ARIZONA GAME AND FISH DEPARTMENT

RESEARCH BRANCH
TECHNICAL REPORT #4

BLACK BEAR HABITAT USE IN EAST-CENTRAL ARIZONA
A Final Report

ALBERT L. LeCOUNT
and JOSEPH C. YARCHIN
September 1990

FEDERAL AID IN WILDLIFE
RESTORATION PROJECT

Arizona Game and Fish Department Mission

To conserve, enhance, and restore Arizona's diverse wildlife resources and habitats through aggressive protection and management programs, and to provide wildlife resources and safe watercraft recreation for the enjoyment, appreciation, and use of present and future generations.

Arizona Game and Fish Department
Research Branch

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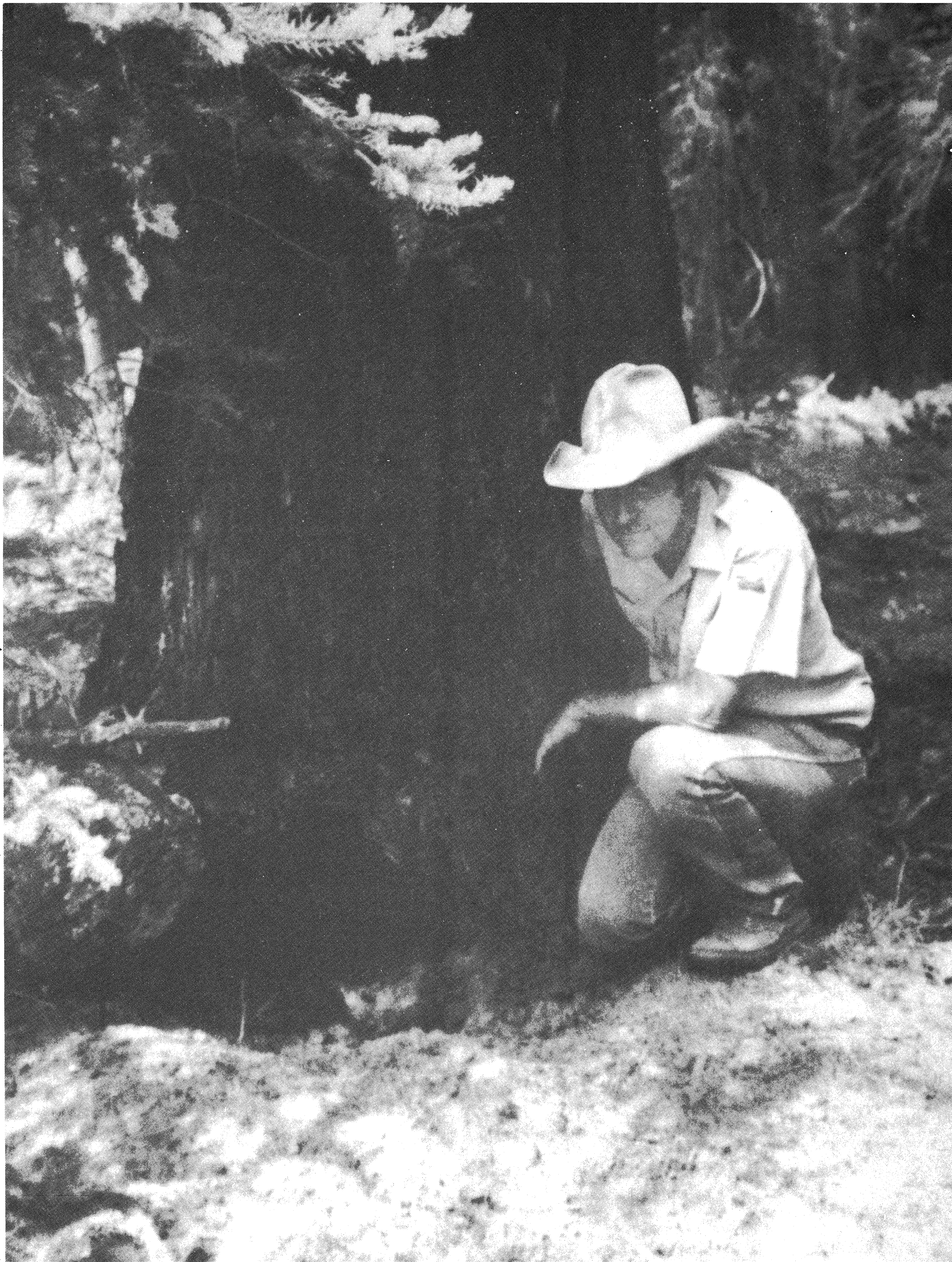


