Grizzly bear use of habitats modified by timber management
by John Steven Waller

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Fish and Wildlife Management
Montana State University

Abstract:
This study employed a sample of 22 radio-collared grizzly bears to document the extent to which grizzly bears used harvested habitats on a seasonal and annual basis and how this use compared to the availability of harvested habitats. Use sites within treated stands were sampled and compared to random sites within the same stand to determine if grizzly bears were selecting unique microsites within stands or if use sites were representative of the stand as a whole. Instrumented grizzly bears significantly avoided using harvested stands within the study area during all seasons. Within composite and seasonal 95% minimum convex polygon home ranges, instrumented grizzly bears used harvested stands in proportion to their availability within their home range polygons. Use of harvested stands did not differ significantly among most of the individual grizzly bears. I found no significant difference in the use of harvested stands between age/sex classes. Instrumented grizzly bears were more likely to use harvested stands in summer than in spring or fall. Clearcuts were used less than other harvest types. Stands harvested 30-40 years ago were more likely to be used than younger or older cuts. Univariate and multivariate analyses of habitat data identified 3 variables that discriminated between use and random sites in 73% of the cases. They were distance to edge, vegetation density between 1.0-1.5 m and amount of huckleberry present. I concluded that a lack of security cover, human disturbance, and food availability, regulated the amount of use that harvested stands received. Also, stands logged in the study area within the last 10 years are unavailable as grizzly bear habitat and should be recognized as such. Although the amount of available grizzly bear habitat in the study area is likely to increase as harvested stands recover, the study area may be currently over-harvested in terms of providing optimal grizzly bear habitat. I suggest that management agencies conduct ecosystem specific investigations of the effects of logging on grizzly bears. It is neither appropriate nor valid to extrapolate the results of studies in one ecosystem to another.

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MONTANA STATE UNIVERSITY
Bozeman, Montana

November 1992

APPROVAL

of a thesis submitted by

John Steven Waller

This thesis has been read by each member of the thesis committee and has been found to be satisfactory regarding content, English usage, format, citations, bibliographic style, and consistency, and is ready for submission to the College of Graduate Studies.

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Date 12-15-92

ACKNOWLEDGMENTS

This work is part of an ongoing study of grizzly bear population dynamics and habitat conducted by the Montana Department of Fish, Wildlife and Parks (MDFWP). Funding was provided by the U.S. Forest Service, the U.S. Fish and Wildlife Service and the MDFWP. The assistance of many people at the Flathead National Forest Supervisor's Office and the Hungry Horse and Spotted Bear Ranger Districts, especially Don Krogstad, Henry Rivera, Ruth Roberson, Nancy Warren and Tom Wittinger is greatly appreciated. This study would have been impossible without the support and encouragement of many people in the Region 1 office of the MDFWP, especially Rick Mace and Tim Manley. I thank statisticians Dr. John Borkowski and Wendy Swanson for their assistance with data analysis and providing critical review. I wish to thank Dr. Harold Picton, committee chairman, for support and encouragement during this study and for giving me the opportunity to pursue an advanced degree. I also thank my committee members Dr. Richard Mackie, Dr. Lynn Irby and Dr. Robert White for providing critical review of this work. I especially thank my wife, Amy Johnston Waller, for enriching my life and work beyond measure.

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ABSTRACT

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INTRODUCTION

The grizzly bear was listed as a threatened species in 1975 under the Endangered Species Act of 1973. Section 7 of the Act precludes all federal agencies from actions that "result in the destruction or adverse modification of habitat" of threatened species (Congress 1973). Portions of currently occupied grizzly bear range administered by the U.S. Forest Service are under multiple-use management. Timber harvest is a primary activity in these areas, yet little information exists on how timber management affects grizzly bears.

Studies describing vegetative response to logging are numerous (Leege and Hickey 1971, Dyrness 1973, Schmidt 1979). Studies describing the response of ungulate forage species to timber harvest have also been conducted (Lyon 1979, Lyon and Basile 1979, Lyon and Jensen 1980). These studies have shown that removal of canopy cover by logging increases forage availability and that ungulate populations respond favorably to this increase. Studies of the effects of logging on black and grizzly bear plant foods suggest that they respond much like those of ungulates (Lindzey and Meslow 1977, Schmidt 1979, Martin 1983, Bratkovich 1985, Hamer and Herrero 1986, Noyce and Coy 1989).

Studies of black bears in the Pacific Northwest have shown that increased availability of foods due to logging has increased the rates of recruitment and vigor (i.e., higher mean body weights) of the black bear populations (Lindzey et al. 1986). Studies have found that black bears preferred selectively logged stands for their high food availability (Lindzey and Meslow 1977, Young and Beecham 1986, Unsworth et al. 1989). Because many of the forage species utilized by black bears in the Northern Continental Divide Ecosystem (NCDE) are used by grizzly bears, it is currently assumed that grizzly bears also respond favorably to the increased amount of forage.

Zager (1980) examined the effects of logging on some key grizzly bear foods in the South Fork of the Flathead River drainage in northwestern Montana. These species generally increased or became more productive after disturbance by logging compared to those in undisturbed stands. Recommendations from this study, and resulting publications, are the basis for many land management decisions made in the NCDE (Zager and Jonkel 1983; Zager, Jonkel and Habeck 1983). Based on these recommendations and the results of studies on black bears, land managers have undertaken a program of logging to increase habitat values for grizzly bears (Garcia 1985, Hillis 1985, Holland 1985).

Literature documenting negative effects of logging on grizzly and black bears is increasing. However, these effects are more the result of increased human activity associated with resource development than to alteration of the physical environment. One such effect is temporary displacement of bears from portions of their habitat. Mace and Jonkel (1980) found that a radio-collared grizzly bear avoided a drainage where active logging was taking place. Zager (1980) found that radio-collared grizzly bears avoided using clearcuts. Archibald et al. (1987) found radio-collared grizzly bears were displaced from the portion of their range where log trucks were hauling and that the number of times the bears crossed roads decreased. McLellan and Shackleton (1988) suggest that roads in their study area represented a loss of 7% to 8% of the available grizzly bear habitat. This displacement seems to be limited to the period of activity; the bears return when activity ceases (Archibald et al. 1987, McLellan and Shackleton 1988). In some cases grizzly bears may not be displaced by activity at all, especially when the area has a high survival value (McLellan and Shackleton 1989). Grizzly bear behavior appears to parallel that of ungulates displaced by logging activities (Lyon 1979, Lyon and Jensen 1980, Edge and Marcum 1985).

Another negative effect of logging is increased bear vulnerability to hunting and poaching. Archibald (1983) suggests this as a reason for the extirpation of some local grizzly bear populations in coastal British Columbia. Johnson (1977) documented high bear mortality around logging camps in Alaska. Brody and Stone (1987) felt that some timber harvest regimes may improve black bear habitat in terms of carrying capacity, but these benefits were outweighed by the concomitant increase in hunting mortality.

Most studies have shown a general avoidance (use significantly less than expected) of clearcuts (as opposed to selection cuts) by grizzly and black bears (Lindzey and Meslow 1977, Zager 1980). The avoidance may be due to the age of the clearcuts (most were less than 20 years old) and the tendency for clearcuts to be heavily scarified (Zager 1980, Young and Beecham 1986, Unsworth et al. 1989). Heavy scarification can significantly delay the recovery of bear foods and cover thus reducing the clearcut's value to bears (Schmidt 1979, Zager 1980, Martin 1983). Apparent avoidance of clearcuts could also be due to other factors including presence of open roads, low carrying capacity and grizzly bear numbers, or the presence of better foraging sites elsewhere (McLellan 1990).

The objectives of this study were to document the extent that grizzly bears used harvested areas, how use of harvested areas varied among seasons and among differing age/sex classes, how use compared to the availability of various harvest types within the study area, and to determine if use sites were representative of the stand as a whole.

STUDY AREA

The study area encompassed approximately 910 km^2 (351 mi^2) within the South Fork Flathead River drainage in northwestern Montana (Fig. 1). The study area was bounded to the north by the main stem of the Flathead River, to the east by the South Fork of the Flathead River and Hungry Horse Reservoir, to the south by the Bob Marshall Wilderness boundary, and to the west by the crest of the Swan Mountains. The area is managed for multiple use by the U.S. Forest Service. Timber harvest is the primary use, but berry picking and recreation are also important activities. Almost every drainage in the study area had been impacted to some degree by timber harvest. Approximately 18% of the study area and 33% of the available timber had been logged by 1990. Most of the drainages were accessible from a primary, secondary or tertiary road, although some of the roads were permanently or seasonally closed to motor vehicles.

