Madeleine Vander Heyden, Oregon Cooperative Wildlife Research Unit, 104 Nash Hall, Oregon State University, Corvallis, Oregon 97331[1]

and

E. Charles Meslow, Wildlife Management Institute, 8035 NW Oxbow Drive, Corvallis, Oregon 97333.

Habitat Selection by Female Black Bears in the Central Cascades of Oregon

Abstract

Public scrutiny over management of black bears (*Ursus americanus*) in Oregon resulted in the passing of a referendum to ban the use of dogs and bait to hunt bears in 1994. Challenges to bear management necessitate the application of regionally derived biological information to bear management. The overall objective of this research was to define habitat characteristics that influence the autecology of female black bears in Oregon. Because habitat-selection processes operating at finer resolutions (e.g., the home range) are inevitably the product of landscape characteristics, we chose to study selection at both the home range and landscape scale. We radio-tracked 14 adult female black bears from June 1993 to December 1995 in the central Cascades of Oregon to determine home-range size and analyze habitat selection. Locations were classified to one of six habitat classes based on stand structure, and digitally overlaid onto a habitat map produced from a LANDSAT Thematic Mapper scene of the study area. A geographic information system was used to determine habitat characteristics at known and random locations; chi-square and logistic regression techniques were used to analyze habitat use. Female black bears were associated with open-canopy sapling/pole and open canopy mature timber, apparently selecting for a combination of foraging opportunities and security cover. Furthermore, black bears were negatively associated with roads and positively associated with streams. Consequently, roads located along watercourses may inhibit the use of riparian areas by bears. Understanding how forest-management practices influence the availability and use of habitats for black bears, and applying this knowledge to bear-management strategies, will ensure that management plans are based on the best available science, and confer greater credibility to state agencies from an increasingly informed and involved public.

Introduction

Managed as a game species under the authority of the Oregon Department of Fish and Wildlife (ODFW), the black bear population in Oregon was estimated at 25,000 animals statewide (ODFW 1992). In recent years, black bear management has become increasingly controversial, culminating in a public referendum in 1994 that banned the use of dogs and bait to hunt black bears. Challenges to bear management underscore the necessity of using the best available information to formulate black bear management guidelines. In addition to demographic data, maintaining viable black bear populations requires information on black bear ecology. Specifically, understanding how female black bears interact with their environment is important because habitat quality and quantity affect reproductive potential (Pelchat and Ruff 1986, Reynolds and Beecham 1980).

Information on habitat use by black bears in Oregon is limited (Barber 1983, McCollum 1973). Although data on habitat use obtained from studies in adjacent western states is somewhat applicable to Oregon (Beecham 1983, Lindzey and Meslow 1977, Poelker and Hartwell 1973), the composition of black bear habitat may differ considerably among states with varying vegetation communities. We studied home ranges and habitat use of female black bears at two scales by use of radio telemetry between June 1993 and December 1995 on the Willamette National Forest in the central Cascades of Oregon. The overall objective of this study was to examine habitat use of black bears in a managed forest. Specific objectives were to: (1) determine home-range sizes of female black bears; (2) compare habitat characteristics of known locations to random locations generated within home ranges; (3) compare habitat use and availability of habitats within home ranges; and 4) compare habitat use and availability within the range of the study-area population.

Study Area

This research was conducted near Oakridge, Oregon on the Rigdon Ranger District of the

[1]Current Address: 1355 Fish Hatchery Road, Jackson, WY 83001, USA

Willamette National Forest (Figure 1). The study area was located on the western slope of the Cascade Mountain Range and encompassed approximately 134,500 ha. Most of the area, with the exception of the adjacent Diamond Peak Wilderness, was extensively managed for timber production and supported an extensive road network. Clearcutting, the predominant logging method, produced a matrix of regenerating timber stands typically < 45 years old interspersed with

