930, P<0.0001, n=10$$

Minimum convex polygon home range (MCP HR):

$$\text{area of +1+2+3} = -0.756 + (0.353 * \text{MCP HR area})$$

$$r^2=0.916, P<0.0001, n=10$$

In both cases the slope was significantly different from zero (AK slope=0.334, P<0.0001; MCP slope=0.353, P<0.0001). Thus, each bear used a significantly different area of suitable (+1, +2 and +3) sites.

Considering the area of all neutral or better map cells (0,+1, +2 and +3) jointly the following equations were obtained:

Adaptive kernel home range (AK HR):

$$\text{area of } 0+1+2+3 = 9.98 + (0.517 \cdot \text{AK HR area})$$

$$r^2=0.900, P<0.0001, n=10$$

Minimum convex polygon home range (MCP HR):

$$\text{area of } 0+1+2+3 = 5.71 + (0.512 \cdot \text{MCP HR area})$$

$$r^2=0.886, P<0.0001, n=10$$

In both cases the slope was significantly different from zero (AK slope=0.517,  $P<0.0001$ ; MCP slope=0.512,  $P<0.0001$ ). Thus, each bear used a significantly different area of neutral or better (0,+1,+2 and +3) suitability class habitat.

The home range sizes of these “comparable” bears varied considerably and the regression results show that the ranges contained significantly different areas of suitable habitat. The hypothesis that the variation in home range size is determined by the variation in the area of unsuitable habitat is thus rejected. Therefore, another factor determines home range size variation. The presence of unsuitable habitats is not causing a dilution effect (fragmentation) detectable by this technique.

### **Discussion:**

None of the variables that elicited a selection behaviour from bears was entirely independent. However, the correlations observed were not surprising: they reflect the similarity of measurements taken (hiding distance and hiding cover), natural relationships (trees create canopy cover) or mathematical relationships (species richness is a component of diversity). Having discussed the possible motivations behind the selection patterns for each variable in the last chapter, the relative strength of the behaviours should now be noted.

Bears showed the strongest selection towards safety trees. As previously mentioned, the selection pattern is not intuitive (and may be linked to the “safety diameter” threshold employed); however, it remains that female bears reacted strongly to safety tree density. This is probably not linked to direct security needs but perhaps to some fixed, innate “maternal instinct” for cub security (Herrero 1972, Young and Beecham 1983). The majority of bears tracked were not accompanied by cubs. A comparison with the behaviour of male bears would be relevant.

A preference for “secure” habitats is also apparent through the strength of selection towards horizontal cover density. In this case, the selection pattern is more intuitive and probably relates to both adult and cub security. Food species diversity elicited an equally strong behaviour. As mentioned in Chapter III, due to the index used, the sites selected are dominated by a few abundant species.

Security and, to a lesser degree, food availability are therefore the principal factors driving habitat use of female bears in the area.

Given the correlation between food species richness and diversity, the strong selection both received and the ease of collecting richness data over diversity data (where abundance is required), only food species richness need be collected in future investigations. If horizontal cover and safety tree density are measured, future researchers in the area should not be concerned with hiding distance or canopy cover.

Home range size variation was observed, yet could not be linked to a fragmentation effect caused by the presence of unsuitable habitats. All regressions showed a positive relationship between home range size and the amount of suitable habitat. As an alternative, a negative relationship (smaller home range, more suitable habitat within it) would have been predicted and would have agreed with optimal foraging theory. The positive relationship obtained was unexpected. This suggests that the availability of

suitable habitat (as defined) is not limiting and that other factors, such as: sex, age, reproductive condition, kinship, social rank or population density are responsible for home range size variation (review in Smith and Pelton 1990). Perhaps habitat conversion does not cause space-use consequences but instead precipitates population size, productivity or dispersal variation effects (Lindzey et al. 1986). Though it must be assumed that bears foraged optimally, it appears that the variable or variables they sought to optimize was not explored.

The relationship shown may suggest a reliance on point sources of abundant food. Bears in the area are intensively baited by hunters from spring to early summer and from late summer to autumn. If bears depended on baits (and to a lesser degree on blueberry fields and abandoned orchards) for nourishment, their movements and space-use would not show an “expected” relationship with habitat.

One interesting hypothetical explanation of the strong relationship between area of ySW and home range size is as follows: if local practice dictated that baits be set in young softwoods (the only +3 habitat), as bears roamed farther afield to seek bait sites, their home ranges would increase, along with the area of ySW habitats within them.

The premises upon which the model rests could be flawed. Due to a lack of location data, all bears had to be considered as equal. Though all female, they ranged from three to 14 years of age. Similarly, assuming that the behaviours of cub-accompanied females were identical to those of solitary ones may also have been incorrect though only summer and fall (when food was available and cubs mobile) were considered. Habitat use differences between the two groups have been observed (Alt et. al. 1980, Rogers 1987, Samson 1995).

Perhaps bears that frequented baits were less concerned with habitat productivity than unbaited bears who expended more time foraging. Whatever differences existed were perhaps too great to assume identical behaviour.