Black Bear Habitat Use In East-Central Arizona

Albert L. LeCount and Joseph C. Yarchin

Abstract: Black bears (*Ursus americanus*) in the White Mountains of east-central Arizona showed strong selection for unlogged, old-growth, mixed-conifer forest characterized by dense (>60%) multi-storied canopies, and understory cover that reduced bear visibility below 100 ft. Such sites usually were located on steep slopes (>20%), away from roads, where there was an abundance (>5 trees/acre) of large (>25-in dbh) standing trees, and a good component of decaying wood. Bears avoided meadows and ponderosa pine areas unless the latter structurally resembled mixed-conifer forest. They also avoided logged areas, especially where canopy cover was reduced below 40% and horizontal visibility exceeded 100 ft. Use of logged areas was restricted to areas that were selectively cut 10 years before the study, with no use recorded in areas intensively logged during the past 10 years, or clearcut during the past 25 years. Many cuts made in the mixed-conifer and spruce/fir portions of the study area during the past 10 years structurally resembled clearcuts more than selective cuts; therefore, it was believed that if the trend in intensive, high-volume, even-aged logging were not altered, a decline in bear numbers because of loss of habitat would occur during the next decade. Uneven-aged management systems appeared superior to even-aged management in meeting bear habitat needs and may help prevent this decline from occurring. Timber management options designed to maintain or enhance black bear habitat are presented.

INTRODUCTION

During the past 25 years Arizona's human population has increased from 750,000 people to approximately 3.5 million, and projections indicate that it will exceed 5 million by the year 2,000 (Valley National Bank 1987). This human population growth could have direct effects on bear populations through increased harvest by hunters, but as Jonkel and Cowan (1971) found, black bears are long lived and population numbers vary little under proper hunting management. A more important recognized factor of increased human population growth is its indirect effect on bears. As human populations grow, increased recreational activities and demands for natural resources such as timber, minerals, and water affect bears and bear habitat (Pelton and Nichols 1973, Lindzey et al. 1976, McCaffrey et al. 1976, Rogers 1976, Rogers et al. 1976, Pelton and Marcum 1977, Mollohan and LeCount 1989).

In Arizona, black bears occupy approximately 10,000 square miles of habitat on non-Indian lands, of which 90% is administered by the United States Forest Service (Arizona Game and Fish Dept. 1987). The Arizona Game and Fish Department stated as one of its major goals in its 5-year Big Game Strategic Plan for black bear management: "to maintain or improve the habitat through cooperation with land managing agencies and private land owners." More specifically, the plan directs Department management and research to "identify critical habitats for bear populations and ensure protection and improve where necessary through cooperation with land managing agencies" (Arizona Game and Fish Dept. 1987).

Cooperation is achieved by the U.S. Forest Service formally recognizing the goals and objectives of the Department's Strategic Plan within individual National Forest Land and Resource Management Plans (Forest Plans). These Forest Plans call for more knowledge of species requirements and for the improvement of habitat quality and diversity. However, to meet both National Forest planning and Game and Fish Department Strategic Plan objectives, the black bear's food, cover, and spatial requirements must be determined.

Studies dealing with habitat use by black bears have been conducted in other parts of the United States (Jonkel and Cowan 1971, Pelton and Nichols 1973, Amstrup and Beecham 1976, Lindzey et al. 1976, McCaffrey et al. 1976, Rogers 1976, Rogers et al. 1976, Pelton and Marcum 1977, Hugie 1982, Young and Ruff 1982, Unsworth 1984, Pelchat and Ruff 1986, Young and Beecham 1986, Brody and Stone 1987). Little of this information relates directly to bears in the Southwest because these studies were conducted in habitats that were vegetatively and topographically different from those found in southwestern forests.

This relative lack of habitat information for southwestern bears led to a study in central Arizona in 1974. Data were collected on habitat characteristics and requirements of a bear population inhabiting desert scrub, chaparral, and oak/woodland vegetation types (LeCount et al. 1984). This information benefited managers responsible for black bear habitat throughout the central part of the state.

In 1980 a second study was initiated to collect information on habitat requirements of black bears in the ponderosa pine and mixed-conifer forests along the Mogollon Rim region of north-central Arizona (Mollohan 1987a, Mollohan et al. 1989, Mollohan and LeCount 1989). This study provided data for wildlife managers working in pine and mixed-conifer habitats throughout north-central Arizona.

The results of these two habitat studies were of limited value to wildlife managers responsible for bear management in the pine, mixed-conifer, and spruce/fir areas of east-central Arizona. These habitats, and the factors affecting them, are quite different from the areas previously studied. Because of higher elevations, the spruce/fir habitat type is found in conjunction with pine and mixed-conifer areas, which give bears different options for habitat use. Terrain is also steeper and more rugged in east-central Arizona than in the coniferous forests along the Mogollon Rim. Because of this topography, habitat manipulations such as patchcutting (clearcut) and steep-slope cable logging, not common in areas previously studied, are applied.