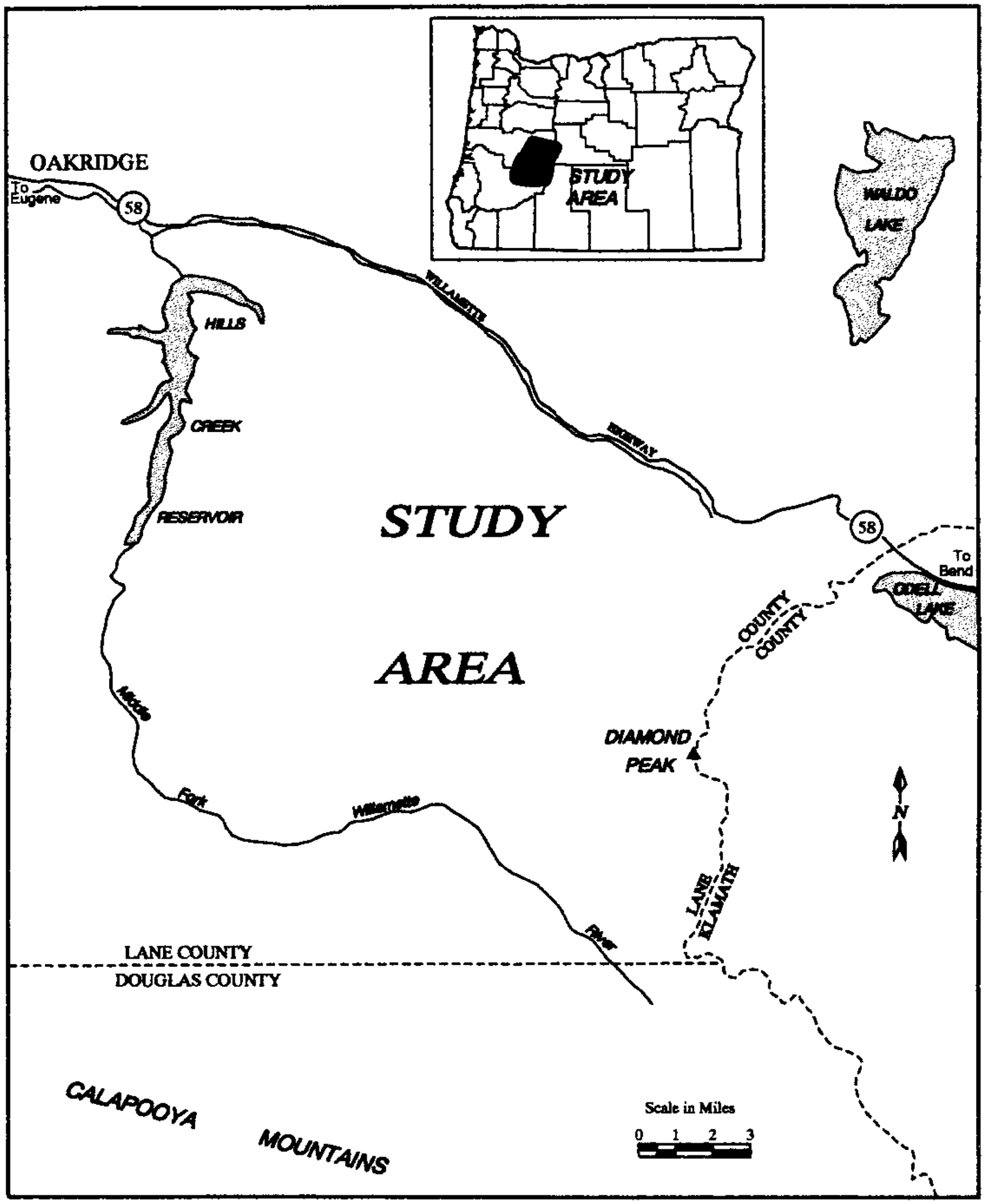

Figure 1. Location of female black bear study in the central Oregon Cascades. 1993-1995.

unmanaged forest > 80 years of age. In September 1988, an arson fire (the Shady Beach Burn) burned 3,708 ha of forest; much of the burned timber was subsequently clearcut resulting in extensive areas of grass-forb habitat surrounded by mature forest characterized by numerous canopy gaps and snags.

Study area elevations ranged from 460 m to 2,460 m at the summit of Diamond Peak. Most ridgetops were approximately 1,300 m. The topography was highly dissected due to glaciation and stream erosion, and was extremely rugged (Hemstrom et al. 1987). Two major watercourses, Hills Creek and the Middle Fork of the Willamette River, drained the area. Annual precipitation ranged from about 114 cm to over 178 cm on the higher ridges. Snow below 900 m was transient and drought conditions in summer were common. Temperatures ranged from approximately -12 C in winter to highs near 38 C in summer.

Dense stands of Douglas-fir (*Pseudotsuga menziesii*) dominated dry, low-elevation sites (Franklin and Dyrness 1973) and quickly regenerated in canopy gaps. Moist, low-elevation forests (below 1,000 m) consisted primarily of the western hemlock (*Tsuga heterophylla*) series. Higher elevations (900 m to 1,500 m) were dominated by the Pacific silver fir (*Abies amabilis*) series including Douglas-fir, western hemlock, and mountain hemlock (*Tsuga mertensiana*). Grassy openings on south slopes contained manzanita (*Arctostaphylos columbiana*) and Pacific madrone (*Arbutus menziesii*). Common understory species found throughout the area included Oregon grape (*Berberis nervosa*), salal (*Gaultheria shallon*), rhododendron (*Rhododendron macrophyllum*), and several species of huckleberry (*Vaccinium* spp.).

Methods

Bear Captures

We captured female black bears in Aldrich foot snares (Flowers 1977) in spring 1993-1995, and immobilized them with tiletamine hydrochloride and zolazapam (Gibeau and Paquet 1991) using a jab stick or capture rifle. Following induction, we radiocollared the bears and extracted a premolar tooth to estimate age (Stoneberg and Jonkel 1966). Bears were monitored to ensure their safe recovery, and we did not track them until > 24 hours had passed to allow for resumption of normal activities.

Radiotelemetry

Bears were radio-tracked from the ground during June 1993-December 1995, and we attempted to evenly distribute the locations into three time periods: dawn-1000, 1000-1500, and 1500-dusk. Each bear was located approximately every other day, for an average of three locations per week. Locations were determined using a combination of triangulation (Nams and Boutin 1991), homing (White and Garrott 1990), and direct observation. To triangulate, azimuths were taken from known locations and immediately plotted onto 7.5-minute United States Geological Survey (USGS) orthophoto quadrangle maps. The bear's location was estimated as the center of the error triangle created from the intersection of 3 bearings (Nams and Boutin 1991). The minimum time allowed to get three intersecting bearings was approximately 30 minutes, after which the previous bearings were discarded and the process repeated. Error triangles that encompassed more than one habitat necessitated using the homing method in which the observer walked along the habitat edges contained within the triangle until one habitat was determined to contain the animal. Disturbance was minimized by not directly walking towards the bear and by not approaching bears any closer than necessary to classify the occupied habitat. If, based on bear activity, we believed we may have caused the bear to move, the subsequent location was not used for habitat analyses. Weak or reflected signals due to dense vegetation and rugged topography also at times prohibited classifying a location to habitat. In such cases the triangulation was used only for home range calculation purposes.