Methodological weaknesses were also present; for instance, the exercise relies on nested assumptions: habitat types chosen would be relevant to bears and a representative sample of these habitats could be obtained by sampling sites in each. Furthermore, when multiple comparison tests did not clearly separate habitat types into defined groups for each variable, box-plots were used to do so graphically.

Considering these potential flaws, it is almost surprising that the most significant model conclusions (avoidance of matHW and preference of ySW) were identical to those of the use versus availability analysis. This adds credibility to the modelling procedure and demonstrates the significance of the behaviours.

The significance of the slopes and the large  $R^2$  values for the regression equations demonstrate that the relationship is not random. The area of +3 habitat (ySW only) alone explains 71.7% of the variation in home range size although the habitat only covers 8.6% of study area. Jointly, the three positive suitability classes explain 93% of the variation in home range size. However, this significant result is beyond the scope of the hypotheses considered. Considering this result and the lack of territoriality observed, the availability of good habitat is apparently not limiting. However, the wide variation in home range area and, consequently, suitable habitat cannot yet be explained.

Affirming that one technique is superior is difficult. This was a comparison, not a validation *per se*. As no data could be excluded from the model to serve as a control and, as the bear's "true" behaviours are unknown, there is no statistical basis upon which to conclude.

Furthermore, the variables evaluated by bears are unknown. When encountering a habitat type, bears behave based on what is important to them. The cartographic model does not reflect this. The researcher selects which variables to sample. Therefore, the mix of variables presented to the bears does not necessarily include the ones they evaluate, though selection may still be shown. With habitat use versus availability, bears are presented with (human) habitats and select them considering the variables they gauge as important.

However, the cartographic technique is a suitable alternative for the examination of relationships between locations and habitat variables and benefits from being able to integrate landscape variables; a further weakness is that model precision depends upon the number of layers included (number of independent variables sampled and eliciting selection). A stepwise regression technique would be superior to both approaches in identifying driving variables but data collection must be planned accordingly.

Though the use versus availability analysis fulfilled the conditions set out in Neu et al. (1974) and Byers et al. (1984), many more locations would be required to conclusively gauge the selection of habitats not covering a significant portion of the study area. The cartographic approach averts this since less abundant habitats are inventoried with the same intensity as others and, on a variable by variable basis, are grouped with other habitats and then assessed for selection (as part of a different group for each variable). Subsequently, when selection results for each variable are integrated, a significant evaluation of each habitat's suitability is achieved whatever its landscape proportion. Cartographic model neutral ratings reflect bear behaviour. In use versus availability testing, they may imply that insufficient locations were collected even if test assumptions were met.



The model and the selection analysis disagreed on the suitability of management-origin forest habitats except for the CP0-6 habitat (unsuitable with either technique). In use versus availability tests, all other managed habitat types were used according to availability by bears (no selection) whereas the cartographic technique rated them as unsuitable except for the SP14+ habitat that was preferred.

The unsuitable management-origin habitats (CP0-6, P7-13, PP14+) represent 12.6% of the study area. As none are found in the Park, the habitats represent 16.1% of the 425 km<sup>2</sup> outside-Park area and, according to the model, one third of the area of unsuitable habitat (CP0-6, P7-13, PP14+ equalled 12.6% vs. 25.2% for matHW and BB). This does not imply that forestry activities increased the area of unsuitable habitats by that much. Some plantations replaced unsuitable natural habitats such as matHW. Therefore, the proportion of unsuitable (or neutral considering the use vs. availability results) habitat is probably only slightly greater now than it was before industrial forest management's introduction. As no dilution effect was shown, the increased proportion of unsuitable habitat in the landscape appears not to have been detrimental.

Unmanaged young softwood habitats (ySW) were either preferred or suitable depending on technique employed. The model rated fourteen-year-old and older spruce plantations (SP14+) as +2 suitability habitats. Thus, as the spruce-dominated CP0-6 and P7-13 habitats age, they will become suitable habitats. However, this period of unsuitability could be avoided if harvesting and silvicultural practices were modified to make these sites more ecologically similar to their unmanaged counterparts: the ySW and BUD preferred in use versus availability tests.

By using appropriate silvicultural practices, it may be feasible to increase horizontal cover density (in CP0-6 and P7-13 habitats) to the 46% "usability" (neutral) threshold (Chapter III). Similarly, large trees could be left on site to act as safety trees.

Results showed an optimal density of 507 to 1122 safety trees per hectare. Leaving this much timber is unreasonable. However, using BUD habitats as a guide, 249 trees per hectare may be sufficient. Individual  $\chi^2$  test results showed BUD was preferred ( $p=0.1$ ) in spite of its “low” density of safety trees. Perhaps the 10 cm dbh threshold used was too small to reflect security provided. As a result, some habitats’ high tree densities may not reflect their real (lower) security value. The BUD habitat trees were mainly mature spruce and birch not affected by the infestation. These trees truly offered security. Manipulating food species diversity is nearly impossible but it should be monitored to ensure that existing levels are not negatively affected. Recent changes in local forest management may already be leading towards these objectives.