Elevations ranged from 940 m (3,084 ft) along the Flathead River to approximately 2,400 m (7,874 ft) along the Swan divide. The rugged mountain topography, influenced by Pacific maritime weather patterns, created complex local climates. Mean 1990 temperatures at the Hungry Horse Dam weather station, located at the northern end of the study

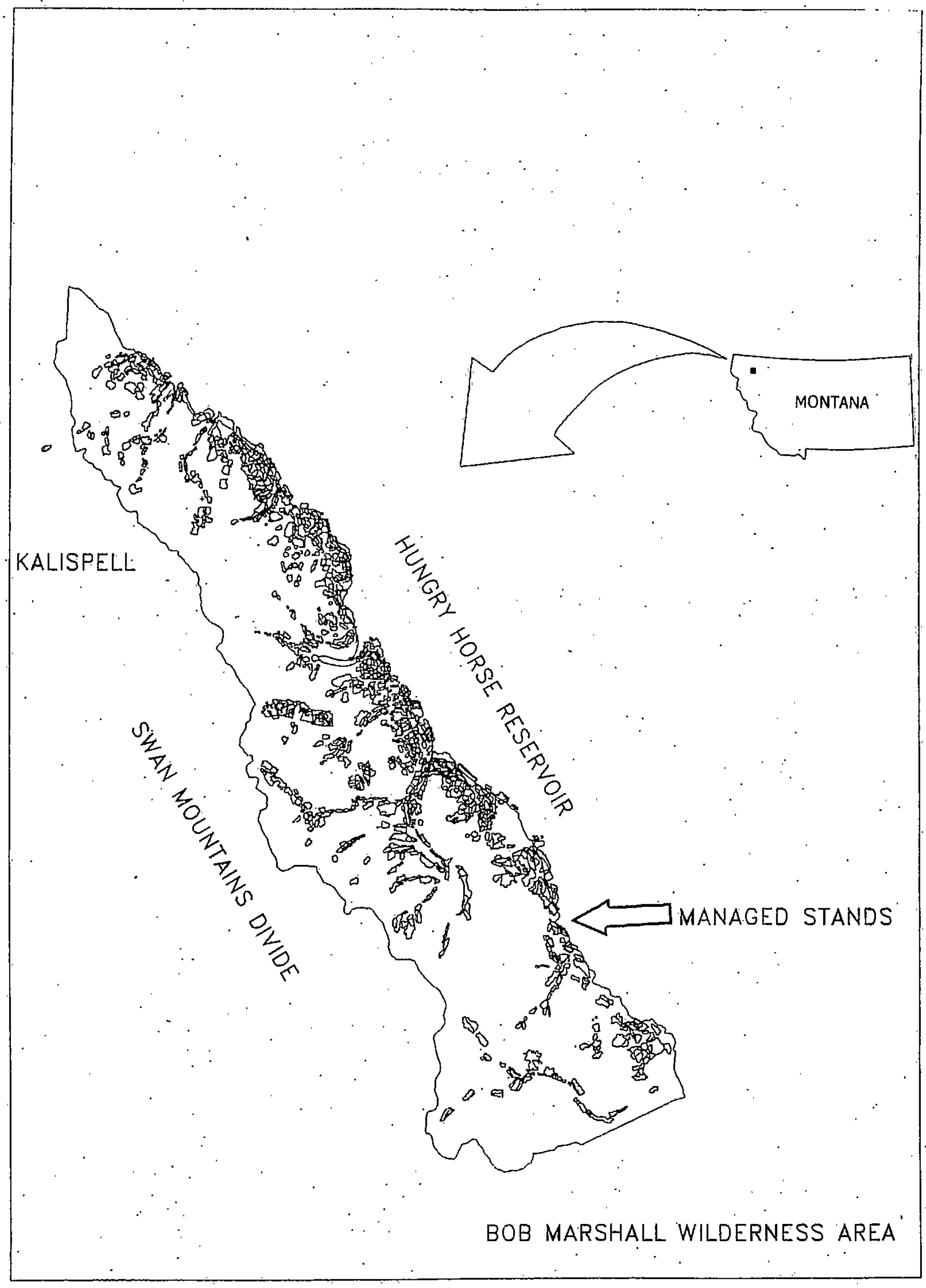

Figure 1. Study area, west side South Fork Flathead River Drainage, Montana.

area, were -5.5° C (22.1° F) for January and 20.5° C (68.9° F) for August. Temperature extremes for 1990 were 35.0° C (95.0° F) on 15 August and -28.8° C (-20.0° F) on 30 December. Annual precipitation for 1990 was 98.7 cm (38.8 in.) (NOAA 1990). Yearly precipitation for the period 1969 to 1985 averaged 81.71 cm (32.2 in) at the dam (Hadden et al. 1987). Weather conditions became much more severe at higher elevations. Snow provided approximately 50% of the precipitation at higher elevations (Mace and Manley 1991).

A mosaic of vegetation types existed within the study area, ranging from closed conifer at lower elevations to true alpine flora at the highest elevations. Dominant conifers with increasing elevation included spruce (<u>Picea spp.</u>), western red cedar (<u>Thuga plicata</u>), lodgepole pine (<u>Pinus contorta</u>), Douglas fir (<u>Pseudosuga menziesii</u>), subalpine fir (<u>Abies lasiocarpa</u>), and whitebark pine (<u>Pinus albicaulis</u>) (Mace and Aune 1988). The spruce/fir habitat types of northwestern Montana have been described by Pfister et al. (1977).

METHODS

South Fork Grizzly Project (SFGP) personnel used standard trapping techniques (Johnson and Pelton 1980) to capture grizzly bears from fall 1988 through fall 1991. Snares were placed throughout the study area using a systematic grid system (Mace and Manley 1991). Captured bears $\geq$ 1.5 years of age were fitted with radio collars (Telonics, Mesa, AZ) equipped with break-away cotton spacers that allowed the collar to fall off after 1 to 4 years.

The 22 grizzly bears monitored during this study represented 6 age/sex classes: adult male, sub-adult male, adult female, sub-adult female, female with young, and female with cub(s). I termed young of the year "cubs" and yearlings through 2.5 years old "young".

Using aerial radio telemetry, SFGP personnel relocated collared grizzly bears once per week (weather permitting) from fall 1988 through fall 1989, and twice per week from spring 1990 through fall 1991. Relocation flights were generally conducted between 8:00 A.M. and 12:00 noon. Each relocation site was photographed with a Polaroid camera. Following development, the location of the bear was marked on the photo while the plane was still over the area. The relocation was later located on a 1:24,000 orthographic photo and slope, elevation, aspect, and Universal Transverse

Mercator (UTM) coordinates recorded. A computer data base was used to store UTM coordinates, bear identification number, relocation number, and other pertinent information. Aerial relocations had an error of approximately 1 ha (2.5 acres).

The U.S Forest Service provided digitized maps of all harvested stands within the study area. The maps were transferred from ERDAS (ERDAS 1991) to floppy disks, then imported into another geographic information system, EPPL7 (Minnesota State Planning Agency 1990). A database queried from the Timber Stand Management Record System (TSMRS) detailing the treatment history of each stand accompanied the stand maps. I reclassified each stand according to harvest method, scarification method, and age class.

Harvested stands within the study area were placed into 1 of 8 classes: clearcut, shelterwood cut, improvements, liberation cut, seed tree, thinning, salvage cut, and other. Included in the other category were such harvest methods as group and individual selection cuts and harvest methods that were not specified in the TSMRS. Harvested stands within the study area were also placed into 1 of 4 post-harvest treatment classes: dozer piling, manual methods, broadcast burning, and unknown. Manual methods included such treatments as lopping, slashing, and hand piling. The unknown category contains stands for which no post-harvest treatment was given in the TSMRS. Each of the harvested stands was placed into 1 of 6 age class categories based upon the time elapsed since the stand was harvested: pre-1950, 1951-1960, 1961-1970, 1971-1980, 1981-1985, and post-1985. When combined, these classifications formed layers of a silviculture map of the study area.

I imported 1,811 aerial relocations of 22 different grizzly bears into EPPL7. I overlaid the relocations on the stand maps and rectified them with the UTM coordinates. Each bear location could then be classified as being either in or out of a harvested stand, and stand attributes could be compared among relocations.

I used Program Home Range (Ackerman et al. 1989) to create 95% minimum convex polygon (MCP) home ranges for each of the 22 grizzly bears. Composite MCPs consisting of locations collected from 1988 to 1991 (all seasons combined) were created, along with spring, summer and fall seasonal MCPs which combined seasonal locations across the 4 years of the study. Changes in food habits documented by SFGP personnel delineated the seasons. Spring was from 30 March to 13 July (106 days), summer from 14 July to 16 September (65 days), and fall from 17 September to 30 October (44 days). The grizzly bears were in dens and inactive during the remainder of the year. I imported the MCPs into EPPL7 and overlaid them on the stand maps. The map layers were checked for accuracy by overlaying them on a rectified Thematic Mapper (TM) satellite image of the study area

(Manley and Mace 1992). This process enabled me to calculate the proportion of harvested stands within the study area, each home range, and the proportion of each harvest type, scarification type, and harvest age-class within the MCPs.

The map layers described above quantified the "availability" of harvested habitats within the study area. Relocations were considered "use" sites. Thus hypotheses concerning "use" and "availability" of treated habitats within the study area and within MCP's could be tested using chi-square goodness-of-fit tests and Bonferroni 95% simultaneous confidence intervals (Neu et al. 1974). Unless otherwise stated, all hypotheses were tested at the 95% confidence level.

During the 1991 field season (May through October), I visited harvested stands that contained relocations. I visited the site within 10 days of the relocation or, if the relocation was in an earlier year, within 10 days of the anniversary of that relocation. For the stand as a whole I recorded habitat type (Pfister et al. 1977), harvest type, scarification type, fuels treatment, and any evidence of bear activity. The center of the 1-ha (2.5 acre) relocation site was marked with flagging. I recorded the cover type (Manley and Mace 1992), 3 dominant plant species, slope shape, plot position, elevation, fuels treatment efficiency, special feature, distance to edge, and type of edge for the

1-ha relocation site. Because the 1-ha macro-plots were too large to sample intensively, I used 4 375-m^2 (1/10 acre) micro-plots randomly situated within the 1-ha macro-plot relocation site. I derived most of the variables from the U.S. Forest Service's ECODATA manual (USDA 1988) and measured them accordingly. The variables measured within the 375-m^2 plot are listed in Table 1 and described in detail in Appendix A.