Because of these differences, wildlife managers in east-central Arizona needed bear habitat use information specific to their portion of the state if they were going to properly manage bear habitat. In 1987, a third black bear habitat study was initiated. The objective of this study was to determine habitat requirements of black bears in the mixed-conifer and spruce/fir habitats of the White Mountains of east-central Arizona. This report gives the results of this study and provides managers with habitat management guidelines for similar habitat throughout east-central Arizona and west-central New Mexico.

STUDY AREA

The eighty-seven square mile study area was located in the White Mountains of east-central Arizona near the Arizona–New Mexico border (Fig. 1). Topography was composed of steep slopes and deep canyons with elevations ranging from 6,800 to 9,300 ft.

Precipitation occurred in a summer/winter pattern. Weather records from the nearest permanent weather station, Alpine, Arizona, showed that about half the average annual total of 19.3 in of moisture fell from July through mid-September in the form of afternoon thundershowers. Most of the remaining moisture occurred from November through March in the form of snow as winter storm fronts moved eastward across Arizona. Snow accumulations reached several feet in depth at higher elevations, and temperatures ranged from summer highs of 70 to 80 F, to winter lows of approximately 10 F (Sellers et al. 1985).

Vegetation on the study area was dominated by Rocky Mountain Montane Conifer Forest and the Rocky Mountain Subalpine Conifer Forest plant communities (Brown et al. 1979). Several vegetation associations occurred within each of these communities. The most abundant vegetation associations were mixed-conifer, which was dominated by varying amounts of Douglas fir *(Pseudotsuga menziesii)*, white fir (*Abies concolor*), and blue spruce (*Picea pungens*). These associations occurred between 8,000 and 9,000 ft, and dominated the study area. Elevations below approximately 8,000 ft were covered by ponderosa pine associations dominated by ponderosa pine (*Pinus ponderosa*), and areas above approximately 9,000 ft were characterized by spruce/fir forest dominated by Engelmann spruce (*Picea engelmannii*) and subalpine fir (*Abies lasiocarpa*). Gambel oak (*Quercus gambelii*) was found throughout the ponderosa pine and lower elevation mixed-conifer areas, and aspen (*Populus tremuloides*) occurred in the higher mixed-conifer and

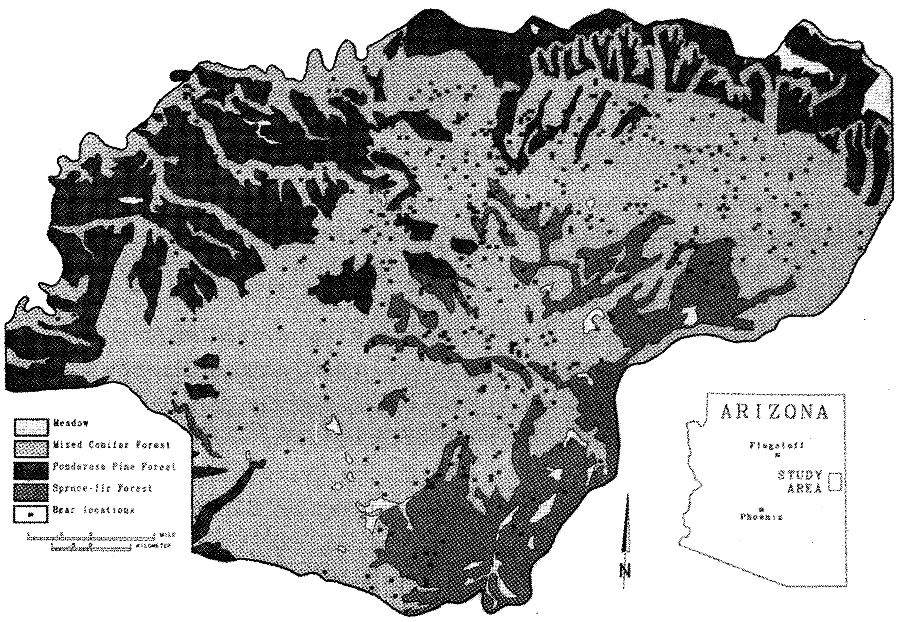


Figure 1.
GIS generated map showing four vegetation types and female black bear locations within the White Mountain study area, Arizona, 1987–89.

spruce/fir zones. Scattered throughout all vegetation communities were small wet meadows, locally known as "cienegas."