Both techniques regarded mature hardwood habitats (matHW - 21.4% of area) as low suitability / avoided habitats. Such agreement supports the assertion that beech bark disease has decreased beechnut production. Other studies with significant beech habitats reported attraction to these sites (Hugie 1982, Costello 1992, Samson 1995).

### **Conclusion:**

Security and food availability appear to drive female bear habitat use in the area. The density of safety trees elicited the strongest behaviour. Horizontal cover and food species diversity drew weaker, but nearly equal, responses.

The presence of unsuitable habitats in the study area was not shown to cause a spatial dilution (fragmentation) effect. The replacement of natural habitats with managed ones (plantations) causes a temporary period of decreased suitability for the areas involved. This could be avoided through changes in harvesting and silvicultural techniques. Natural habitats were generally considered to be more suitable than

management-origin habitats with the exception of mature hardwoods (considered unsuitable by both techniques).

There are advantages and disadvantages to both methods used. For simplicity and direct applicability, the use versus availability analysis is recommended. However, having explanatory information makes a multi-resource forest inventory desirable. This allows the quantification of habitat variables that can then be managed. At the very least, it can be assumed that selected habitats have an adequate combination of variables.

In situations with limited resources, the cartographic modelling approach is a good compromise between the descriptive use versus availability approach and the more labour intensive regression modelling technique in which use *sites* are sampled.

Cartographic modelling would excel if used as a re-analysis or data mining tool. Existing animal location sets that once served to quantify *where* animals were could be efficiently “recycled” by integrating easily-produced landscape variable maps and habitat variable maps into a cartographic modelling process that would help explain *why* animals chose specific locations. A random point multi-resource inventory is more efficient and feasible than navigating to imprecise animal location sites to record habitat characteristics as is required of regression techniques. Data sets in which the animal’s location is imperfectly known yet a habitat type recorded would be perfect for the application of this technique if habitat characteristics had not changed substantially in the time elapsed.

## **Conclusions and Recommendations**

This project has provided a new outlook on the ecology of female bears, the effects of forest harvesting and Fundy National Park's regional conservation role. New research and management considerations have also emerged.

Individual habitat variables' contributions to habitat use have been shown. Safety tree density was the independent habitat variable that elicited the strongest response from female bears; two other variables also influenced bear behaviour to a lesser degree: horizontal cover and food species diversity calculated using the Simpson index (Simpson 1949). Security thus appears to be a very important factor. Surprisingly, bears showed no habitat use response to ground cover of food species in a habitat. No behaviour was shown towards distance to water either.

Female bears preferred habitats with 507.5 to 1122 safety trees per hectare yet showed no response to habitats with lower densities and avoided habitats with a greater density. This should be investigated but may be linked to the methodology used. Instead of using an arbitrarily-set threshold (10 cm), tree diameters should be measured to assist in explaining the relationship. A strong behaviour was shown towards horizontal cover density (concealment measured with a cover pole); this relationship was more understandable as habitats with low cover (0-46.1%) were avoided, those with medium densities (46.1-66.25%) were neutral and habitats with higher cover densities were preferred. Female bears sought the security of concealment.

Bears showed a similarly strong response towards food species diversity. They preferred habitats with low (0-0.362) food species diversity, avoided those with medium diversity (0.362-0.596) and used those with greater diversity according to their

availability. The Simpson index assigned greater weight to dominant species. Therefore, the low diversity habitats' preference stems from the characteristics of such sites: few species yet high ground cover of each. Reactions towards the other diversity groups should be further investigated as they may reflect the plant composition and fruiting chronology of habitats. Medium diversity habitats may only provide limited food for a short period and be avoided otherwise, whereas high diversity habitats may also provide small quantities of food but over a longer period as different species come into fruit. The latter sites could thus be used according to their availability. Food plant community ecology should be investigated.

The above findings were reflected in habitat type selection test results. Clearcuts and plantations of up to six years of age (CP0-6) were avoided though they had the second highest level of ground cover of food species (after commercial blueberry fields). The CP0-6 habitats had very little horizontal cover and no safety trees. Conversely, young natural softwood stands (ySW) had the least amount of food of any habitat yet were a preferred habitat. In contrast, ySW had medium safety tree density and high canopy cover.

A scat analysis study is needed to quantify the importance of bunchberry on a seasonal and multi-year basis. The species' nutritional value and electivity to bears should be compared to those of other berries to establish the use of this abundant edible species and determine whether or not it is a food of last resort. General investigations of bear food plants' nutrient content and the relationship between their ground cover and available biomass should be considered. A simple programme of food productivity monitoring should be established as it would provide advance warnings of later-season bear problems and serve in bear population management.