Error trials were conducted using 61 locations of test transmitters. Transmitter placement was as unbiased as possible to approximate actual bear tracking, and locations were chosen by a third party to reflect a variety of habitats and topography (Vander Heyden 1997). The trials resulted in a mean linear error of 89 m and a mean areal error triangle of 4 ha. Three of 61 (5%) transmitters were assigned to the wrong stand.

Defining Availability

We determined habitat availability based on the size of female bear home ranges and the area sampled (snared) for bears. We placed a circle with a diameter equal to twice the largest 95%

Minimum Convex Polygon (MCP, Mohr 1947) home range calculated for a female bear (3,595 ha) around every snare site available to capture bears. The area enclosed by the outer boundary of the circles was delineated and used to define the study area perimeter and to determine habitat availability at the landscape scale. Because we wanted to examine habitat use by bears in a managed forest, we excluded areas falling within the Diamond Peak Wilderness from calculations of availability. Use of the largest MCP home range belonging to a resident female bear was intended to delineate a study area large enough to encompass the maximum distances a female bear may have traveled to reach a snare.

Habitat Classification

We created a habitat map from a 1992 LANDSAT Thematic Mapper (TM) image of the study area using Earth Resources Data Analysis System (ERDAS, Atlanta, GA) software for digital-image analysis. The resolution of the TM image was 30 x 30 m (0.09 ha). Thirty spectrally distinct classes were identified, and we used an unsupervised classification (Jenson 1986) to group the classes into six broad habitats with a minimum mapping unit of 4 ha. Field reconnaissance and aerial photograph interpretation were used to further refine the classification. Habitat classes were based on stand structure and approximated a successional hierarchy ranging from early successional grass-forb to mature forest (Table 1). Map accuracy was computed with standard techniques for land cover classification (Lillesand and Kiefer 1979), and described in detail in Vander Heyden (1997). Logging activity between 1992 and the years of this study was minimal, thus we believe that any potential implications of land cover change on map accuracy and habitat analyses were largely inconsequential.

The habitat map was integrated into a GIS along with bear locations, stream, road, and digital elevation model (DEM) coverages. Variables obtained from the DEM included elevation, slope, and aspect. The stream coverage depicted first- through third-order streams, and the road coverage, while it did not distinguish between road types (e.g., primary, secondary), included all roads recognized on USGS orthophotoquads created in 1986. Although an accuracy assessment was not performed on the road layer, we found few discrepancies between it and the actual road system. Secondary, graveled logging roads composed the majority of the roads in the area.

To assess the significance of habitat edges to bears, we constructed an edge buffer with a width of 50 m on either side of every stand boundary. Locations falling within this buffer also were classified into a separate habitat category called "edge." Edge locations were then divided into two

TABLE 1. Habitat classes used by female black bears in the central Cascades of Oregon, 1993-95.

Habitat Class	Description[1]	Proportion in study area
Grass-forb	Very little vertical stand structure; seedling trees and shrubs are not dominant.	0.17
Shrub	Shrubs dominant, trees provide less than 30% crown closure.	0.10
Open-canopy sapling /pole	Canopy closure <60%; shrub understory common.	0.10
Closed-canopy sapling/pole	Canopy closure 60-100%; little ground vegetation.	0.13
Closed-canopy mature timber	Canopy closure >80% but usually <100%; average tree dbh. > 53 cm. Some ground vegetation present.	0.32
Open-canopy mature timber	Canopy closure <80%, average tree dbh. >53 cm. Understory of shrubs, small trees, and other vegetation common.	0.18
Total		1.00

[1]Based primarily on Brown (1985).

TABLE 2. Habitat combinations for the variable "edge type" used in the logistic regression models for female black bears in the central Cascades of Oregon, 1993-95.

Low contrast edge	High contrast edge
Grass-forb/shrub	Grass-forb/open-canopy sapling/pole
Shrub/open-canopy sapling/pole	Grass-forb/closed-canopy sapling/pole
Open-canopy sapling pole/closed-canopy sapling/pole	Grass-forb/closed-canopy mature timber
Closed-canopy/sapling pole/closed-canopy mature timber	Grass-forb/open-canopy mature timber
Closed-canopy mature timber/open-canopy mature timber	Shrub/closed-canopy/sapling/pole
	Shrub/closed-canopy mature timber
	Shrub/open-canopy mature timber
	Open-canopy sapling/pole/closed-canopy mature timber
	Open-canopy sapling/pole/open-canopy mature timber
	Closed-canopy sapling/pole/open-canopy mature timber

categories, "high contrast" and "low contrast" based on the structural contrast of the habitat classes composing the buffer (Table 2).

Home Range Estimates and Analyses

We used two methods to quantify annual home range sizes: the 95% adaptive kernel (ADK) method using the program CALHOME (Baldwin and Kie 1992) with the default parameters, and the 95% minimum convex polygon (MCP) method using the program HOMERANGE (Ackerman et al. 1990). We used the 95% ADK home range in all analyses to facilitate comparisons among bears with variable sample sizes.