The entire study area was located within the Apache Sitgreaves National Forest, which covers a major portion of the watershed providing water to the Phoenix metropolitan area (Salt and Gila Rivers). Major land uses included timber production, livestock grazing, and recreation. Timber harvest and livestock grazing occurred throughout the spring, summer, and fall, and recreation throughout the year.

METHODS

Capture and Telemetry

Ninety-four individual black bears (54 M, 40 F) were captured as part of a companion population characteristics study on the White Mountain study area between July 1986 and August 1989 (LeCount 1990). Thirty-three animals greater than 1 year of age (11 M, 22 F) were fitted with radio collars, and 16 (4 M, 12 F) adult (>3 yr) resident animals were monitored for this study. Presence or absence of cubs was determined by visiting the winter dens of collared females. Twenty-six cubs (13 M, 13 F) were radio collared with "breakaway" collars (LeCount 1987) during these den visits.

Bear use sites were identified to the "microsite" level by ground-locating radio collared females at various times of the day during each week bears were not denned. Females were approached as close as possible without disturbing them and were either visually observed or located as precisely as possible. To obtain precise nonvisual locations, the radio tracker would take numerous radio location points while attempting to complete a 360-degree circle around the bear. Once located as precisely as possible, the site was marked and the bear was left undisturbed until it departed the area. After the bear's departure, the site was gridded for sign to verify the radio location. If fresh bedding or feeding sign were not found, the site was not sampled. Based on sign, sites were classified as feeding or bedding. Den sites were marked during winter visits to allow vegetation and topographic sampling the following summer.

Vegetation Type Comparisons

US Forest Service Terrestrial Ecosystem Survey maps (TES) were used to identify various vegetation types on the study area. Boundaries of vegetation types (meadow, ponderosa pine, mixed-conifer, spruce/fir) were entered into the Geographical Information System (GIS), and area of each type was calculated. These vegetation maps were validated on the ground using data from randomly selected sites.

Control sites were randomly selected throughout the study area by computer generated random Universal Transverse Mercator (UTM) coordinates. These sites were plotted on USGS 7.5 minute topographic maps of the study area, located on the ground, and sampled during the same time period as actual bear use sites.

An array of vegetation and physiographic variables were measured at each random control site to characterize vegetation types. Comparisons of vegetation structure were made both among random sites (ponderosa pine, mixed-conifer, spruce/fir), among bear use sites, and between random and used sites.

Habitat Selection

Site Measurements. Bear use sites were measured as soon as possible after the bear departed. The bed, feeding sign, or den was used as the center of a vegetation inventory plot. Sites were classified by vegetation type or association based on Moir and Ludwig (1979). Aspect (recorded in degrees) was measured with a compass, and percent slope with a clinometer. Timber structural stages (RO3WILD Wildlife-Habitat Relationships Model; Byford et al. 1984) were recorded at each site. Logging activity was classified as to type of treatment and approximate time span since logging occurred. Distance to nearest water was estimated using USGS 7.5 minute topographic maps. Site location in relation to topography (ridge top, canyon wall, canyon bottom, etc.) was recorded at each site. Bear forage plants on the site were identified and phenologically described according to West and Wein (1971).

A 100-ft line intercept transect, with the 50-ft mark located at the center of the plot, was established at each site. This line intercept was run at three height levels (<1 ft, 1–6 ft, and >6 ft). Grasses, forbs, and shrubs were not identified to species, and trees were only identified as coniferous or deciduous. All vegetation, rocks, and litter were measured and percent cover of each category was calculated at each height level.

A 1/20 acre circular plot was used to obtain densities of trees and shrubs per acre, and a 1/100 acre plot was used to determine conifer and deciduous trees per acre. Total overstory vegetative cover (canopy closure) was determined by averaging four densiometer readings taken in four cardinal directions on the perimeter of the 1/20 acre plot.

Horizontal visibility was measured as the distance in feet at which 90% of an average size black bear would be hidden from view. A cloth silhouette of an average size Arizona black bear was placed in the center of the plot. An observer walked in each cardinal direction until 90% of the bear silhouette was obscured from view. The four distances were then measured and averaged for each site (LeCount et al. 1984). Averages of horizontal visibility distances for each site were combined by vegetation type to obtain a mean horizontal visibility distance for ponderosa pine, mixed-conifer, and spruce/fir sites.

The same data collected on actual bear use sites were also collected on the set of random control sites. The proportion of bear observations occurring in each habitat category defined the degree of habitat use. The proportion of random control sites occurring in each habitat category defined availability of those habitat components.