The study was not free from methodological concerns. Though the habitat types used were relevant to foresters and were based upon the results of previous studies, they remain human constructs. The forced aggregation of bears and their “summer-fall season” locations due to lack of data may have hidden some behaviours. Neutral selection results towards some habitats may have resulted from aggregation-related “compensation”: the behaviour of females with cubs may have compensated for that of solitary females, or perhaps habitats preferred in the summer may have been avoided in the fall. Another methodological concern is that of habitat variable assessment: the analysis groupings were aggregations of the original habitat types; therefore, the responses to each variable were perhaps not entirely independent of strong responses to other variables expressed towards a habitat within a group. Had data been suitably collected, a regression analysis of use sites and random sites would have been superior owing to its simultaneous consideration of each variable and discrimination of each’s influence. However, when combined with the use versus availability analysis of habitat types, the habitat inventory does permit anecdotal insight into the reasons behind bears’ reactions to a habitat.

Insights have been gained into the effects of forest harvesting and management activities upon adult female bears in the area. Principal among these was that no fragmentation effect in the form of dilution of usable habitat was shown. The variation in home range sizes was not linked to the variation in the amount of unsuitable habitat within them: another factor determined size variation in home ranges. Most (72%) of the variation in home range area was accounted for by the variation in the area of young softwood habitat within them. This surprising relationship merits further attention and, when considered with the lack of selection showed towards food species ground cover,

suggests that -wild- plant food may not be a limiting factor in the area. Point sources of food may play a greater role in spatial dynamics than observed elsewhere.

The lack of a fragmentation effect probably relates to the fact that management-origin habitats did not appear to increase overall landscape unsuitability. These habitats (neutral in use vs. availability tests / unsuitable in the cartographic model) made up approximately 1/3 of the unsuitable areas of the landscape; this does not necessarily translate into a significant increase in unsuitable habitat as many plantations replaced what were probably unsuitable or neutral habitats originally. As these currently unsuitable management-origin habitats age, their suitability increases and they will eventually become preferred habitats.

Changes in harvesting techniques should be implemented to ensure that plantations and newly cut areas contain elements that would make them a preferred habitat thus eliminating the 14-year unsuitability period. New cuts should simulate the structure of severely budworm-defoliated habitats (preferred in selection tests yet low safety tree density) until pre-commercial thinning. Cut patterns could even simulate those of the naturally-occurring gap disturbance regime. Foresters should ensure that the proportion of unsuitable habitat in the landscape never reaches a level that would decrease its carrying capacity. This level should be quantified but, as no “dilution of suitable habitats” fragmentation effect was shown with the current degree of management origin habitat in the landscape, the present proportion may serve as a good baseline.

Stand geometry did not affect bear habitat use at the scale at which it was investigated. A significant equipment-related detectability bias was found that precluded the study of the effects of roads upon bears. Such a study is necessary but cannot be conducted using conventional ground-based telemetry.

Alien species should be monitored to identify possible impacts: many plantations were stocked with species not native to New Brunswick. The resultant community may offer a different level of suitability to bears than that of native communities.

Unintentionally introduced species such as the causative agents of beech-bark disease must also be monitored.

Assessing the Park's role as a local bear conservation anchor was also a project objective. Results suggest that the Park plays a minor role at best. Bears whose home ranges overlapped the Park boundary showed no preference for either side. The habitat mosaic outside of Park boundaries is more varied than the Park's due to the presence of management-origin habitats. Some bears maintained home ranges entirely outside of the Park, confirming that the outside-Park habitat mosaic can fulfil local bears' requirements. One bear never left the Park, all other bears used portions of the outside and some made directed excursions towards point sources of food (blueberry fields and abandoned orchards). The Park is only three times the mean home range size of a female bear (whereas male ranges are much greater than those of females [Garshelis and Pelton 1981, Hugie 1982, Rogers 1987]) and thus cannot be considered to be an important refuge.

With respect to habitat, the strong avoidance of mature hardwood stands is very alarming: what is a very productive habitat elsewhere (Hugie 1982, Samson 1995) has been debilitated by beech-bark disease. The strong avoidance of the habitat, personal observations of grossly infected beech stands and the failure of beechnut crops is evidence of the deterioration of the Park's ecological integrity. This situation should serve as a warning to regions not yet infected by this spreading disease and as a testimonial to the impacts of invasive alien species on wildlife.



However, two “wrongs” may almost make a “right”; the lack of hard mast is probably somewhat counter-balanced by an alien (but non-invasive) food source: the decadent apple orchards found in the abandoned settlements and homesteads that dot the landscape. These provide large quantities of soft mast in the fall (with occasional remnants in spring) when no other natural food plants are available and when bears’ energetic needs are at a critical point (Kolenosky and Strathearn 1987). As analysed, the tracking data could not show that bears did congregate in these orchards in the fall. Within the Park, these sites should be protected and maintained for three reasons: their representation of the Park’s cultural history, their direct ecological role in bear energetics and, their role in keeping bears in the Park during the fall hunting season thus probably reducing bear mortality.

Beech-bark disease should be investigated. The focus should be on active management to reduce the disease’s impacts; this would provide prevention and control insight for areas with yet-unaffected beech populations.