After sampling the "use" site, a number of random sites were sampled in the same manner. The number of random sites sampled depended upon the size of the harvested stand. I chose to sample 16% of each harvested stand, thus a 20.2 ha (50 acre) stand would have 3 1-ha random macro-plots plus any number of "use" sites (usually only one). I sampled 33 different stands containing 35 different use sites from 16 different grizzly bears.

I entered the data into a computer database and used Program SAS (SAS Inst. 1990) for analysis. I averaged values for continuous variables recorded in the 4 micro-plots within each macro-plot so that for each variable there was only 1 value. Nominal variables could not be averaged so I created a new variable for each category of each variable. These "dummy" variables consisted of zeros or ones denoting presence or absence. The value of these variables for the macro-plot was the total percentage of

Table 1. Variables measured in 375-m^2 microplots to determine differences between use and random sites in cutting units.

Slope
Aspect
Cover type
Three dominant cover species
Ground cover disturbance
Duff depth
Percent ground cover for soil, gravel, rock, wood, and moss
Phenology class of shrubs and deciduous trees, forbs, and graminoids
Percent total tree cover
Percent cover of seedlings, saplings, poles, mature and large mature trees
Percent total shrub cover
Percent cover of low, medium, and tall shrubs
Percent total grass cover
Percent total forb cover
Bear food density
Percent *Heracleum* cover
Horizontal vegetation density
Number of stumps
Number of stumps disturbed

micro-plots occurring within that category, i.e. 0, 0.25, 0.50, 0.75 or 1.

I tested for differences between random and use macro-plots using univariate methods. I used chi-square tests to detect differences among the following nominal variables: macro-plot cover type, slope shape, plot position, special feature, micro-plot cover type, scarification efficiency, and bear food density. Because the data for each continuous variable was non-normally distributed, Wilcoxon's rank-sum test was used to detect differences between random and use sites for the following variables: slope, duff depth, edge distance, elevation, percent ground cover of soil, gravel, rock, wood and moss, percent total tree cover, percent cover of seedlings, saplings, poles, mature, and large mature trees, percent total shrub cover and percent cover of low, medium and tall shrubs, percent total grass cover, percent total forb cover, horizontal vegetation density, number of stumps, and number of stumps disturbed.

I used stepwise logistic regression to investigate the relationship between the binary response proportions (random and use) and the "explanatory" variables. The stepwise logistic procedure first estimates parameters for the variables forced into the model, starting with the intercept. Next the procedure computes the adjusted chi-squared statistic for all the variables not in the model and examines the largest of these statistics. If the statistic is significant at the p=0.15 level, it is entered into the model. Each forward selection step is followed by one or more backwards elimination steps. The chi-squared statistics are recomputed when a variable is accepted into the model. If the new chi-squared statistic exceeds the p=0.15 level (based upon maximum likelihood estimates) it is excluded from the model. The procedure continues until no further variables can be added to the model.

The hypotheses tested in this study relied upon EPPL7 to classify each relocation as to occurrence within a harvested stand. As stated earlier, the accuracy of the relocations is 1 ha. Thus, relocations closer than 100 m (328 ft) to the edge of a stand may have been classified as "in" when they were actually "out". Conversely, relocations on the outside edge of a stand may actually have been "in" but classified as "out". Visual sightings of the bears were made during some of the relocation flights. I checked these relocations and corrected them if they were incorrectly classified by EPPL7.

To address the possibility that relocations were erroneously classified, I tested several hypotheses excluding all inside edge locations and including all outside edge locations. This in effect shows likely minimum and maximum usage of harvested stands by the instrumented bears.

RESULTS

Use and Availability Within the Study Area

The study area contained 1,065 harvested stands that accounted for approximately 18% of the study area. From fall 1988 through spring 1991 radio-collared grizzly bears were relocated at least once in 112 (10.5%) of the 1,065 harvested stands. Eighteen harvested stands contained 2 (1.7%) relocations and only 9 contained more than 2 (0.8%) relocations. Of the 1,811 radio relocations used in this study, 161 (8.9%) were within harvested stands (Table 2). Thus the hypothesis that instrumented grizzly bears use harvested areas in proportion to their availability within the study area was rejected (X^2=102.005, d.f.=1, $p<0.001$). Grizzly bears used harvested stands within the study area significantly less than expected and unharvested areas significantly more than expected in each season, spring (X^2=62.134, d.f.=1, $p<0.001$), summer (X^2=9.986, d.f.=1, $p=0.002$), and fall (X^2=46.329, d.f.=1, $p<0.001$).

In examining use of harvested stands versus unharvested areas for each individual grizzly bear (all seasons combined), I found that 14 of 22 grizzly bears (63.6%) used harvested stands significantly less than expected and unharvested areas significantly greater than expected

Table 2. Age, sex, and total number and percent of relocations of radio-collared grizzly bears and relocations in harvested stands for each season in the South Fork Flathead study area 1987-90.

			Total Relocations in Harvested Stands							Total Relocations						
Bear	Age in 1990	Sex	Spring	(%)	Summer	(%)	Fall	(%)	Total	Spring	(%)	Summer	(%)	Fall	(%)	Total
1a	12.0	F	1	11.1	0	0	1	11.1	2	3	33.3	1	11.1	5	55.5	9
3	4.5	F	2	2.5	2	2.5	0	0	4	39	48.1	28	34.6	14	17.3	81
5	10.5	F	2	1.3	12	8.1	1	0.7	15	59	39.9	54	36.5	35	23.6	148
14	12.5	F	0	0	0	0	0	0	0	31	33.3	41	44.1	21	22.6	93
18	3.5	F	2	1.8	1	0.9	0	0	3	44	40.0	42	38.2	25	22.7	110
22	4.5	M	5	5.4	9	9.7	3	3.2	17	39	41.9	36	38.7	18	19.3	93
25	4.5	M	1	1.2	8	9.6	0	0	9	28	33.7	36	43.4	19	22.9	83
42	1.5	M	0	0	0	0	0	0	0	33	37.5	37	42.0	18	20.4	88
45	19.5	F	1	1.2	1	1.2	0	0	2	30	35.3	37	43.5	18	21.2	85
48	10.5	F	0	0	7	7.9	1	1.1	8	34	38.2	37	41.6	18	20.2	89
71	2.5	M	3	3.5	11	12.8	3	3.5	17	32	37.2	35	40.7	19	22.1	86
94	10.5	F	9	7.4	9	7.4	4	3.3	22	60	49.2	42	34.4	20	16.4	122
96	17.5	F	0	0	0	0	0	0	0	50	41.0	43	35.2	29	23.8	122
137	3.5	F	3	2.7	4	3.7	1	0.9	8	42	38.5	43	39.4	24	22.0	109
139	6.5	F	5	10.9	1	2.2	1	2.2	7	21	45.6	18	39.1	7	15.2	46
143	7.5	F	3	3.1	3	3.1	1	1.0	7	43	44.5	32	33.3	21	21.9	96
144	13.5	M	0	0	2	5.3	0	0	2	18	47.4	13	34.2	7	18.4	38
146	7.5	M	0	0	2	4.3	0	0	2	20	43.5	16	34.8	10	21.8	46
147	4.5	F	8	6.1	13	9.8	0	0	21	55	41.7	50	37.9	27	20.4	132
148a	9.5	M	0	0	1	3.3	0	0	1	14	46.7	13	43.3	3	10.0	30
149	10.5	M	1	1.7	3	5.2	0	0	4	20	34.5	29	50.0	9	15.5	58
150	8.5	M	5	10.9	4	8.7	1	2.2	10	25	54.3	12	26.1	9	19.6	46
TOTALS:			51	4.6	93	57.8	17	10.5	161	740	40.9	695	38.4	376	20.8	1811

a. Deceased or lost collar prior to 1990. Age shown is age at last relocation.

($p \leq 0.04$). The remaining 8 (4 adult females and 4 young adult males) used harvested stands in proportion to their availability within the study area ($p \geq 0.51$). No bears used harvested stands significantly more than expected (Table 3).

Use of harvested stands differed significantly among some of the grizzly bears ($X^2=97.786$, d.f.=21, $p<0.001$). Five grizzly bears, 4 adult females (bear number 14, 18, 45, and 96) and 1 juvenile male (bear number 42) used harvested stands significantly less than the other 17 grizzly bears.

During spring, 9 of 22 grizzly bears (40.9%) used harvested stands less than expected ($p \leq 0.047$), and the remaining 13 used harvested stands in proportion to their availability (Table 4). During summer, 6 of 22 grizzly bears (27.3%) used harvested stands less than expected ($p \leq 0.020$), 15 used harvested stands in proportion to their availability, and 1 used harvested stands greater than expected ($p=0.029$) (Table 5). During fall, 8 of 22 grizzly bears (36.4%) used harvested stands less than expected ($p \leq 0.047$) and the remaining 14 used harvested stands in proportion to their availability (Table 6).

Table 3. Results of chi-square analyses of observations of radio-collared grizzly bears in harvested and unharvested habitats within the study area, all seasons combined 1987-90. Expected observations in harvested stands calculated as $(n_1+n_2) \times 0.18$. Expected observations in unharvested stands calculated as $(n_1+n_2) \times 0.82$. Degrees of freedom=1.