Statistical Analysis. The chi-square (χ^2) goodness-of-fit test (Zar 1974) was used to test differences between availability and observed use of vegetation types (meadow, ponderosa pine, mixed-conifer, spruce/fir), physiographic characteristics (landform, percent slope, slope position, distance to water, distance to roads, etc.), and vegetative characteristics (canopy structure, percent canopy cover, logging history, etc.). If the null hypothesis was rejected, preference or avoidance of each component was tested by applying a modified "z" statistic (Marcum and Loftsgaarden 1980). A habitat component was "selected for" if it was used significantly more than expected based on availability data; a habitat component was "selected against" if it was used significantly less than expected. For each habitat component analysis, information from all bears initially was pooled, then females with and without cubs were tested separately to determine if selection differed based on presence of cubs. Selection of habitat components was also tested separately for feeding, bedding, and denning sites. Statistical significance was judged at $P \leq 0.05$ and $P \leq 0.1$ for the χ^2 and modified "z", respectively.

The Kruskal-Wallis analysis of variance by ranks test was used to test differences in components measured at each use site between feeding sites, bed sites, den sites, and cub presence or absence. The Mann-Whitney test was used to detect differences at each activity (feeding, bedding, denning) by presence or absence of cubs. The latter was also used to determine differences between use sites and random sites.

Differences in line intercept and horizontal cover measurements between vegetation types, activities, and females with and without cubs was tested using Tukey's multiple comparisons procedure. The Tukey test was used as a control for experiment-wise error and unequal cell sizes (SAS Institute Inc. 1982). For the Kruskal-Wallis, Mann-Whitney, and Tukey tests, significance was judged at $P \leq 0.05$.

Diet

Bear diets were determined by examining fresh scats collected throughout the study area. Scats were collected randomly by field personnel in conjunction with other field work. As scats were collected, date and location were recorded. All droppings were then frozen and analyzed during winter.

For analysis, scats were separated by month collected, thawed, and washed through a No. 30 mesh sieve. Food items were sorted, identified, and percent composition was determined volumetrically. Mean monthly use of major food items was calculated by averaging the percent composition of each food type per scat, by month of collection.

Frequency of occurrence of each species found was also recorded. Frequency of occurrence, percent volume, and number of years each food type was consumed were used to calculate an overall Importance Value (I) for each food type (LeCount et al. 1984).