Bears preferred younger habitats to older ones. Since forest harvesting is not allowed in the Park, early successional habitats can only be created through natural disturbance. Fires do occur, but insect infestations are the predominant disturbance. A spruce budworm infestation took place in the early 1980s. Though provincial lands were sprayed, Park managers resisted pressures and did not undertake control efforts. The extensive areas of 7 to 13-year-old plantations now surrounding the Park result from salvage-logging undertaken as a response. The current high quality of unmanaged budworm-defoliated sites in terms of variables examined and the preference exhibited towards them stands as a testament to park managers that allowed nature to take its course. Had budworm been controlled, the Park would now be dominated by “artificially” older habitats of little value to bears. The presence of budworm-defoliated habitats ensures

that the Park is of value to the bears throughout the year and means that they need not leave the Park to fulfill (qualitatively at least) their habitat needs.

Many issues must be examined when considering the long term population and habitat viability of bears in the area. The effects of hunting are the most important. Commercial bear hunting outfitters operate around the Park; their clients have harvested up to nearly 40 bears a year within a 10-km radius of the Park during spring and fall hunts. An unsustainably managed hunt would threaten the long term viability of the local bear population and undermine the Park's role in the preservation of the ecological integrity of a representative portion of the Caledonian Highlands ecoregion.

Investigations should now focus on hunting effects since habitat-related activities were not shown to be more than a temporary and, if the proportions of unsuitable managed habitat are maintained, non-detrimental decrease in the landscape's suitability to bears. Conservation-oriented changes in forestry practices now occurring will likely address any remaining habitat-related concerns. Hunting should now be examined to gauge its effect on the long term viability of the local bear population. Though the management of the bear hunt has been improved since the study by the introduction of outfitter territories and other measures, an analysis of the hunt's effects and management options should still be initiated to ensure that the current harvest is sustainable. Another study should investigate the importance of bait sites to bear movements, habitat use and energetics.

Though the data were not analysed in a manner that could show this, some bears remained in the vicinity of bait sites for periods of a week or two, whereas other bears did not show baiting influence. The quantities of bait offered are substantial and may be affecting the energetic balance and spatial ecology of bears. Other point sources of food

should also be considered. Abandoned apple orchards outside the Park should be listed as ecologically significant features with development and forestry authorities to prevent their destruction. An educational program should be developed to inform landowners of the importance of these sites to wildlife with a focus on ensuring orchard preservation and maintenance.

The “defence” of blueberry fields should also be investigated. “Park” bears made directed long-distance movements to these sites. The “use” of blueberry fields by bears obviously conflicts with human interests. Thus, all terrain vehicle-equipped armed “guardians” are employed to patrol these fields and are allowed to kill bears “causing damage to crops” and do so regularly. No other means of depredation control were observed. Field guardians and other stakeholders should be the objects of an educational program aimed at promoting alternatives to the use of lethal force and enhancing stakeholder understanding of bear ecology in the locale.

Alternatively, as blueberry fields are harvested every second year, a situation exists where fields on opposite sides of roads may be scheduled for harvesting in opposing years yet any bears in the area are targeted for control. Therefore, the harvesting of fields in an area should be synchronized so that bears could be allowed to use the area freely every two years. Human activities and non-lethal control methods would quickly guide bears to areas not scheduled for harvesting.

It should be noted that all area landfills were decommissioned in the years before the study and that, accordingly, no garbage-related spatial behaviours were ever observed.

Tourism development could also negatively affect bears. The possible construction of a paved parkway leading to the Park, along with an increase in cottage development and outdoor recreation, will increase human presence in previously

uninhabited areas. To prevent problem bear issues from arising, an educational program aimed at developers, cottagers and visitors should be implemented.

Outfitters should be involved in the development and delivery of all proposed educational programs as they have a stake in ensuring the viability of bear populations and limiting non-hunting mortality.

Given the shared yet contradictory nature of bear population management in the area and the challenges faced, the creation of a broadly-based stakeholder group mandated to develop an adaptive management plan for this bear population is suggested to ensure its long-term viability.

Habitat is only one component of a solution.

**Literature Cited:**

- Alt, G.L., G.J. Matula, Jr., F.W. Alt, and J.S. Lindzey. 1980. Dynamics of home range and movements of adult black bears in northeastern Pennsylvania. *Int. Conf. Bear Res. and Manage.* 4:131-136.
- Amstrup, S.C., and J. Beecham. 1976. Activity patterns of radio-collared black bears in Idaho. *J. Wildl. Manage.* 40:340-348.
- Aune, K.E. 1994. Comparative ecology of black and grizzly bears on the Rocky Mountain Front, Montana. *Int. Conf. Bear Res. and Manage.* 9(1):365-374.
- Berducou, C. 1994. Useful habitat suitability indicators for special forest management plans in the Brown Bear area of France. in *Proc. XXIst Congress IUGB, Halifax, Nova Scotia, 1993*. I.D. Thompson, editor, Petawawa National Forestry Institute, Chalk River, Ontario.
- Boileau, F. 1993. Utilisation de l'habitat par l'ours noir dans le parc de conservation de la Gaspésie. M.Sc. Thesis. Laval University, Québec, Québec. 53pp.
- Burt, W.H. 1943. Territoriality and home range concept as applied to mammals. *J. Mammal.* 24:346-352.
- Byers, C.R., R.K. Steinhorst, and P.R. Krausman. 1984. Clarification of a technique for analysis of utilization-availability data. *J. Wildl. Manage.* 48:1050-1053.
- Costello, C. M. 1992. Black bear habitat ecology in the central Adirondacks as related to food abundance and forest management. M.Sc. Thesis. State University of New York, Syracuse, New York. 165pp.
- Costello, C.M. and R.W. Sage, Jr. 1994. Predicting black bear habitat selection from food abundance under 3 forest management systems. *Int. Conf. Bear Res. and Manage.* 9(1):375-387.
- Craig, K. N. 1991. New Brunswick black bear project. 1989 - 1991. Final Report. Fish and Wildlife Branch. Department of Natural Resources and Energy. Fredericton, New Brunswick. 55pp.
- Crane, M.F. 1989. Cornus canadensis. In: Fischer, William C., compiler. The Fire Effects Information System [Data Base]. Missoula, MT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Intermountain Fire Sciences Laboratory. Magnetic Tape Reels; 9 track; 1600 bpi, ASCII with Common LISP present. Available online at:  
<http://www.fs.fed.us/database/feis/plants/shrub/corcan/introductory.html>