Bear ID	Obs. in cuts (n_1)	Exp. Obs. in cuts	Obs. in uncut (n_2)	Exp. Obs. in uncut	X^2	P
1a	2	1.6	7	7.4	0.108	0.742
*3	4	14.6	77	66.4	9.373	0.002
*5	15	26.5	133	121.3	6.215	0.012
*14	0	16.7	93	76.2	20.428	0.000
*18	3	19.8	107	90.2	17.399	0.000
22	17	16.7	76	76.2	0.005	0.946
25	9	14.8	74	68.0	2.887	0.089
*42	0	15.8	88	72.1	19.330	0.000
*45	2	15.3	83	69.7	13.680	0.000
*48	8	16.0	81	73.0	4.905	0.026
71	17	15.5	69	70.5	0.180	0.671
94	22	22.0	100	100.0	0.000	0.994
*96	0	22.0	122	100.0	26.799	0.000
*137	8	19.6	101	89.4	8.405	0.003
139	7	8.3	39	37.7	0.243	0.622
*143	7	17.3	89	78.7	7.469	0.006
*144	2	6.8	36	31.1	4.181	0.040
*146	2	8.3	44	37.7	5.815	0.015
147	21	23.8	111	108.2	0.395	0.529
*148	1	5.4	29	24.6	4.376	0.036
*149	4	10.4	54	47.5	4.851	0.027
150	10	8.3	36	37.7	0.433	0.510

a. may not be a valid X^2 test, average of both categories <6.
* used harvested stands significantly less than expected.

Table 4. Results of chi-square analyses of spring observations of grizzly bears in harvested and unharvested stands within the study area 1987-90. Expected observations in cuts calculated as $(n_1+n_2) \times 0.18$. Expected observations in uncut calculated as $(n_1+n_2) \times 0.82$. Degrees of freedom=1.

Bear ID	Obs. in cuts (n_1)	Exp. Obs. in cuts	Obs. in uncut (n_2)	Exp. Obs. in uncut	X^2	P
1a	1	0.5	2	2.5	0.477	0.489
3a	2	2.0	9	9.0	0.000	0.988
5a	0	1.6	9	7.4	1.977	0.159
*14	0	5.6	31	25.4	6.809	0.009
*18	2	7.7	41	35.2	5.197	0.022
22	5	7.0	34	32.0	0.711	0.399
25	1	4.9	26	22.1	3.742	0.053
*42	0	5.9	33	27.0	7.249	0.007
*45	1	5.4	29	24.6	4.376	0.036
*48	0	6.1	34	27.9	7.468	0.006
71	3	5.8	29	26.2	1.616	0.203
94	9	10.8	51	49.2	0.368	0.544
*96	0	9.0	50	41.0	10.983	0.000
137	3	7.6	39	34.4	3.359	0.066
139	5	4.0	17	18.0	0.332	0.564
*143	3	8.8	46	40.2	4.689	0.030
*144	0	3.2	18	14.7	3.954	0.046
*146	0	3.6	20	16.4	4.393	0.036
147	8	9.9	47	45.1	0.447	0.503
148	0	2.5	14	11.5	3.075	0.079
149	1	3.6	19	16.4	2.293	0.130
150	5	4.5	20	20.5	0.067	0.795

a. May not be a valid X^2 test, average of both catagories <6.
* use of cuts significantly less than expected.

Table 5. Results of chi-square analyses of summer observations of grizzly bears in harvested and unharvested stands within the study area 1987-90. Expected observations in cuts calculated as $(n_1+n_2) \times 0.18$. Expected observations in uncut calculated as $(n_1+n_2) \times 0.82$. Degrees of freedom=1.

Bear ID	Obs. in cuts (n_1)	Exp. Obs. in cuts	Obs. in uncut (n_2)	Exp. Obs. in uncut	X^2	P
1a	0	0.2	1	0.8	0.220	0.639
*3	2	10.1	54	45.9	7.906	0.004
5	14	18.7	90	85.3	1.457	0.227
*14	0	7.4	41	33.6	9.006	0.002
*18	1	7.6	41	34.4	6.948	0.008
22	9	6.5	27	29.5	1.191	0.275
25	8	6.5	28	29.5	0.433	0.510
*42	0	6.3	35	28.7	7.688	0.005
*45	1	6.3	34	28.7	5.442	0.019
48	7	6.7	30	30.3	0.021	0.885
71b	11	6.1	23	27.9	4.737	0.029
94	9	7.6	33	34.4	0.332	0.564
*96	0	7.6	42	34.4	9.226	0.002
137	4	7.6	38	34.4	2.048	0.152
139	1	3.2	17	14.7	1.891	0.169
143	3	5.8	29	26.2	1.616	0.203
144	2	2.3	11	10.6	0.061	0.805
146	2	2.9	14	13.1	0.329	0.566
147	13	8.8	36	40.2	2.409	0.120
148	1	2.3	12	10.6	0.937	0.333
149	3	5.2	26	23.8	1.154	0.282
150	4	2.2	8	9.8	1.908	0.167

a. May not be a valid X^2 test, average of both catagories <6.
* use of cuts significantly less than expected.
b. use of cuts significantly greater than expected.

Table 6. Results of chi-square analyses of fall observations of grizzly bears in harvested and unharvested stands within the study area 1987-90. Expected observations in cuts calculated as (n_1+n_2) x 0.18. Expected observations in uncut calculated as (n_1+n_2) x 0.82. Degrees of freedom=1.

Bear ID	Obs. in cuts (n_1)	Exp. Obs. in cuts	Obs. in uncut (n_2)	Exp. Obs. in uncut	X^2	P
1a	1	0.9	4	4.1	0.013	0.907
3	0	2.5	14	11.5	3.075	0.079
*5	1	6.1	33	27.9	5.228	0.022
*14	0	3.8	21	17.2	4.613	0.031
*18	0	4.5	25	20.5	5.492	0.019
22	3	3.2	15	14.7	0.022	0.882
*25	0	3.4	19	15.6	4.174	0.041
*42	0	3.2	18	14.7	3.954	0.046
*45	0	3.2	18	14.7	3.954	0.046
48	1	3.2	17	14.7	1.891	0.169
71	3	3.4	16	15.6	0.063	0.801
94	4	3.6	16	16.4	0.054	0.816
*96	0	5.2	29	23.8	6.370	0.011
137	1	4.3	23	19.7	3.115	0.077
139a	1	1.3	6	5.7	0.066	0.797
143	1	3.8	20	17.2	2.496	0.114
144a	0	1.3	7	5.7	1.538	0.215
146a	0	1.8	10	8.2	2.197	0.138
*147	0	4.9	27	22.1	5.931	0.014
148a	0	0.5	3	2.5	0.659	0.416
149a	0	1.6	9	7.4	1.977	0.159
150a	1	1.6	8	7.4	0.290	0.590

a. May not be a valid X^2 test, average of both catagories <6.
* use of cuts significantly less than expected.

I found no significant difference in the use of harvested stands between the different age/sex classes (X^2=6.956, d.f.=5, p=0.223). Instrumented grizzly bears used harvested stands more during the summer than during the spring and fall (X^2=58.244, d.f.=2, p<0.001).

Clearcuts accounted for 53.2% of all the harvested stands, shelterwood cuts 7.5%, improvements 5.2%, liberation cuts 7.5%, seed tree cuts 4.9%, thinning 7.2%, salvage cuts 9.8%, and others 4.7%. There was a significant difference in the harvest types used (X^2=21.457, d.f.=7, p=0.003). The instrumented grizzly bears used clearcuts less than, and salvage cuts greater than, the remaining categories.

Of the post-harvest treatment methods, dozer piling accounted for 57.9% of the harvested stands, manual methods 3.6%, burning 12.1%, and unknown 26.4%. There were no significant differences in use among post harvest treatment methods (X^2=7.360, d.f.=3, p=0.060).

The area occupied by each of the harvest age classes was as follows: pre-1950 0.54%, 1951-1960 12.6%, 1961-1970 31.6%, 1971-1980 36.2%, 1981-1985 10.9%, and post-1985 8.3%. I found significant differences in use of the different stand age classes (X^2=33.370, d.f.=5, p<0.001). The instrumented grizzly bears (all seasons combined) used the pre-1950 age class in proportion to availability, the 1951-1960 age class greater than expected, the 1961-1970 age class and the 1971-1980 age class in proportion to availability, and the 1981-1985 and post-1985 age classes less than expected.

The average elevation of harvested stands was 1,364 m (4,475 ft) and the standard deviation (sd)=191 m (627 ft). They ranged from 1,067 m (3,500 ft) to 2,164 m (7,100 ft). The average elevation of 1,811 grizzly bear relocations was 1,670 m (5,477 ft) and the sd=283 m (928 ft). The average elevation of the 130 stands with 1 to 2 relocations was 1,419 m (4,654 ft) and the sd=190 m (622 ft). The average elevation of the 9 stands with at least 3 relocations was 1,609 m (5,278 ft) and the sd=102 m (336 ft).

Use and Availability Within MCPs

All but 4 of the instrumented grizzly bears selected home ranges that contained less than 18% harvested area (Table 7). Composite and seasonal home range polygon areas are given in Appendix B.

When I examined use of harvested stands versus unharvested areas within each individuals composite home range polygon, chi-square goodness-of-fit tests indicated that all but 4 individuals (2 adult females, 1 juvenile male, and 1 adult male) used harvested stands in proportion to their availability within their composite home range polygon ($p \geq 0.058$). The 2 females and the juvenile male used harvested stands less than expected ($p \leq 0.042$) while the

Table 7. Percentage of 95% minimum convex polygon home ranges occupied by cut and uncut stands for 22 grizzly bears in the South Fork Flathead study area 1987-90.