Twenty-six annual MCP home ranges were calculated for 14 individuals; 24 ADK home ranges were calculated for 12 individuals. We excluded two bears from the ADK calculations because of small sample sizes (< 24). The number of locations used per bear for the ADK estimates ranged from 24 to 85 with a mean of 48 (SE = 18). In addition, we calculated 95% ADK "composite" (multi-year) home ranges for each bear to determine the overall area used by each bear in the course of the study.

We used analysis of covariance to assess the presence of an association between the following explanatory variables and 95% ADK home range size: individual bear variation defined by the variable "bear", reproductive status, year, and number of locations. We used stepwise backwards variable selection procedures to eliminate insignificant variables ($P \leq 0.05$) from the model.

Habitat Analyses

We investigated habitat selection at two scales, the home range and the landscape, using individuals as the primary sampling units (Thomas and Taylor 1990). For our landscape-scale analysis, we measured habitat use for each radio-marked animal and measured availability over the entire study area; for our home-range-scale analysis, we measured both use and availability at the individual level. Both designs resulted in separate resource selection "functions" for each animal, thereby allowing individuals to vary in their habitat selectivity. We used these individual estimates to make inferences to the population of animals (Cox and Hinkley 1974).

Home Range Scale

Univariate Analysis. —We used a Chi-square goodness-of-fit test (Neu et al. 1974, Byers et al. 1984) to compare habitat availability within the composite 95% ADK home range for each bear (n = 12) to use. This tests the null hypothesis that bears used habitats within their home ranges randomly. We chose $P \leq 0.10$ in recognition of the limited power implicit to our small sample size. When a Chi-square statistic was significant, we constructed Bonferroni 95% confidence intervals (Neu et. al 1974, Byers et. al 1984) to determine which habitat classes differed in use from expected.

Logistic Regression. —We used logistic regression (Ramsey et al. 1994) to identify and model habitat variables that best distinguished known-bear locations (obtained from radio telemetry) from random locations (points). This resulted in odds ratios that described the probability that a particular observation was a bear location. The number of random locations generated within the 95% ADK annual home range for each bear was approximately three times the number of locations obtained from radio telemetry. The ratio of three random points per every known point is optimal in terms of reducing the standard errors of the estimates (Ramsey, pers. comm.).

In addition to habitat class and edge type, we tested the following explanatory variables for significance to bear habitat selection: patch (stand) size, slope gradient, aspect, elevation, and distance to the nearest road, stream, and edge. Slope, aspect, and elevation variables were calculated from a DEM at a scale of 1:250,000 obtained from the USGS. Elevation was measured as a continuous variable; slope and aspect were categorical. Slope was divided into two categories based on gradient. We considered locations falling on slopes ranging from 25-48 degrees "steep" and locations falling on slopes < 25 degrees "moderately steep." Aspect, initially expressed in degrees from 0 to 360, was divided into eight categories, each containing a range of 45 degrees, as well as a ninth category defined as "no aspect." All variables were obtained from digital overlays created within a GIS by use of road, stream, and DEM coverages. These coverages were juxtaposed with the coverage of bear locations, and the GIS was queried for association with known-bear locations and random points.

Initially, we fit a single model for each bear with the largest multiple year sample sizes using "bear" as both a main effect and an interaction term, using a variable selection procedure based on the drop-in-deviance test (Ramsey et al. 1994). This test assesses the contribution of the proposed variables relative to the observed data; variables that led to a significant reduction in model deviance ($P \leq 0.10$) were retained in the model. Interactions were not detected, nor were any variables highly correlated ($r < 0.4$). No year effect was present, which allowed us to combine data from multiple years into one model for each bear (12), using the nine variables described above. These 12 models were then examined, and any variable significantly associated with any bear's habitat selection ($P \leq 0.10$) was included in a "grand" model. Data for each of the 12 bears were then fit to the grand model, using Chi-square and P-values from drop-in-deviance tests, which compared the final model with a series of reduced models. This resulted in 12 model summaries each containing the same variables along with their estimated coefficients and standard errors. Lastly, we calculated odds ratios to quantify the effects of each variable, examined if the affects were consistent among bears, and made inferences to the population.

Habitat Analyses: Landscape Scale

Habitat Use By Individual Bears.—We examined habitat use for each bear using a Chi-square goodness-of-fit test ($P \leq 0.10$) to compare habitat availability within the entire study area to use. When the Chi-square statistic was significant for any bear, we constructed Bonferroni 95% confidence intervals to determine which categories differed in use from expected.

Seasonal Habitat Use.—We pooled all bear locations and divided them into three seasons based on plant phenology: spring (den emergence-15 June), summer (16 June-15 September), and fall (September 16-den entry). For each season, we used a Chi-square goodness-of-fit test ($P \leq 0.10$) to determine if observed use of the six habitat classes was different from expected, followed by 95% Bonferroni confidence intervals to determine which habitats were used greater than, equal to, or less than their availability.

Results

Home Range Size

The mean 95% annual ADK home range for 12 bears was 3,212 ha (range: 1,667-8,519 ha, SE =

TABLE 3. Annual and composite (all years) 95% adaptive kernel home range sizes (ADK, ha); annual 95% minimum convex polygon home ranges (MCP, ha), and the number of locations per female black bear radiocollared in the central Cascades of Oregon, 1993-95.