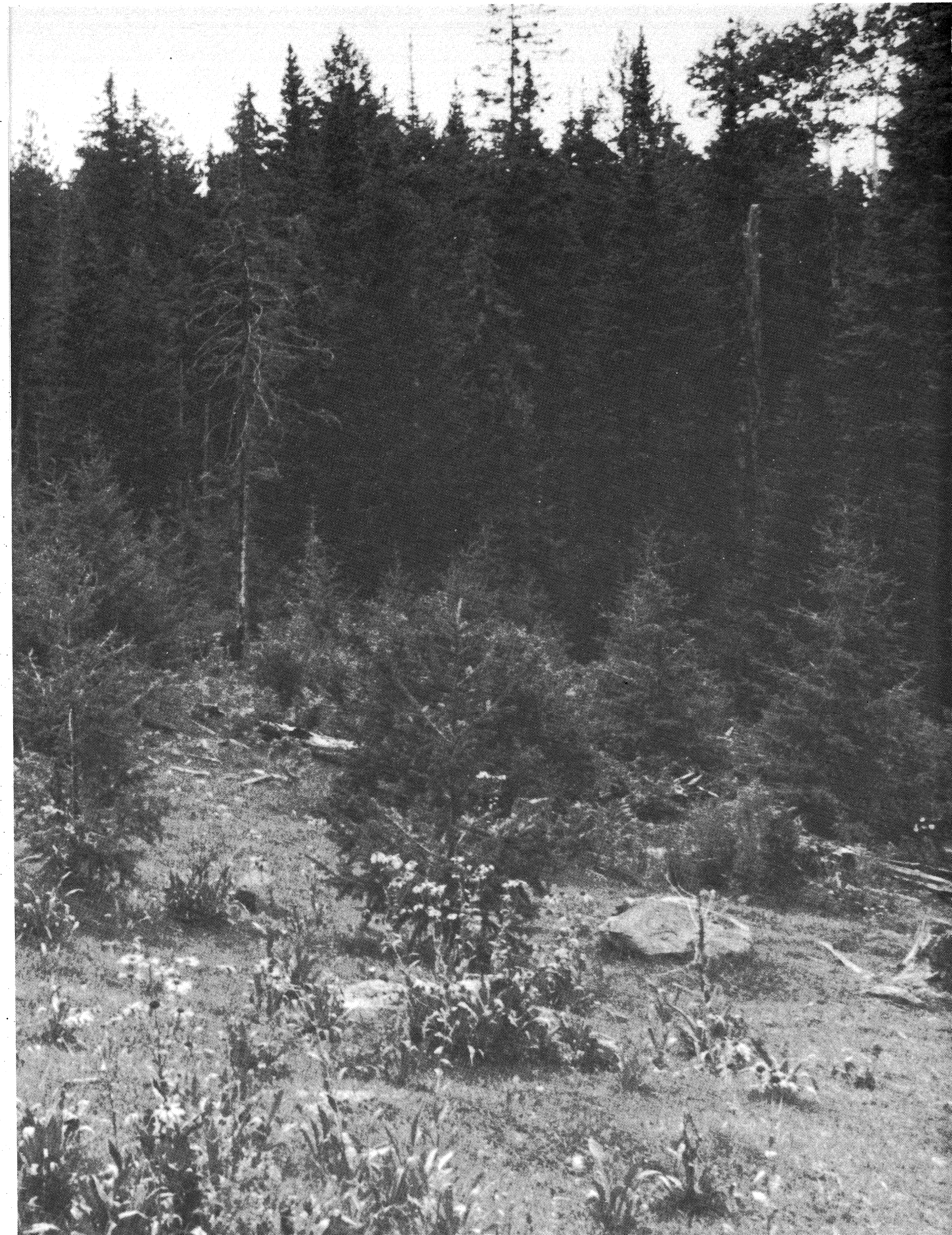
Home Range and Movements

Radio locations of adults obtained from weekly flights were used to obtain home range and movement information. Locations were plotted on USGS 7.5 minute topographic maps using the UTM coordinate system. All coordinates were entered into a computer program adapted from Koeln (1983) that calculated home range size using the minimum convex polygon method (Mohr 1947). Typical and atypical fall movements of individual bears were determined by measuring distances to locations outside of the approximate centers of their spring and summer use areas.

Human Activities

Timber Harvest. In addition to the logging activity data collected at each random and actual bear use site, information was collected from throughout the study area to evaluate the effects of timber harvest on bear use. While performing other duties, field personnel visited areas cut under various timber management techniques and time periods. These areas were inspected for evidence of bear use, and the same logging-related information that was gathered at random and use sites was collected.

Roads. Road systems on the study area were entered into a GIS from US Forest Service Transportation maps. Roads digitized included collector, arterial, and terminal roads. Two zones (0–600 ft, >600 ft) were delineated around each road with the GIS. All ground and aerial locations, plus random sites, were plotted within each 600-ft zone. Because most ground locations involved obtaining initial radio contact from roads, to avoid possible bias, only aerial locations were used to analyze the relationship between bear use and distance to roads. These aerial locations were made at midmorning when ground radio tracking indicated most bears were bedded.



RESULTS

Information from the 12 radio collared females was used for habitat selection analysis. These 12 bears represented most of the adult female population on the study area (LeCount 1990). Home ranges of these females were distributed throughout the study area, and all vegetation types were used (Fig. 1). Information was obtained from 129 use sites. Sixty-two of these sites were of females with cubs-of-the-year. Of the 129 use sites, 89 were feeding sites, 22 were beds, and 18 were dens.

Data were collected at 118 random sites throughout the study area. These data were then compared with data from actual use sites for analysis. The area of different vegetation types found on the study area was similar between the TES maps and ground locations; amounts differed by only 1–3%. Therefore, the sample size of random sites is believed to be adequate, and the chi-square statistic is appropriate (Thomas and Taylor 1990).

Vegetation Type Comparisons

Some differences in the amount of vegetation cover and the degree of slope were noted between the ponderosa pine, mixed-conifer, and spruce/fir vegetation types on the study area (Fig. 2). Available ponderosa pine sites