	Composite		Spring		Summer		Fall	
Bear	%uncut	%cut	%uncut	%cut	%uncut	%cut	%uncut	%cut
1	91.7	8.3	*	*	100.0	0	84.8	15.2
3	94.3	5.7	96.4	3.6	96.7	3.3	89.2	10.8
5	90.4	9.6	88.4	11.6	90.7	9.3	88.6	11.3
14	98.3	1.7	98.1	1.8	97.9	2.1	100.0	0
18	91.6	8.4	90.6	9.4	92.2	7.8	93.5	6.5
22	85.6	14.4	84.9	15.1	81.9	18.1	81.5	18.5
25	89.8	10.2	90.3	9.7	90.1	9.9	95.3	4.7
42	93.3	6.6	94.9	5.1	98.0	2.0	100.0	0
45	94.9	5.1	96.3	3.7	93.3	6.7	96.6	3.4
48	85.9	14.1	89.9	10.0	84.9	15.1	95.7	4.3
71	83.8	16.2	82.9	17.1	86.6	13.4	73.5	26.5
94	72.4	27.6	69.6	30.4	84.0	16.0	73.7	26.3
96	96.3	3.7	98.6	1.4	97.2	2.8	94.7	5.3
137	87.9	12.1	90.6	9.4	92.9	7.1	97.6	2.4
139	92.7	7.3	93.5	6.5	83.5	16.4	94.1	5.9
143	90.4	9.6	89.4	10.6	85.5	14.5	87.0	13.0
144	86.9	13.1	92.4	7.6	69.0	31.0	93.1	6.8
146	92.6	7.4	91.2	8.8	90.3	9.7	97.2	2.8
147	88.1	11.8	88.3	11.7	85.4	14.5	87.8	12.2
148	98.1	1.9	98.7	1.3	86.8	13.2	*	*
149	89.4	10.6	90.4	9.6	90.3	9.7	89.0	10.9
150	88.0	12.0	87.3	12.7	88.4	11.6	90.1	9.9
mean:		9.9		9.4		11.2		9.4
s.d.:		5.6		6.5		6.7		7.5

* Insufficient sample size to build home range polygon

adult male used harvested stands greater than expected ($p=0.042$) (Table 8). Instrumented grizzly bears also used harvested stands within their home range polygons more often in the summer than during spring and fall ($X^2=61.774$, d.f.=2, $p<0.001$).

Use of harvested stands within home range polygons differed significantly among some of the grizzly bears ($X^2=101.657$, d.f.=21, $p<0.001$). Five used harvested stands significantly less than expected. These were the same 5 bears that used harvested stands less than expected within the entire study area.

Use of harvested stands within each individual's home range polygon for each season was nearly identical to use of harvested stands over the entire study area. The only difference was that 1 adult female used harvested stands less during the fall than spring or summer. Results were also similar comparing use of harvested stands between differing age/sex classes; no significant difference was observed ($X^2=8.511$, d.f.=5, $p=0.129$). With only 161 relocations in harvested stands, sample sizes were insufficient to test for differences in the use of different harvest types, scarification methods, and harvest age classes between individuals or age/sex classes.

Of the 161 relocations within harvested stands, 144 were within 100 m of the edge of the stand (89.4%) and only 28 of these relocations had visual sightings of the bears.

Table 8. Results of chi-square analyses of observations of radio-collared grizzly bears in harvested and unharvested portions of their composite 95% minimum convex home range polygons 1987-90. Expected observations in cut and uncut calculated as n_1+n_2 x % area given in Table 7. d.f.=1.

Bear Id.	Obs. in cuts (n_1)	Exp. Obs. in cuts	Obs. in uncut (n_2)	Exp. Obs. in uncut	X^2	P
1a	1	0.7	8	8.2	0.090	0.763
3	4	4.5	75	74.5	0.060	0.807
5	15	13.4	126	126.6	0.212	0.675
14	0	1.6	93	91.4	1.608	0.204
*18	3	8.8	102	96.2	4.150	0.041
22	17	12.5	70	74.5	1.865	0.172
25	9	7.5	65	66.4	0.311	0.577
*42	0	5.9	88	82.1	6.319	0.011
45	1	4.1	79	75.9	2.450	0.117
48	8	11.4	73	69.5	1.208	0.271
71	17	13.6	67	70.4	1.009	0.315
94	22	30.9	90	81.0	3.581	0.058
*96	0	4.5	122	117.5	4.687	0.030
137	7	12.2	94	88.7	2.554	0.110
139	6	3.1	36	38.9	3.029	0.081
143	6	8.0	77	75.0	0.538	0.463
144	2	4.8	35	32.1	1.921	0.165
146	2	3.4	44	42.6	0.622	0.430
147	21	15.2	107	112.9	2.492	0.114
148	1	0.4	21	21.6	0.837	0.360
149	4	5.5	48	46.5	0.470	0.493
150b	10	5.5	36	40.5	4.120	0.042

a. May not be a valid X^2 test, average of both catagories <6.
* used cuts significantly less than expected.
b. used cuts significantly greater than expected.

Thus, 116 of the relocations (72.0%) were questionable as to whether or not they were in a harvested stand.

Tests Excluding Inside Edge Relocations

Instrumented grizzly bears used harvested stands within the study area significantly less than expected and unharvested areas significantly greater than expected (X^2=278.777, d.f.=2, $p<0.001$). The same was true for each season ($p<0.001$). I found no significant differences in use of harvested stands among seasons (X^2=5.411, d.f.=2, $p=0.065$). Also, each age/sex class used harvested stands within the study area equally (X^2=8.435, d.f.=5, $p=0.133$).

No significant differences in the use of differing harvest types were observed (X^2=9.652, d.f.=7, $p=0.208$). Each of the post-harvest treatment categories was used in proportion to availability within the study area (X^2=4.311, d.f.=3, $p=0.228$).

There were significant differences in use among the stand age classes (X^2=14.860, d.f.=5, $p=0.011$). The pre-1950, 1981-1985, and post-1985 harvest age classes were used less than expected, the 1951-1960 and 1961-1970 age classes were used equal to expected, and the 1971-1980 age class was used greater than expected.

Tests Including Outside Edge Relocations

Instrumented grizzly bears used harvested stands and unharvested areas within the study area in proportion to their availability (X^2=2.151, d.f.=1, p=0.142). Grizzly bears used harvested stands within the study area less than expected and unharvested areas greater than expected during spring (X^2=4.579, d.f.=1, p=0.032) and fall (X^2=9.269, d.f.=1, p=0.002). Harvested stands were used greater than expected and unharvested areas equal to expected during summer (X^2=4.338, d.f.=1, p=0.037).

Grizzly bears used harvested stands more often than expected during the summer and less often in spring and fall (X^2=47.181, d.f.=2, p<0.001). Each of the age/sex classes used harvested stands equal to expected (X^2=7.367, d.f.=5, p=0.194).

Use and Random Site Habitat Sampling

Among all the variables sampled only 2, food density and horizontal vegetation density, were identified by the univariate tests as significantly different between use and random plots. The remainder had p-values $\geq$0.085. Horizontal vegetation density was divided into 3 categories; below 0.5 m, 0.5-1 m, and 1-1.5 m (Griffith and Youtie

1988). The below 0.5 m category (mean veg. density A) was not significantly different between use and random sites. The 0.5-1.0 m section (mean veg. density B) was non-significant at p=0.085 and the 1.0-1.5 m category (mean veg. density C) was significantly different at p=0.013 (Table 9). Bear foods were generally scarce in the stands, so all species found were lumped into 2 categories, globe huckleberry (Vaccinium globulare) and other (Table 10). There was no significant difference in abundance of foods in the other category between use and random sites. There was significantly more globe huckleberry in the use sites than the random sites (X^2=6.260, d.f.=2, p=0.044).

Stepwise logistic regression (SAS 1990) identified 5 variables that best fit the logistic model. These were edge distance, horizontal vegetation density in the 1-1.5 m category, northerly aspects, stumps, and presence of roads. Horizontal vegetation density and stumps had negative parameter estimates, i.e. low values for these variables were associated with higher use. The association of predicted probabilities and observed responses was concordant in 73.3% of the cases, discordant in 26.6% of the cases, and tied in 0.1% of the cases. The stepwise logistic procedure and an analysis of maximum likelihood estimates are summarized in Appendix C.

Table 9. Wilcoxon rank sum comparisons of habitat variables at random and grizzly bear relocation sites in the South Fork Flathead study area 1990. HO: The class distribution functions are equal.

Variable	Class	N	Sum of Scores (O)	Expected Under HO (E)	Std. Dev. Under HO	Mean Score	Z	Prob. >|Z|
Slope	Random	115	9031.5	9257.5	263.5	78.5		
	Use	45	3848.5	3622.5	263.5	85.5	0.855	0.392
Duff-Depth	Random	115	9207.0	9257.5	262.9	80.1		
	Use	45	3673.0	3622.5	262.9	81.6	0.190	0.849
Edge-Distance	Random	115	9627.0	9257.5	261.9	83.7		
	Use	45	3253.0	3622.5	261.9	72.3	-1.410	0.159
Elevation	Random	107	7976.5	8078.5	240.4	74.5		
	Use	43	3348.5	3246.5	240.4	77.9	0.423	0.673
% Ground Cover-soil	Random	115	9453.5	9257.5	260.9	82.2		
	Use	45	3424.5	3622.5	260.9	76.1	-0.757	0.449
% Ground Cover-gravel	Random	115	9357.0	9257.5	261.2	81.4		
	Use	45	3523.0	3622.5	261.2	78.3	-0.379	0.705
% Ground Cover-rock	Random	117	9753.5	9594.0	268.8	83.4		
	Use	46	3612.5	3772.0	268.8	78.5	-0.591	0.554
% Ground Cover-wood	Random	115	9427.5	9257.5	260.7	82.0		
	Use	45	3452.5	3622.5	260.7	76.7	-0.650	0.516
% Ground Cover-moss	Random	115	8947.0	9257.5	244.6	77.8		
	Use	45	3933.0	3622.5	244.6	87.4	1.267	0.205
% Total Tree Cover	Random	115	9299.0	9257.5	263.4	80.9		
	Use	45	3581.0	3622.5	263.4	79.6	-0.155	0.876
% Total Tree Cover-seedl.	Random	115	9399.5	9257.5	263.1	81.7		
	Use	45	3480.5	3622.5	263.1	77.3	-0.538	0.591
% Total Tree Cover-sapling	Random	115	9120.5	9257.5	263.3	79.3		
	Use	45	3759.5	3622.5	263.3	83.5	0.518	0.604
% Total Tree Cover-pole	Random	115	9260.5	9257.5	261.5	80.5		
	Use	45	3619.5	3622.5	261.5	80.4	-0.009	0.992
% Total Tree Cover-mature	Random	115	9424.0	9257.5	247.6	81.9		
	Use	45	3456.0	3622.5	247.6	76.8	-0.670	0.503
% Total Tree Cover-lge.mat.	Random	115	9246.5	9257.5	203.8	80.4		
	Use	45	3633.5	3622.5	203.8	80.7	0.051	0.958

Table 9. Continued.