- Day, S.M. 1997. Aspects of Newfoundland black bear (*Ursus americanus hamiltoni*) food habits and habitat use in human-influenced environments. M.Sc. Thesis. Acadia University, Wolfville, NS, Canada. 112 pp.
- Eastman, R.J. 1997. Idrisi for Windows. User's guide. Version 2.0. Clark Labs for Cartographic Technology and Geographic Analysis. Clark University. Worcester, MA. USA. 376 pp.
- Ecological Stratification Working Group. 1995. A National Ecological Framework for Canada. Agriculture and Agri-Food Canada, Research Branch, Centre for Land and Biological Resources Research and Environment Canada, State of the Environment Directorate, Ecozone Analysis Branch, Ottawa/Hull. Report and national map at 1:7 500 000 scale.
- Elowe, K.D. 1984. Home range, movements, and habitat preferences of black bears (*Ursus americanus*) in western Massachusetts. M.Sc. Thesis, University of Massachusetts. Amherst, MA. 112pp.
- Garshelis, D.L., and M.R. Pelton 1980. Activity of black bears in the Great Smoky Mountains National Park. *J. Mamm.* 61:8-19.
- Garshelis, D.L., and M.R. Pelton 1981. Movements of black bears in the Great Smoky Mountains National Park. *J. Wildl. Manage.* 45:912-925.
- Gavin, T. A. 1991. Why ask "Why": The importance of evolutionary biology in wildlife science. *J. Wildl. Manage.* 55: 760-766.
- Griffith, B. and B. A. Youtie. 1988. Two devices for estimating foliage density and deer hiding cover. *Wildl. Soc. Bull.* 16(2):206-210.
- Harris, L.D. 1984. The fragmented forest. Island biogeographic theory and the preservation of biotic diversity. University of Chicago Press, Chicago, Illinois.
- Harris, S., W.J. Cresswell, P.G. Forde, W.J. Trehwella, T. Woollard, and S. Wray. 1990. Home Range analysis using radio-tracking data - a review of problems and techniques particularly as applied to the study of mammals. *Mammal. Rev.* 20:97-123.
- Herrero, S. 1972. Aspects of evolution and adaptation in American black bears (*Ursus americanus Pallus*) and brown and grizzly bears (*Ursus arctos* Linne.) of North America. *Int. Conf. Bear Res. and Manage.* 2:221-231
- Hirvonen, R., and R.J. Madill. 1978. Fundy National Park, N.B. and the proposed western extension integrated resource survey. Canadian Forestry Service, Forest Management Institute Information Report FMR-X-105, 215p.

- Hugie, R.D. 1982. Black bear ecology and management in the northern conifer-deciduous forests of Maine. Ph.D. thesis, University of Montana. Missoula, Montana. 215 pp.
- Johnson, K. G. and M. R. Pelton. 1980. Prebaiting and snaring techniques for black bears. *Wildl. Soc. Bull.* 8(1) 46-54.
- Jonkel, C.J. and I. M. Cowan. 1971. The black bear in the spruce-fir forest. *Wildl. Monogr.* 27. 57pp.
- Keppie, D. M. 1990. To improve graduate student research in wildlife education. *Wildl. Soc. Bull.* 18:453-458.
- Kie, J.G., Baldwin, J.A., Evans C.J. 1994. Calhome. Home range analysis program. U.S. Forest Service, Pacific Southwest Research Station, 2081 East Sierra Avenue, Fresno, CA.
- Klenner, W. 1987. Seasonal movements and home range utilization patterns of the black bear, *Ursus americanus*, in western Manitoba. *Can. Field Nat.* 101(4):558-568.
- Kolenosky, G.B. 1990. Reproductive biology of black bears in east-central Ontario. *Int. Conf. Bear Res. and Manage.* 8: 385-392.
- Kolenosky, G.B. and S.M. Strathearn. 1987. Black bear, p.442- 454 *in*: Novak, M., J.A. Barker, M.E. Obbard and B. Malloch *editors*. *Wild Furbearer Management and Conservation in North America*. Ontario Trappers Association. North Bay. ON. Canada. 1150 pp.
- Krebs, J.R., 1978. Optimal foraging: Decision rules for predators, p. 23-63, *in* Krebs, J.R., and N.B. Davies, *ed.*, *Behavioural ecology*. Sinauer, Sunderland, MA. USA.
- Larivière, S., J. Huot, and C. Samson. 1994. Daily activity patterns of female black bears in a northern mixed-forest environment. *J. Mamm.* 75:613-620
- LeCount, A.L. 1986. Causes of black bear cub mortality. *Int. Conf. Bear. Res. and Manage.* 7:75-82.
- Lemmon, P. E. 1957. A new instrument for measuring forest overstory density. *J. For.* 55:667-669.
- Leopold A.1933. *Game Management*. Scribner, New York, USA. 481 pp.
- Lindzey, F.G. and E.C. Meslow. 1977. Home range and habitat use by black bears in southwestern Washington. *J. Wildl. Manage.* 41:413-425.