Bear	1993			1994			1995			Composite	
	Size		*n*	Size		*n*	Size		*n*	Size	*n*
	ADK	MCP		ADK	MCP		ADK	MCP		ADK	
93-009[1]		2042.00	19								
93-011	2632.00	2017.00	60	2951.00	1352.00	47	2407.00	2253.00	49	3363.00	156
93-016[2]	3988.00	2359.00	54	2203.00	1639.00	44				4165.00	98
93-018[3]	8519.00	6334.00	30	5845.00	4052.00	34				9149.00	64
93-024[4]	2391.00	8626.00	32								
93-026	2145.00	1348.00	56	1828.00	1220.00	42	5817.00	2143.00	49	2925.00	147
94-037[5]				2168.00	1213.00	35	1954.00	1318.00	85	1835.00	120
94-038[5]				1667.00	1085.00	32	1749.00	1194.00	72	1728.00	104
94-041[5]				2036.00	1033.00	29	2094.00	1411.00	60	2671.00	89
94-045[5]				5939.00	2468.00	25	6315.00	3578.00	80	5238.00	105
94-049[5]				2001.00	9014.00	24	5373.00	2064.00	48	5528.00	72
94-050[5]				1971.00	7650.00	24	2278.00	1290.00	68	2461.00	92
94-051[6]					489.00	21					
95-063[7]							2231.00	1510.00	74		

[1]No Adaptive Kernel Home Range was calculated due to small sample size; bear was killed after 1993.
[2]Mortality, no data after 1994.
[3]Dropped collar, no data after 1994.
[4]Mortality, no data after 1993.
[5]Bears not captured until 1994.
[6]Bear captured in 1994, no data for 1995 because of subsequent mortality.
[7]Bear captured in 1995.

1,716 ha; Table 3). The mean 95% MCP was 2,994 ha (range: 1,033-9,014 ha, SE = 2,189 ha) (Table 3). On average, MCP estimates were 7% smaller than ADK estimates. Composite (multi-year) 95% ADK home ranges averaged 3,906 ha (Table 3).

Adaptive kernel home-range sizes estimates were not significantly related to number of locations ($P = 0.26$), presence of cubs (seven females had cubs of the year, $P = 0.76$), or year ($P = 0.45$). The only variable associated with ADK home range was "bear" ($P = 0.03$).

Habitat Use: Home Range Scale

Univariate Analysis.—Most bears (10 of 12) used habitats disproportionately to their availability within their home ranges. Because low sample sizes limited the power of tests to determine significance, an examination of trends (disregarding significance) is helpful in discerning use patterns among individuals (Table 4). Female black bears used grass-forb less than expected and open-canopy sapling/pole and mature timber classes more than expected. The majority used grass-forb, shrub, and closed-canopy sapling/pole types less than availability, and open-canopy sapling/pole, open-canopy mature timber and closed-canopy mature timber more than availability.

Logistic Regression.—Eight of the nine variables included in the full models for each of the 12 bears were significant for at least one bear; the exception was edge type. The number of significant variables ($P \leq 0.10$) per bear ranged from one to five, including stream distance, aspect, elevation, slope gradient, patch size, road distance, edge distance, and habitat class. These variables explained habitat characteristics that differed between random and known bear locations, and were used to construct a general-habitat-association model (i.e., the "grand" model). The parameter estimates and standard errors are described in detail in Vander Heyden (1997). The results of the grand model are explained below, beginning with the categorical variables.

TABLE 4. Habitat use versus availability within composite home ranges (n=10) of female black bears in the central Cascades of Oregon, 1993-95. Small sample sizes prohibited the ability to find significance at $P \leq 0.10$, therefore a comparison is made at both $P \leq 0.10$ and $P > 0.10$.

	Use compared to expected[1]				
	$P \leq 0.10$			$P > 0.10$	
Habitat Class	Less than	Not different than expected	More than	Less than	More than
Grass-forb	4	5	1	9	1
Shrub	2	7	1	8	2
Open-canopy sapling/pole	0	7	3	3	7
Closed-canopy sapling/pole	2	8	0	7	3
Closed-canopy mature timber	0	8	2	2	8
Open-canopy mature timber	1	6	3	2	8

[1] Selection was based on the Pearson Chi-square goodness-of-fit test and Bonferroni confidence intervals. Expected values were calculated using proportion of habitat classes within 95% adaptive kernel composite home ranges for each bear.

The variable "habitat" was significant for five bears ($P \leq 0.007$). It had six levels (i.e. types of habitat) with grass-forb used as the reference level to which all other habitats were compared. With only one exception (bear 93 - 011), the odds of a location being a known bear location rather than a random point increased from grass-forb to all other habitats. For three of the five bears, open-canopy sapling/pole had the highest odds of a location being known rather than random when compared to grass-forb. The highest odds for the other two bears were for the habitat classes closed-canopy mature timber (bear 93 - 011) and closed-canopy sapling/pole.

"Aspect" was significant for two of the bears in the final models ($P = 0.007$ and $P = 0.002$). These bears were more often found on southeast aspects than at any of the other levels. "Slope gradient", defined by the indicator variable "moderate slope", was significant for two bears at $P = 0.03$, and $P = 0.07$. In both of these models, the odds were higher that a bear location was on a steep slope.