Variable	Class	N	Sum of Scores (O)	Expected Under HO (E)	Std. Dev. Under HO	Mean Score	Z	Prob. >|Z|
% Total Shrub	Random	115	9059.0	9257.5	263.2	78.8		
Cover	Use	45	3821.0	3622.5	263.2	84.9	0.752	0.452
% Total low	Random	115	9294.0	9257.5	261.3	80.8		
shrub cover	Use	45	3586.0	3622.5	261.3	79.7	-0.138	0.890
% Total mid	Random	115	9150.5	9257.5	262.5	79.6		
shrub cover	Use	45	3729.5	3622.5	262.5	82.9	0.406	0.685
% Total tall	Random	115	9196.0	9257.5	263.3	80.0		
shrub cover	Use	45	3684.0	3622.5	263.3	81.9	0.232	0.817
% Total	Random	115	9515.5	9257.5	260.7	82.7		
Grass cover	Use	45	3364.5	3622.5	260.7	74.8	-0.988	0.323
% Total	Random	115	9397.0	9257.5	263.1	81.7		
Forb cover	Use	45	3483.0	3622.5	263.1	77.4	-0.528	0.597
*Mean Veg.	Random	115	8994.0	9257.5	226.0	78.2		
Density-A	Use	45	3886.0	3622.5	226.0	86.3	1.164	0.244
Mean Veg.	Random	115	8822.5	9257.5	252.3	76.7		
Density-B	Use	45	4057.5	3622.5	252.3	90.2	1.722	0.085
Mean Veg.	Random	115	8608.5	9257.5	261.0	74.9		
Density-C	Use	45	4271.5	3622.5	261.0	94.9	2.484	0.013
Number of	Random	115	9445.0	9257.5	263.0	82.1		
Stumps	Use	45	3435.0	3622.5	263.0	76.3	-0.711	0.478
Number of	Random	115	9200.5	9257.5	260.6	80.0		
dist. stumps	Use	45	3679.5	3622.5	260.6	81.8	0.217	0.828

* Mean Veg. Density-A refers to the horizontal density of vegetation 0-0.5 m above the ground. Veg. Density-B refers to horizontal vegetation density 0.5-1.0 m above the ground. Veg. Density-C refers to horizontal vegetation density 1.0-1.5 m above the ground.

Table 10. Summary statistics for grizzly bear food items recorded in habitat plots in the South Fork Flathead study area 1990.

			Counts of food item within plots				
Food Item	Class	N Obs.	N	Min.	Max.	Mean	Std. Dev.
Amelanchier	Random	114	2	6.00	30.00	18.00	16.97
	Use	46	2	31.00	400.00	215.00	260.00
*Ants	Random	114	68	(recorded as presence or absence, 0/1)			
	Use	46	31				
Equisetum	Random	114	5	1.50	27.50	11.24	11.02
	Use	46	4	4.00	8.14	5.78	1.77
Graminoids	Random	114	31	1.00	25.45	10.19	5.65
	Use	46	10	1.50	22.00	11.37	7.15
Osmorhiza	Random	114	9	1.00	3.86	1.99	1.08
	Use	46	6	1.00	8.00	2.33	2.80
Taraxacum	Random	114	4	1.00	2.00	1.58	0.50
	Use	46	2	1.00	1.00	1.00	0.00
Vaccinium	Random	114	62	1.00	175.16	36.81	34.77
	Use	46	31	2.25	141.00	51.16	41.38

* Ants were recorded as presence or absence of an ant colony. If an ant colony was found, a 1 was recorded. A colony could be in rotted logs, stumps or in the ground.

DISCUSSION

Use and Availability

If use less than expected reflects avoidance, then instrumented grizzly bears clearly avoided harvested stands in the study area. Four years of radio-tracking a large portion of the grizzly bear population within the study area failed to show appreciable use of harvested stands. Many of the harvested stands had high globe huckleberry production, yet less than 1% of all harvested stands contained more than 2 relocations.

The study area had a relatively high density of grizzly bears, approximately 4.5 per 100 km^2 (60 mi^2). Under conditions approaching carrying capacity, sub-dominant individuals might be forced into marginal habitats. I found no statistically significant differences in the use of managed stands among differing age/sex classes, however, my sample of adult males was too small for adequate tests.

Johnson's (1980) hierarchial classification of habitat selection provides a framework in which to interpret the results of this study. First order selection involves the geographic area an individual selects for its home range. First order selection of the study area by grizzly bears may be largely by default. The adjoining Swan and Flathead River valleys have large human populations and are generally unavailable for occupancy. Other portions of the NCDE have high densities of grizzly bears (Aune and Kasworm 1989) so are also unavailable for establishment of new home ranges. Thus, grizzly bears born in the study area generally must remain there due to limited dispersal options.

Second order selection determines the home range of an individual. Within the study area, the average home range included 9.37% harvested area in the spring and fall and 11.16% in the summer (Table 3.). This may have been the amount of harvested area tolerable to a grizzly bear. It could be argued that the high density of grizzly bears within the study area was forcing individuals to have a greater proportion of harvested area within their home ranges.

Third order selection pertains to habitat use within the home range. Most (81.8%) of the marked grizzly bears used harvested stands in proportion to their availability within their home range. This, together with the lack of differential use by sub-dominant age/sex classes, suggests that the acceptable area hypothesis is more likely to be correct. Each individual grizzly bear can be expected to develop its own unique survival strategy and the observed differences in the use of harvested stands reflected the nature of that strategy. Some individuals were never relocated in a managed stand, while others were found in harvested stands up to 31% of the time.

Use of harvested stands increased during the summer. Summer is the berry season and some harvested stands have exceptionally high berry production. Thus it seems reasonable that grizzly bears increase their use of harvested stands to take advantage of this resource. Large influxes of professional berry pickers may explain why use of harvested stands is not higher during the summer. The study area has a national reputation as having high berry production. During the berry season nearly all accessible stands had pickers in them. Many of these pickers were armed and constituted a threat to, and may have displaced, foraging grizzly bears.

Use of harvested stands decreased in the fall. Phenological shifts of the vegetal food base to higher elevations or to unharvested areas and the opening of the general big game hunting season may explain this change in use. The drop may also be due to decreased sample size. The frequency of days with weather unsuitable for flying increased as winter approached. Thus, fewer relocations were collected in fall than in summer. The length of the fall season was also shorter than the other 2 seasons.

The average elevation of grizzly bear relocations was substantially higher than the average elevation of harvested stands. Harvested stands used by instrumented grizzly bears had a higher mean elevation than stands in general, and the 9 stands with the greatest use were higher still. Grizzly bears within the study area spent very little time in the elevation zones where harvested stands were most common. I believe this was because human use of harvested stands kept bears at higher elevations. Every managed stand was accessible by road, though some stands were more accessible than others. That 7 of the 9 stands with the highest use had limited access (closed gates and/or over-grown roads) suggests that human disturbance was the factor keeping bears at higher elevations. Also Mace and Manley (1990) found that remote camera stations were more likely to detect grizzly bears at elevations above 1,567 m (5,140 ft). Roads in harvested stands at higher elevations (especially above 1,524 m (5,000 ft)) were more likely to have limited access than those at lower elevations.

Grizzly bears in the North Fork of the Flathead River drainage made extensive use of river bottom habitats (McLellan and Shackleton 1988). Creation of the Hungry Horse reservoir in the late 1950's eliminated these habitats in the South Fork drainage. The remaining low elevation habitats in the study area tend to be non-riparian and may not have a survival value high enough to tempt grizzly bears into risking encounters with humans to reach them.

Use of cutting units was so low that differentiating use of one harvest type over another was difficult. That grizzly bears avoided clearcuts more than other types of cuts may have been due to shortcomings in the method used to test for selection (Neu et al. 1974). In the study area, clearcuts made up 53.2% of the total harvested area. For this habitat to be "preferred", observed use would have to exceed 53.2%. Expecting this level of use may be unrealistic (McLellan 1985).

Conclusions concerning the use of stands with one type of post-harvest treatment versus another type could not be drawn due to shortcomings in the TSMRS which resulted in a large unknown component. This database of stand information relies on old records to document past stand histories. In many cases these records are incomplete. In some cases more than one treatment method was used in a single stand. Due to computer limitations I was forced to class the stand based on the treatment accounting for the most acreage. This may have obscured biological responses to the treatment method.