- Lindzey, F.G., K.R. Barber, R.D. Peters, and E.C. Meslow. 1986. Responses of a black bear population to a changing environment. *Int. Conf. Bear Res. and Manage.* 6:57-64.
- MacArthur, R.H., and E.R. Pianka, 1966. On optimal use of a patchy environment. *Am. Natur.* 100:603-609.
- Manville, A.M. 1983. Human impact on the black bear in Michigan's Lower Peninsula. *Int. Conf. Bear Res. and Manage.* 5:20-33.
- Mattson, D.J. 1990. Human impacts on bear habitat use. *Int. Conf. Bear. Res. and Manage.* 8:33-56.
- McCutchen, H.E. 1990. Cryptic behavior of black bear (*Ursus americanus*) in Rocky Mountain National Park, Colorado. *Int. Conf. Bear Res. and Manage.* 8:65-72.
- Mohr, C.O. 1947. Table of equivalent populations of North American mammals. *Amer. Midland Nat.* 37:223-249.
- Mollohan, C.M. 1987. Characteristics of adult female black bear daybeds in northern Arizona. *Int. Conf. Bear Res. and Manage.* 7:145-149.
- Mollohan, C. M. and A. L. LeCount. 1989. Problems of maintaining a viable black bear population in a fragmented forest. United States Department of Agriculture, Forest Service. Rocky Mountain Forest and Range Experiment Station. General Technical Report RM-185. Multiresource management of ponderosa pine forests. P.149-159.
- Mollohan, C. M., W. W. Brady and A. L. LeCount. 1989. Habitat use of an Arizona ponderosa pine - mixed conifer forest by female black bears. *West. J. Appl. For.* 4:6-10.
- Nams, V.O. 1991. Locate II. User's manual. Pacer Software. Truro, Nova Scotia. 79pp.
- National Parks Act 1988. Department of Justice, Ottawa, ON. Canada  
Available online: <http://canada.justice.gc.ca/STABLE/EN/Laws/Chap/N/N-14.html>
- Neu, C.W., C.R. Byers, J.M. Peek, and V. Boy. 1974. A technique for analysis of utilization - availability data. *J. Wildl. Manage.* 38:541-545.
- Noyce, K. V. and P. L. Coy. 1990. Abundance and productivity of bear food species in different forest types of northcentral Minnesota. *Int. Conf. Bear Res. and Manage.* 8:169-181.



- Pelchat B.O. 1983. Habitat and spatial relationships of black bears in boreal mixedwood forest of Alberta. M.Sc. Thesis. University of Wisconsin. Madison, WI. USA. 46pp.
- Pelchat, B.O. and R.L. Ruff. 1986. Habitat and spatial relationships of black bears in boreal mixedwood forest of Alberta. *Int. Conf. Bear. Res. and Manage.* 6:81-92.
- Peyton, B. 1987. Criteria for assessing habitat quality of the spectacled bear in Macchu Picchu, Peru. *Int. Conf. Bear Res. and Manage.* 7:135-143.
- Reynolds, D.G. and J.J. Beecham. 1980. Home range and reproduction of black bears in west-central Idaho. *Int. Conf. Bear Res. and Manage.* 4:181-190.
- Rogers, L.L. 1976. Effects of mast and berry crop failures on survival, growth, and reproductive success of black bears. *Trans. North Am. Wildl. And Nat. Resour. Conf.* 41:431-438.
- Rogers, L.L. 1987. Effects of food supply and kinship on social behavior, movements and population growth of black bears in northeastern Minnesota. *Wildl. Monogr.* 97. 72pp.
- Sokal, R.R. and F.J. Rohlf. 1995. *Biometry: the principles and practice of statistics in biological research.* Third edition. W.H. Freeman and Company, New York, USA. 887 pp.
- Romesburg, H. C. 1981. Wildlife science: gaining reliable knowledge. *J. Wildl. Manage.* 45:293-313.
- Saltz, D. 1994. Reporting error measures in radio location by triangulation: a review. *J. Wildl. Manage.* 58(1):181-184.
- Saltz, D. and P.U. Alkon. 1985. A simple computer-aided method for estimating radio-location error. *J. Wildl. Manage.* 49:664-668.
- Saltz, D. and G.C.White. 1990. Comparison of different measures of error in simulated radio-telemetry locations. *J. Wild. Manage.* 54:169-174.
- Samson, C. 1995. *Écologie et dynamique de population de l'ours noir dans une forest mixte protégée du sud du Québec (Canada).* Ph.D. Thesis. Laval University, Québec, Québec. 201pp.
- Schooley, R.L. 1990. Habitat use, fall movements, and denning ecology of female black bears in Maine. M.Sc. Thesis. University of Maine at Orono. Orono, ME, USA. 115 pp.