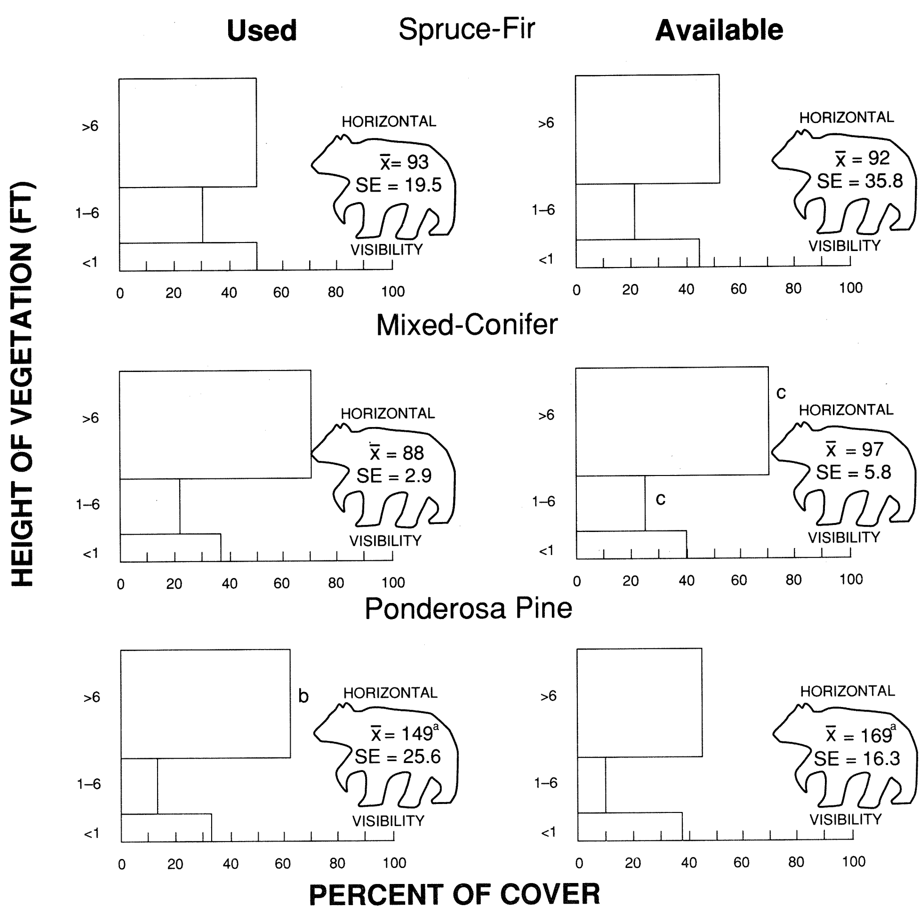


Figure 2.
Percent vegetation cover at three height categories, and horizontal visibility (ft) of female black bear use sites and available sites in the White Mountains, Arizona, 1987–89. Cover measured less than 6 ft may include rock and dead and down material.

[a] Significantly different from mixed-conifer and spruce/fir ($P \leq 0.05$).
[b] Significantly different from available ($P \leq 0.05$).
[c] Significantly different from available ponderosa pine ($P \leq 0.05$).

had significantly less cover above 1 ft than available mixed-conifer sites. Horizontal visibility was significantly greater in both available and used ponderosa pine areas than available and used mixed-conifer and spruce/fir sites, which is indicative of the relative openness of ponderosa pine areas. There were no differences in cover at any height class in use sites between ponderosa pine, mixed-conifer, and spruce/fir. All mixed-conifer sites were generally, but not significantly, steeper than pine sites (35% slope and 23% slope, respectively).

Habitat Selection

Generally, aspect and clumped or even under- and overstories were all used in proportion to availability by all bears, for all activities (Tables 1, 2). All bears selected against single- and double-storied canopies. Bears preferred old-growth forests (USDA Forest Service 1987) and selected it for all activities except feeding. Seedling/sapling and grass/forb structural stages also were avoided by all bears, for all activities. No significant differences were detected in the mean number of forage plants at feeding (3.4 plants), bed (3.1), or den (3.2) sites. All bear use sites were significantly closer (P = 0.03) to water than available. However, there was no difference in distance to water between feeding, bed, or den sites (overall $\bar{x}$ distance = 0.15 mi).

Vegetation. Use versus availability data were tested by vegetation type (meadow,

Table 1. Comparison of observed balck bear habitat utilization (actual proportion of usage) and expected (proportion available on study area) for parameters at White Mountains, Arizona 197-89.