Grizzly bears avoided stands harvested since 1980. In most of these stands the vegetation had not recovered enough to provide security cover. They preferred to use stands that were harvested 30 to 40 years ago. Schmidt (1979) reported that scarified clearcuts required about 4 years to recover 25% of their pre-harvest shrub volume. Extrapolating from this, it would take 16 years to recover 100% of pre-harvest shrub volume. In old growth stands within the study area, shrubs did not provide 100% of the security cover. It is conceivable that 200% of the pre-harvest shrub volume is required to compensate for the loss of trees that also contributed to security cover. Thus it may take 30 years to establish a level of regeneration sufficient to provide hiding cover to a grizzly bear. Harvested stands produce the most bear foods 8 to 15 years after harvest (Zager 1980, Martin 1983), but in many cases may not be used due to lack of security cover.

Because some of the locations may have been misclassified as to being in or out of managed stands, I provided a "range of possibilities" by testing use vs. availability using samples that included and excluded edge locations. Approximately 89% of the relocations within managed stands were less than 100 m from the edge of the stand. This is consistent with the findings of other studies of grizzly bear habitat use (Zager 1980, Blanchard 1983, Aune and Kasworm 1989). Whether or not the bear actually entered the stand may be irrelevant if it was using, and deriving benefits from, edge habitats associated with the stand. If bears on the outside edge actually entered the stand (quite likely given the grizzly bears capacity for movement) then use of harvested stands within the study area becomes proportional to availability at $p=0.142$. This may still be considered avoidance, though not statistically significant avoidance. Harvested stands were still significantly avoided in spring and fall.

Habitat Sampling

According to the logistic regression, none of the variables measured could accurately discriminate between random and use sites. Even though univariate tests identified 2 variables that were different, I could not reject the null hypothesis that use sites within managed stands were the same as the stand as a whole. Stands were delineated by the Forest Service on the basis of like community types, so at a large scale, one would not expect to find dramatic differences within stands. Furthermore, the process of selecting use and random sites is subject to error. Random sites were not necessarily non-use sites and in some cases I may have been comparing 2 or more use sites.

According to the logistic regression, 73% of the sites used by grizzly bears were closer to the edge of the stand, had less cover between 1.0-1.5 m in height, had north aspects, had fewer stumps, and were closer to a road than random sites. Distance to edge was by far the most important variable in the logistic regression. The foregoing results and discussion also indicated the importance of this factor. I do not know why areas with less cover above 1 m would be selected. This category was significant in the univariate tests as well. Perhaps areas with less cover in this category provided better visibility, better food resources or may have been easier to negotiate. The greater occurrence of north aspects among use sites may be due to higher abundance of foods, thicker vegetation (security cover), or cooler temperatures.

Most of the harvested stands had many roads running through them, both logging roads and re-vegetated skid trails. In many cases overgrown logging roads were used as travel corridors by a variety of wildlife, including grizzly bears, but were difficult for humans to negotiate. Because the roads formed a terrace, they often had a more highly developed shrub overstory, allowing wildlife to travel unseen. I suspect that, in some instances, the roads created moist microsites that produced higher levels of bear foods than their more xeric surroundings. Despite these possibilities, the regression failed to correctly classify 26.6% of the cases examined.

Globe huckleberry was significantly more abundant in use sites than at random sites. This suggests that food availability was of importance in site selection within harvested stands, but these data were not entered into the logistic model.

MANAGEMENT IMPLICATIONS

Historically, the grizzly bear ranged the entire North American continent (Craighead and Mitchell 1982) and successfully exploited a large variety of habitats. Given the wide amplitude of suitable habitats, the alteration of forested areas in the NCDE to earlier successional stages should not, in and of itself, impair the grizzly bear's ability to survive. However, too much logging accompanied by increased human access may decrease grizzly bear survival.

The study area receives over 80 cm of precipitation per year and is relatively productive when compared to other ecosystems occupied by grizzlies. Zager (1980) found that logging generally increased the amounts and kinds of bear foods in harvested stands in the South Fork drainage. However, in less productive habitats, logging may have a more severe effect on the availability of critical food and cover (Mattson and Knight 1991). Vegetation studies need to be repeated in different ecosystems to quantify these differences. The results from studies in one ecosystem, or even in one habitat type, do not necessarily apply to another. Furthermore the interactions between long-term changes in landscape dynamics and their ultimate effects on the grizzly bear have not been investigated.

Stands harvested in the study area since 1980 represent a loss of grizzly bear habitat. They are likely to remain so for at least 15 years. This loss needs to be recognized in forest management plans.

It appears that human disturbance is the factor preventing grizzly bears from using some harvested stands. If the enhanced human access resulting from timber harvest is maintained, the area may never regain its pre-harvest level of usefulness. Certainly not all stands are useful as grizzly bear habitat. Prior to initiating a timber sale the potential of the stand as grizzly bear habitat should be evaluated and confirmed.

Most of the harvested stands in the study area were cut between 1961 and 1980. As these stands recover, the potential grizzly habitat in the study area is likely to increase, provided new timber sales do not cause further losses. This may result in an increase in the grizzly bear population.

Instrumented grizzly bears in the study area selected home ranges that were, on the average, up to 11% harvested. The study area itself is over 18% harvested and 33% of the available timber has been harvested. It is possible that the study area is over-harvested in terms of providing optimal grizzly bear habitat.

Using the Timber Stand Management Record System

The TSMRS is a convenient source of information concerning the treatment history of harvested stands. However the system cannot replace the original records kept in the District's stand files. Older stands often have incomplete records, and as a result, the TSMRS records do not fully describe what occurred. I found that the TSMRS was reasonably accurate in describing the activities that occurred within a stand in general terms, but it is usually impossible to verify these activities after the fact. The descriptions of stand activities are cursory. One or 2 4-digit numbers are used to describe how a stand was harvested and scarified. Sometimes the only source of information on stand activities are the memories of those persons who were in charge of overseeing the operation. These people can be a valuable source of more specific information concerning harvested stands. Also the information in the TSMRS concerning the current status of a stand is only as good as the last stand exam. If the exam was conducted a long time ago the information may not be accurate.

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APPENDICES

APPENDIX A

DESCRIPTION OF VARIABLES MEASURED DURING FIELD DATA COLLECTION

Table 11. Variables included in field data collection. Most are derived from USFS Ecosystem Classification Handbook FSH 12/87 R-1 Suppl., while others are from SFGP files. The remainder have been created for this study.

GENERAL INFORMATION

1) OBSERVER - name of collector(s)

2) DATE - entered as mm/dd/yy.

3) START TIME - entered as military time to nearest minute.

4) BEAR DATE - the date and time of the relocation.

5) STAND I.D. - the stand i.d. number is the same as that used by the Forest Service.

6) PLOT I.D. - each plot is identified by a unique number.

7) EVIDENCE OF BEAR ACTIVITY - any evidence of past or present bear activity at the site or if noted on old relocation forms.

STAND INFORMATION

8) HABITAT TYPE - the habitat type of the stand is verified using Pfister et al. (1977) and coded using the standard USFS ADP system.

9) HARVEST TYPE - dominant tree removal method used within the stand; coded as follows:

Code	Harvest type
4110	Clearcutting
4121	Shelterwood prep cut
4122	Seed tree prep cut
4131	Shelterwood seed cut
4132	Seed tree seed cut
4141	Shelterwood removal cut
4143	Overstory removal cut
4146	Shelterwood final cut
4147	Seed tree final cut
4151	Individual selection cut
4152	Group selection cut
4211	Liberation cut
4220	Thinning
4230	Salvage
99	Other (specify)
-1	not recorded

Table 11. Continued.

10) SCARIFICATION TYPE - method used to prep site for planting, seeding or natural regen; coded as follows:

Code	Method
1	burning
2	chemical
3	mechanical
4	manual
99	other (specify)
-1	not recorded

11) FUELS TREATMENT - describes the method used to treat logging residues on the site; coded as follows:

Code	Treatment
4975	dozer piles burned
4976	handpiles burned
4977	grapplepiles burned
4978	broadcast burn
4979	jackpot burn
4980	understory burn
4981	wildfire
4982	lopping
4983	grapple piling
4984	dozer piling
4985	wildlife burn
4986	hand piling
4994	fuel break
4997	burn landings
-1	not recorded

MACROPLOT (2.5 acre) INFORMATION

12) SFGP COVER TYPE - the cover type of the 2.5 acre plots was recorded using the following cover type classifications:

Code	Cover Type
1	coniferous forest (>40% conifer)
2	deciduous forest (>40% deciduous trees)
3	alpine (above timberline)
4	tree wetland (>25% trees)
5	shrub wetland (>25% shrubs)
6	herbaceous wetland (>10% herb.)
7	shrubland (>15% shrub, <40% tree)
8	grass/forbland (>10% herb.)
9	rockland (>40% rock, <10% veg.)
10	nonvegetated (<10% rooted veg.)
-1	not recorded

Table 11. Continued.

13) SFGP COVER TYPE SPECIES - Recorded the name of the three most dominant species (>50% aggregate coverage) composing the cover type listed above.

14) SLOPE SHAPE - the topographic shape of the 2.5 acre plot was recorded as follows:

Code	Slope Shape
1	Even or straight
2	Convex or rounded
3	Concave or depression
4	Patterned (microrelief of hummock and swale or other)
5	Undulating pattern of low relief ridges or knolls and draws
-1	not recorded

15) PLOT POSITION - the position of the 2.5 acre plot on the slope was recorded using the following codes:

Code	Position
11	wide valley bottom (>0.5 miles wide)
12	slope in a wide valley bottom
13	ridgetop or rounded knoll in wide valley bottom
14	narrow valley bottom (100′-.5 m. wide)
15	draw (<100′ wide)
01	toeslope
02	footslope
03	lower slope
04	midslope
05	shoulder
06	bench or terrace in mountainous terrain
07	narrow ridge
08	platform summit or broad ridge summit
09	saddle, gap or pass on a ridge
10	short slope, neither upper or lower
-1	not recorded

16) ELEVATION - recorded from topo map to nearest contour interval (40 feet).