"Stream distance" was significant for four bears, with bear locations tending to be closer to streams than random points. The mean distance to the nearest stream of any order for bears in this study was 167 m (Table 5). "Patch size" was significant for bear 94 - 041 ($P = 0.04$) and bear 94 - 050 ($P = 0.05$). For both of these bears, the odds that a location was a known-bear location became less and less likely as the patch size increased. In other words, these bears were more likely to be found in small patches. "Road distance" was significant for five bears; the odds of a location being known increased the farther from a road the location became. The mean distance to the nearest road in this study was 307 m (Table 5). "Elevation" was significant for three bears; for two of the three, a location was more likely to be a random point (and not a bear location) the higher the elevation became. "Edge distance" was significant ($P = 0.07$) for one bear, 93 - 011. This bear was likely to be found close to habitat edges. The overall mean distance from edge for all bear locations was 62 m (Table 5).

TABLE 5. Mean and standard error (SE) values for known and random continuous variables measured per female black bear (n = 12) in the central Cascades of Oregon, 1993-1995.

	Known		Random	
Variables	$\bar{X}$	SE	$\bar{X}$	SE
Distance to stream (meters)	167.00	97.00	228.00	124.00
Distance to road (meters)	307.00	215.00	287.00	200.00
Distance to edge (meters)	62.00	20.00	64.00	16.00
Patch size (hectares)	682.00	1103.00	693.00	1052.00
Elevation (meters)	968.00	188.00	970.00	240.00

Habitat Use: Landscape Scale

Habitat Use by Individual Bears Compared to Availability in the Study Area.—All but one bear used at least some habitats disproportionately to their availability across the study area landscape ($P \leq 0.10$; Table 6). The habitats used more than availability by any of the bears were open-canopy sapling/pole, and both open-and closed-canopy mature timber. The most frequently under-used

TABLE 6. Number of female black bears (n=11) using each habitat class less than or more than its availability ($P \leq 0.10$) in the central Cascades of Oregon, 1993-95.

Habitat Class	Use compared with expected[1] ($P \leq = 0.10$)		
	Less than	Use not different than expected	More than
Grass-forb	8	3	0
Shrub	4	7	0
Open-canopy Sapling/pole	1	3	7
Closed-canopy sapling/pole	2	9	0
Closed-canopy mature timber	1	9	1
Open-canopy mature timber	2	7	2

[1]Selection was based on the Pearson Chi-square goodness-of-fit test and Bonferroni 95% confidence intervals. Expected values were calculated using the proportion of habitat classes within the study area boundary.

habitats were grass-forb (8/11 bears) and shrub (4/11 bears).

Seasonal Habitat Use.—Bonferroni 95% confidence intervals indicated that in the spring, bears used grass-forb less than expected; in the summer, bears used shrubs and closed-canopy mature timber less than expected, and open-canopy sapling/pole and open-canopy mature timber more than expected (Table 7). In the fall, bears used grass-forb and shrub less than expected, and closed-canopy-mature timber more than expected.

Discussion

Black bears are highly opportunistic and extremely mobile; necessary traits in an environment in which food resources vary both temporally and spatially. The patchy and fluctuating nature of black bear food resources leads to diverse selection strategies based on the composition and availability of habitats within each bear's home range. Nonetheless, some consistent trends were evident.

Home Range Size

Home ranges in the Cascades of Oregon were much larger than those reported elsewhere in similar habitats. In western Washington, for example, home ranges of black bears were reported to average 4 km^2 (Barber 1983), and 2 km^2 (Lindzey and Meslow 1977) on Long Island, and 5 km^2 (Poelker and Hartwell 1973) in western Washington (mainland). The much larger home range size for female bears in this study may be attributed to lower habitat productivity in the Cascades, or lower densities of bears relative to carrying capacity.

TABLE 7. Seasonal habitat use[1] by a pooled sample of female black bears (n = 12) in the central Oregon Cascades, 1993 - 1995.

Habitat Class	Season		
	Spring n = 315	Summer n = 448	Fall n = 286
Grass-forb	–	no difference	–
Shrub	no difference	–	–
Open-canopy sapling/pole	no difference	+	no difference
Closed-canopy sapling/pole	no difference	no difference	no difference
Closed-canopy mature timber	no difference	–	+
Open-canopy mature timber	no difference	+	no difference

[1] "–" use less than expected, ($P \leq = 0.10$); "+" use greater than expected, ($P \leq = 0.10$). Selection was based on the Pearson chi-square goodness of fit test and Bonferroni confidence intervals.

Habitat Use at the Landscape and Home Range Scale

At both the home range and landscape scales, female black bears mostly selected a combination of open-canopy/sapling pole stands, and both open-canopy and closed-canopy mature timber. These stands seemingly offered a combination of light-dependent food plants (berries, in particular) with the security of tree cover. Berries (primarily *Vaccinium* spp.) ripened starting in mid-June, and bears used open-canopy sapling/pole stands more than expected throughout the summer. Both closed and open-canopy mature stands were structurally diverse, had large amounts of downed woody debris, and had a variety of plant species in the understory, especially in canopy gaps. This may explain why closed-canopy mature timber was the most prevalent habitat in 10 of the 12 home ranges, and was used significantly more than expected in the fall, along with open canopy mature timber. These stands presumably offered alternative bear foods as summer foods became scarce, and escape cover when hunting seasons increased vehicular and human disturbance.