- Seaman D. E. and R.A. Powell. 1990. Identifying patterns and intensity of home range use. *Int. Conf. Bear Res. and Manage.* 8:243-249.
- Simpson, E.H. 1949. Measurement of diversity. *Nature* 163:688.
- Sinclair, A. R. E. 1991. Science and the practice of wildlife management. *J. Wildl. Manage.* 55:767-773.
- Smith, T.R. and M.R. Pelton. 1990. Home ranges and movements of black bears in a bottomland hardwood forest in Arkansas. *Int. Conf. Bear Res. and Manage.* 8:213-218.
- Tomlin, C.D. 1990. Geographic information systems and cartographic modelling. Prentice-Hall. Upper Saddle River. N.J. USA. 322 pp.
- Tukey, J.W. 1977. Exploratory data analysis. Addison-Wesley, Reading, MA. USA. 688 pp.
- VanWinkle, W. 1975. Comparison of several probabilistic home-range models. *J. Wildl. Manage.* 39:118-123.
- White, G.C. and R.A. Garrot. 1990. Analysis of wildlife radio-tracking data. Academic Press, Inc., San Diego, CA, U.S.A.. 383pp.
- Wilkinson, L., G. Blank and C. Gruber. 1996. Desktop data analysis with Systat. Prentice-Hall. Upper Saddle River. NJ. USA. 798pp.
- Woodley S., and G. Forbes. 1997. Forest management guidelines to protect native biodiversity in the Fundy Model Forest. New Brunswick Co-operative Fish and Wildlife Unit, University of New Brunswick. Fredericton. NB. Canada. 36 pp.
- Worton, B.J. 1989. Kernel methods for estimating the utilization distribution in home-range studies. *Ecology* 70:164-168.
- Young, D. D. and J. J. Beecham. 1983. Black bear habitat use at Priest Lake, Idaho. *Int. Conf. Bear Res. and Manage.* 6:73-80.
- Young, B.F., and R.L. Ruff. 1982. Population dynamics and movements of black bears in east-central Alberta. *J. Wildl. Manage.* 46:845-860.

**Appendix I: Cartographic model suitability map query results.**  
**Adaptive kernel home range estimates:**

Area (km <sup>2</sup> ) bearing suitability index value								
Bear	-3	-2	-1	0	1	2	3	total (km <sup>2</sup> )
F01	19.6	1.3	4.8	24.7	22.2	3.4	10.1	86.2
F02	40.7	6.4	13.9	25.1	25.4	3.6	14.5	129.5
F03	12.5	0.1	2.6	17.9	11.4	1.5	3.6	49.7
F04	6.2	0.5	3.6	12.3	8.8	1.0	6.8	39.1
F05	5.8	0	3.0	20.0	12.1	0.1	0.3	41.3
F06	3.8	5.6	7.8	64.0	20.6	0.5	2.3	104.5
F08	46.4	10.2	32.5	43.5	33.6	18.1	21.3	205.6
F09	17.7	4.0	10.3	15.7	12.7	5.3	7.8	73.5
F10	43.4	7.1	20.6	33.0	29.2	4.2	17.9	155.5
F11	13.2	3.2	11.4	10.1	10.3	4.1	10.4	62.8

**Minimum convex polygon home range estimates:**

Area (km <sup>2</sup> ) bearing suitability index value								
Bear	-3	-2	-1	0	1	2	3	total (km <sup>2</sup> )
F01	11.9	1.0	2.5	18.7	16.6	2.0	6.1	58.8
F02	22.9	2.8	5.1	9.5	13.2	2.1	7.7	63.2
F03	6.4	0.1	1.7	11.7	7.1	1.1	2.5	30.6
F04	4.0	0.2	2.3	9.0	5.2	0.6	4.6	26.0
F05	3.2	0	1.8	9.3	7.2	0	0.3	21.8
F06	2.0	4.7	2.6	38.9	9.4	0.2	0.3	58.0
F08	29.3	7.2	24.0	27.9	22.6	11.9	16.3	139.2
F09	7.8	2.0	4.8	7.5	5.3	1.4	3.9	32.8
F10	32.0	5.0	11.1	14.0	17.7	2.7	8.6	91.3
F11	6.8	1.7	6.5	5.9	5.0	1.4	5.3	32.5