Table 11. Continued.

17) FUELS TREATMENT EFFICENCY - subjectively evaluated completeness of residue removal; coded as follows:

Code	Fuel Loading Class
11	light logging slash, varying in continuity
12	moderate, continuous logging slash
13	heavy, continuous logging slash
-1	not recorded

18) SPECIAL FEATURE - recorded the presence of any unusual or unique feature within the plot; coded as follows:

Code	Special Feature
99	not applicable
01	avalanche chute with non-scoured surface
02	avalanche chute with scoured surface
03	talus (rock fragments at base of cliff)
04	scree (rock fragments mantling a slope)
07	wet meadow
09	swamp (shrub dominated; soil surface wet in mid-summer
12	swale (concave or bench area with no surface water but moist soil)
13	seep (lower concave or bench area with surface water)
14	riparian area (adjacent to stream, river pond or lake; within 3'vertical and 100' horizontal)
16	snow catchment area (retains snow 2-4 weeks longer than surrounding areas of same aspect)
18	rock outcrop
19	road
00	other (specify)
-1	not recorded

19) DISTANCE TO EDGE OF CUT - measure of the shortest distance from plot center to the edge of the cutting unit in meters. May be paced or measured from maps.

Table 11. Continued.

MICROPLOT (0.1 acre) INFORMATION

20) SLOPE - a clinometer was used to measure percent slope at plot center and was recorded directly as percent. These may be recoded as follows:

Code	Class	Midpoint
0	0 - 10%	5%
1	11 - 20%	15%
2	21 - 30%	25%
3	31 - 40%	35%
-1	not recorded	

21) ASPECT - aspect was recorded at plot center and entered directly as degrees. This may be coded as follows:

Code	Aspect	Range	Midpoint
1	level or rolling	0	0
2	north	337-22	360
3	northeast	23-67	45
4	east	68-112	90
5	southeast	113-157	135
6	south	158-202	180
7	southwest	203-247	225
8	west	248-292	270
9	northwest	293-336	315
-1	not recorded		

22) SFGP COVER TYPE - the cover type of the 0.1 acre plots was recorded using the cover type classifications used for the macroplots (#12).

23) SFGP COVER TYPE SPECIES - Record the name of the three most dominant species (>50% aggregate coverage) composing the cover type listed above.

24) SCARIFICATION EFFICENCY - measures of post-harvest site condition are used to estimate intensity and completeness of scarification. The three measures are ground cover disturbance, duff depth, and ground cover. These variables were combined into one variable (scarification efficency). They will be coded as follows:

Table 11. Continued.

24a) GROUND COVER DISTURBANCE

Code	Disturbance class
99	undisturbed (ground cover stable)
1	low (if mechanical disturbance, 5-20% of ground cover removed exposing bare soil and pavement; if fire, most fine fuels burned, some charring of 3+" fuels, woody plants scorched but not burned to ground; uneven patch burning of duff and litter)
2	moderate (if mechanical disturbance, 20-40% of ground cover removed exposing bare soil and pavement; if fire, nearly all fine fuels consumed, some consumption of 3+" fuels, some woody plants consumed; patch distribution of duff and litter consumption)
3	high (if mechanical, 40-100% of ground cover removed exposing bare soil and pavement; if fire, many areas of exposed mineral soil, many woody plants consumed, most 3+" fuels charred and many consumed; fairly even distribution of duff and litter consumption)
-1	not recorded

24b) DUFF DEPTH - recorded depth of duff layer to nearest 1/2 inch (duff layer is between mineral soil and litter where active decomposition is occuring) at plot center.

24c) GROUND COVER - cover class was estimated for each of the following ground cover categories:

S - bare soil (<1/16" diam. soil particles)
G - gravel (1/16" - 3" diam.)
R - rock (>3" diam.)
W - wood (downed wood >1/4" diam.)
M - moss
O - other (specify)

Table 11. Continued.

Code	Range of class	Midpoint
0	0% cover	0%
1	>0 - <1% cover	0.5%
2	1 - <5% cover	3.0%
3	5 - <15% cover	10.0%
4	15 - <25% cover	20.0%
5	25 - <35% cover	30.0%
6	35 - <45% cover	40.0%
7	45 - <55% cover	50.0%
8	55 - <65% cover	60.0%
9	65 - <75% cover	70.0%
10	75 - <85% cover	80.0%
11	85 - <95% cover	90.0%
12	95 - 100% cover	97.5%
-1	not recorded	

25) PHENOLOGY CLASS - the developmental stage of each vegetation class was recorded using the following classes:

<u>Shrubs and broadleaved trees:</u>
1 - less than 3/4 leaf development without flowers
2 - 3/4 to full leaf development without flowers
3 - flowering with leaves developed
4 - seeds developed with leaves developed
5 - fruits developed with leaves developed
6 - senescent leaves
7 - flowers developed prior to 3/4 leaf development
8 - no floral development this year, full veg. growth
-1 - not recorded

<u>Forbs:</u>
1 - less than 3/4 leaf development without flowers
2 - 3/4 to full leaf development without flowers
3 - flowering with leaves developed
4 - seeds developed with leaves developed
5 - seeds dispersed with leaves developed
6 - senescent leaves
8 - no floral development this year, full veg. growth
-1 - not recorded

Table 11. Continued.

Graminoids
1 - leaves partially developed, no heads
2 - inflorescence inside the sheath (in the boot)
3 - inflorescence partially exerted from the sheath
4 - inflorescence fully exerted from the sheath
5 - seed heads dispersed
6 - senescent leaves
8 - no seed head this year, full vegetative growth
-1 - not recorded

Fields 26 through 29 use the same cover classifications as those used in field 24c.

26) TOTAL TREE COVER - estimated % canopy cover for trees as a life form, then by subclass. This field can serve as a measure of post-harvest regeneration, and removal efficency. Code as follows:

seedling (<1" d.b.h.)
sapling (1 - 5" d.b.h.)
pole (5 - 9" d.b.h.)
mature (9 - 13.9" d.b.h.)
large mature (14+" d.b.h.)

27) TOTAL SHRUB COVER - estimated % cover for shrubs as a life form then by subclass. Coded as follows:

low shrub (<6" high)
mid shrub (6" - 4.5′ high)
tall shrub (> 4.5′ high)

28) TOTAL GRAMINOID COVER - estimated % cover for graminoids (grasses, sedges and rushes) as a life form.

29) TOTAL FORB AND FERN COVER - estimated % cover for forbs and ferns as a life form.

30) HORIZONTAL VEGETATION DENSITY - a measure of the thickness of surrounding vegetation. Analogous to "hiding cover". A "cover pole" was used following the method of Griffith and Youtie (1988).

31) BEAR FOOD DENSITY - I counted the number of bear food plants within 4 randomly placed 51x51 cm (20x20 in) plot frames. When berry bushes were encountered (Sorbus, Amelanchier or Vaccinium spp.) the number of berries were counted.

32) FINISH TIME - recorded time plot was completed.

APPENDIX B

AREAS OF HOME RANGE POLYGONS

Table 12. Areas in km^2 of 95% minimum convex home range polygons in the South Fork Flathead study area 1987-90.

Bear ID.	Composite	Spring	Summer	Fall
1	331.0	*	0.26	46.4
3	448.6	268.6	123.7	91.6
5	77.2	89.6	52.6	37.0
14	177.4	164.7	19.8	25.5
18	69.7	36.0	50.8	6.6
22	496.0	443.9	314.3	80.9
25	235.2	224.1	37.4	87.7
42	31.9	26.2	15.9	3.3
45	82.4	35.0	78.4	7.9
48	67.1	25.4	55.8	12.6
71	507.6	471.7	338.1	45.1
94	60.9	42.3	30.7	34.7
96	101.0	63.6	58.6	25.9
137	133.9	21.7	140.9	14.9
139	121.5	85.3	15.5	34.6
143	57.8	49.8	34.8	23.3
144	545.2	370.4	77.0	37.8
146	420.1	297.8	213.2	64.3
147	242.2	171.8	100.4	87.8
148	785.8	375.7	44.4	*
149	1036.0	989.7	645.7	212.2
150	390.0	166.8	273.0	132.5

* Insufficient sample size to build polygon.

APPENDIX C

SUMMARY OF STEPWISE LOGISTIC PROCEDURE

Table 13. Summary of stepwise logistic procedure.

Step	Variable Entered	Score X^2	Pr>X^2
1	Edge Distance	5.2609	0.0218
2	Mean Veg. Den. C	4.2876	0.0384
3	Aspect Catagory 2	3.7964	0.0514
4	Stumps	3.3830	0.0659
5	Spec. Feat. 19	2.2488	0.1337

Table 14. Analysis of maximum likelihood estimates.

Variable	d.f.	Parameter Estimate	Standard Error	Pr>X^2	Standardized Estimate	Odds Ratio
Intercept	1	3.3270	1.1027	0.0026		27.856
Asp. Cat. 2	1	1.3191	0.7788	0.0903	0.216279	3.740
Edge Dist.	1	0.0038	0.0026	0.1417	0.208531	1.004
Sp. Feat. 19	1	3.6430	2.4324	0.1342	0.237629	38.207
Mean Den. C	1	-0.6700	0.2240	0.0028	-0.449676	0.512
Stumps	1	-0.2189	0.1139	0.0546	-0.228584	0.803

Table 15. Association of predicted probabilities and observed responses.

Concordant = 73.3%	Somers' D = 0.466
Discordant = 26.6%	Gamma = 0.467
Tied = 0.1%	Tau-a = 0.194
(4905 pairs)	c = 0.733