In contrast, bears made little use of closed-canopy sapling/pole stands at either scale (Tables 4 and 6). Despite their potential security value, closed-canopy sapling/pole stands may have limited use for black bears in the Central Cascades. Prior to stem exclusion these stands often are extremely dense and little light penetrates the canopy (Brown 1985); understory vegetation, and presumably bear food, is sparse. Grass-forb habitats, although prevalent in many home ranges and often containing bear foods (grass, anthills, berries), were also avoided, with bears more likely to occur in shrub or open-canopy sapling/pole stands. These two seral stages differed from grass-forb primarily in their relative abundance of cover. In agreement with this study, (Lindzey and Meslow 1977) reported that older clearcut units in western Washington were more often selected than recently cut units even when recent cuts apparently had food available. They also found that bears did not begin to use clearcut units greater than availability until the cuts were 18-25 years old. These units approximated our open-canopy sapling/pole habitat, which occurs 10-20 years following clearcutting.

In addition to the potential influence of within-stand cover, adjacency to mature forest may also affect habitat selection. Two of the bears that made use of young seral stages (shrub and open-canopy sapling pole) selected for smaller patches from which forested areas were easily accessible. The home ranges of these two bears were somewhat unique in that they contained large contiguous blocks of forest, with logged stands of early seral condition mainly along the periphery. Activity was concentrated in the smaller of these logged stands; larger stands may have inhibited use because the bears may have been reluctant to forage very far into areas with limited cover. The proximity of cover to feeding areas has been postulated as influencing habitat selection in several other studies (Novick and Stewart 1982, Grenfell and Brody 1986).

The variables related to edge were minimally significant although in both this study and the study in western Washington (Lindzey and Meslow 1977) over half of all bear locations were in edge habitat (< 50 m from the boundary of two habitats). It could be that edge truly did not play a role in habitat selection but rather was an artifact of the high degree of fragmentation in the area. Conversely, perhaps the edge classification, based on structural contrast between habitat types, was inappropriate, or the edge buffer specified, (50 m on each side of a habitat boundary), was too large.

Bears were more likely to occur at increasing distances from the nearest road. Most of the roads in the study area were open to the public, consequently traffic could have caused considerable disturbance to bears especially during the hunting season when traffic levels were high. Additionally, logging activity, although decreased in recent years, may have also contributed to black bears avoidance of roads. Measures of road distances to bear locations vary among studies, and disparate road densities and road types confound comparisons.

In general, bears preferred low elevations, steep slopes, and southeasterly exposures. In corroboration with this study, Novick and Stewart (1982) also found higher activity on drier southern slopes in Southern California, and both Mollohan (1989) and Unsworth et al. (1989) found selection for steep slopes. Exposure influences floristic composition, with southern exposures in our study area containing manzanita, mountain ash, and grass, and slope gradient may confer greater security value and facilitate early detection of threats.

Lastly, bears were more likely to occur close to streams. Young and Beecham (1986) suggested that water may offer important feeding opportunities by influencing the availability of riparian vegetation and perhaps providing fish carcasses and aquatic invertebrates, and Kellyhouse (1980) stated that streamside buffers may provide important cover and travel opportunities in areas otherwise devoid of timber. These observations apply to our study area as well.

Management Implications

Silvicultural techniques that promote the development and maintenance of open-canopy sapling/pole stands and mature timber should benefit black bears. Therefore, decreasing dense canopy closures by thinning, pruning, or creating canopy gaps would promote the growth of understory vegetation important for both foraging and hiding cover. Maximizing food and cover could likely be achieved by using uneven-age management practices to create structurally diverse stands (Hunter 1990), and maintaining patches containing high plant diversity may provide for a variety of bear foods.

We also suggest minimizing the use of clearcutting, or limiting the size of harvest units. Placing cuts adjacent to mature timber and open-canopy sapling/pole stands would maximize the combination of food and cover and create edge habitat. Lastly, the continued protection of streamside buffers, implementing road closures, and putting old roads "to bed" may encourage use by black bears.

In conclusion, we recommend that black bear management be responsive to vegetation composition and structure, taking into account the effects of roads and streams on habitat selection. Ultimately, what is needed is an understanding of how habitat change affects black bear population viability. To this end, we advocate future research on the effects of forest practices on black bear demography.

Acknowledgements

This paper is a contribution of the Oregon Cooperative Wildlife Research Unit at Oregon State University, the U.S. Fish and Wildlife Service, U.S. Geological Survey Biological Resource Division, and was produced with the cooperation of the Wildlife Management Institute. The Oregon Department of Fish and Wildlife supported this research, and provided logistic, technical, and field assistance. T. O'Neil was instrumental to the success of this project, and K. Laudon provided invaluable field assistance. T. Maan provided statistical services; M. Wing and G. White conducted numerous GIS - related tasks and spatial analyses, and C. Kiilsgaard oversaw the production of the LANDSAT classification. We thank F. T. van Manen, F. G. Lindzey, and J. Ratti for review of the manuscript and helpful comments.

Literature Cited

Ackerman, B., F. Leban, M. Samuel, and E. Gorton. 1990. User's manual for HOMERANGE. Forest Wildlife and Range Experiment Station, University of Idaho, Moscow, Idaho, USA.

Baldwin, J., and J. Kie. 1992. Program CALHOME. U.S. Forest Service Science Laboratory, unpublished, Fresno, California, USA.

Barber, K. R. 1983. Use of clearcut habitats by black bears in the Pacific Northwest. M.S. Thesis, Utah State University, Logan, Utah.

Beecham, J. J. 1983. Population characteristics of black bears in west-central Idaho. Journal of Wildlife Management 47:405-412.

Brown, E. R., editor. 1985. Management of wildlife and fish habitats in the forests of western Oregon and Washington, volume 1. USDA Forest Service. Pacific Northwest Region, Portland, Oregon, USA.

Byers, C. R., R. K. Steinhorst, and P. R. Krausman. 1984. Clarification of a technique for analysis of utilization-availability data. Journal of Wildlife Management 48:1050-1053.

Cox, D. R., and D. V. Hinkley. 1974. Theoretical statistics. Chapman and Hall, London, UK.

Flowers, R. 1977. The art and technique of snaring bears. Washington Forest Protection Association, Seattle, Washington, USA.

Franklin, J. F., and C. T. Dyrness. 1973. Natural vegetation of Oregon and Washington. USDA Forest Service General Technical Report PNW-8. Pacific Northwest Research Station, Portland, Oregon, USA.

Gibeau, M., and P. Paquet. 1991. Evaluation of Telazol for immobilization of black bears. Wildlife Society Bulletin 19:400-402.

Grenfell, W. O., and A. J. Brody. 1986. Black bear habitat use in the Tahoe National Forest, California. Proceedings of the International Conference for Bear Research and Management 6:65-72.

Hemstrom, M. A., S. E. Logan, and W. Pavlat. 1987. Plant association and management guide, Willamette National Forest. USDA Forest Service, Pacific Northwest Region Publication R6-ECOL 257 B-86. Portland, Oregon, USA.

Hunter, M. L. 1990. Wildlife, forests, and forestry: principles of managing forests for biodiversity. Prentice-Hall, Englewood Cliffs, New Jersey, USA.

Jenson, J. R. 1986. Introductory digital image processing: a remote sensing perspective. Prentice-Hall, Englewood Cliffs, New Jersey, USA.

Kelleyhouse, D. G. 1980. Habitat utilization by black bears in northern California. Proceedings of the International Conference for Bear Research and Management 4:221-227.

Lillesand, T. M., and R. W. Kiefer. 1979. Remote sensing and image interpretation. John Wiley and Sons, New York, New York, USA.

Lindzey, F. G., and E. C. Meslow. 1977. Home range and habitat use by black bears in southwestern Washington. Journal of Wildlife Management 41:413-425.

McCollum, M. T. 1973. Habitat utilization and movements of black bears in southwest Oregon. M.S. Thesis, Humboldt State University, Arcata, California, USA.

Mohr, C. O. 1947. Table of equivalent populations of North American small mammals. American Midland Naturalist 37:223-249.

Mollohan, C. 1989. Habitat use of an Arizona ponderosa-mixed conifer forest by female black bears. Western Journal of Applied Forestry 4:6-10.

Nams, V. O., and S. Boutin. 1991. What is wrong with error polygons? Journal of Wildlife Management 55:172-176.

Neu, C. W., C. R. Byers, and J. M. Peek. 1974. A technique for analysis of utilization availability data. Journal of Wildlife Management 38:541-545.

Novick, H. J., and G. R. Stewart. 1982. Home range and habitat preferences of black bears in the San Bernadino Mountains of southern California. California Department of Fish and Game 67:21-35.

Oregon Department of Fish and Wildlife. 1992. The Oregon black bear management plan. 1993-1998. Portland, Oregon, USA.

Pelchat, B. O., and R. L. Ruff. 1986. Habitat and spatial relationships of black bears in boreal mixedwood forest of Alberta. Proceedings of the International Conference for Bear Research and Management 6:81-92.

Poelker, R. J., and H. D. Hartwell. 1973. Black bear of Washington. Washington State Game Department Biological Bulletin Number 18. Olympia, Washington. USA.

Received 31 January 1999
Accepted 18 August 1999

Ramsey, F., M. McCracken, J. A. Crawford, and M. S. Drut. 1994. Case-control habitat association studies. Pages 189-209 *In* N. Lange (editor) Case studies in biometry. John Wiley and Sons, New York, New York, USA.

Reynolds, D. C., and J. J. Beecham. 1980. Home range activities and reproduction of black bears in west-central Idaho. Proceedings of the International Conference for Bear Research and Management 3:181-190.

Stoneberg, R., and C. Jonkel. 1966. Age determination of black bears' cementum layer. Journal of Wildlife Management 30:411-414.

Thomas, D. L. and Taylor, E. J. 1990. Study designs and tests for comparing resource use and availability. Journal of Wildlife Management 54:322-330.

Unsworth, J. W., J. J. Beecham, and L. R. Irby. 1989. Female black bear habitat use in west central Idaho. Journal of Wildlife Management 53: 668-673.

Vander Heyden, M. 1997. Female black bear habitat selection and home range ecology in the central Cascades of Oregon. M.S. Thesis, Oregon State University, Corvallis, Oregon, USA.

White, G. C., and R. A. Garrott. 1990. Analysis of wildlife radio -tracking data. Academic Press, San Diego, California, USA.

Young, D. D., and J. J. Beecham. 1986. Black bear habitat use at Priest Lake, Idaho. Proceedings of the International Conference for Bear Research and Management 6:73-80.