	ALL BEARS		WITH CUBS		WITHOUT CUBS		FEEDING		BED		DEN	
VEG TYPE:	OBS[a] n=129	Exp[b] n-115	OBS n=62	Exp n=114	OBS n=64	Exp n=115	OBS n=89	Exp n=114	OBS n=22	Exp n=115	OBS n=18	Exp n=114
Meadow	**0**[c]	.042	**0**	.042	**0**	.042	**0**	.042	**0**	.042	**0**	.042
Spuce-Fir	**.048**	.158	**.066**	.158	**.030**	.158	**.045**	.158	.091	.158	**0**	.158
Ponderosa Pine	**.071**	.193	**.033**	.193	**.104**	.193	**.090**	.143	**0**	.193	.067	.193
Mixed-conifer	**.881**	.643	**.902**	.649	**.836**	.643	**.865**	.643	**.909**	.643	.778	.699
LANDFORM:												
Canyon Bottom	.047	.061	**0**	.061	.090	.061	.045	.061	.045	.061	.050	.061
Canyon Wall	**.558**	.357	.484	.357	**.627**	.357	.506	.357	.591	.357	**.778**	.357
Draw	.209	.209	.277	.209	.149	.209	.191	.209	.318	.209	.167	.209
Ridgetop	.163	.173	.210	.173	.119	.173	.225	.170	**.045**	.173	**0**	.173
Bench	**.023**	.165	**.032**	.165	**.015**	.165	**.034**	.165	**0**	.165	**0**	.165
Meadow	0	.036	0	.036	0	.036	0	.036	0	.036	0	.036
% SLOPE:												
0-19	**.287**	.426	.403	.426	**.179**	.426	.393	.426	**.091**	.426	**0**	.426
20-39	.333	.278	.341	.278	.299	.278	.351	.278	.409	.278	**.056**	.278
40-59	.271	.226	.195	.226	**.388**	.226	.213	.226	.364	.226	.444	.226
>60	.109	.071	.061	.071	.134	.070	.043	.071	.136	.070	**.500**	.070
POSITION ON SLOPE:												
Upper 1/3	.519	.539	.484	.538	.578	.539	.506	.539	.455	.539	.587	.539
Mid 1/3	.279	.183	**.371**	.183	.194	.183	.258	.183	**.409**	.183	.222	.183
Lower 1/3	.202	.278	**.145**	.278	.228	.278	.236	.278	.136	.278	.191	.278
DISTANCE TO ROADS: [d]												
0-600 ft.	**.341**	.699										
>600 ft.	**.659**	.321										

Table 1. (continued)

	ALL BEARS		WITH CUBS		WITHOUT CUBS		FEEDING		BED		DEN	
CANOPY:	OBS[a] n=129	Exp[b] n=115	OBS n=62	Exp n=114	OBS n=64	Exp n=115	OBS n=89	Exp n=114	OBS n=22	Exp n=115	OBS n=18	Exp n=114
Single	**.008**	.052	0	.052	.015	.052	.011	.052	0	.052	0	.052
Double	**.008**	.052	0	.052	.015	.052	.011	.052	0	.052	0	.052
Multi-Storied	.194	.187	.194	.187	.194	.187	.177	.187	.208	.189	.201	.187
Uneven Aged	.790	.708	.806	.708	.776	.708	.801	.708	.792	.708	.799	.708
% CANOPY COVER:												
0-39	**.031**	.174	**.032**	.174	**.003**	.174	**.045**	.174	**0**	.174	.100	.174
40-59	.333	.322	.323	.322	.353	.322	.404	.322	**.091**	.322	.276	.322
>60	**.636**	.504	.645	.504	.627	.504	.551	.504	**.909**	.504	.622	.504
LOGGING HISTORY:												
Logged	**.341**	.565	.484	.565	**.209**	.565	.438	.565	**.227**	.565	**0**	.565
Unlogged	**.659**	.435	.516	.435	**.791**	.435	.562	.435	**.773**	.435	**1.0**	.435
RO3WILD:[e]												
Grass/Forb	No random or use sites											
Seedling/Sapling	**.008**	.118	**0**	.118	**.015**	.118	**.011**	.118	**0**	.118	**0**	.118
Pole timber 5-11.9 dbh	.217	.345	.274	.345	**.164**	.345	.281	.345	**.091**	.345	**.056**	.345
Immature Saw Timber 12-15 dbh	.140	.118	.145	.118	.134	.118	.169	.118	.136	.118	**0**	.118
Mature Saw Timber >15 dbh	.047	.073	.081	.073	.015	.073	.056	.073	**0**	.073	**.056**	.073
Old-growth	**.589**	.345	.500	.345	**.672**	.345	.483	.345	**.773**	.345	**.889**	.345

[a]Observed
[b]Expected
[c]Bold figures represent observed values significantly ($P \leq 0.1$) different than expected (see Methods, Tables 2, 3, 4)
[d]Only data from aerial locations (see Methods) n=336
[e]Modified after Byford et al. (1984)

ponderosa pine, mixed-conifer, spruce/fir) for all bears, bears with and without cubs, feeding sites, bed sites, and den sites. Significant differences were noted for all bear and site categories (Tables 1, 3). Overall, bears selected against ponderosa pine and meadows, and for mixed-conifer areas. No use sites were found in meadows, and only 7% were found in pine, although it included 19% of the vegetation on the study area. The majority of the study area was mixed-conifer (64%). Eighty-eight percent of the use sites were found in this vegetation type. Spruce/fir made up 15% of the study area but only 5% of the use sites occurred in this type.

There were significant differences between use and availability of vegetation types for feeding, bed, and den sites (Tables 1, 3). Bears selected for mixed-conifer and against pine areas for feeding and bedding. Females, whether with or without cubs, also selected for mixed-conifer and against ponderosa pine areas. There was no apparent selection for vegetation types for denning, but the majority of dens (78%) were found in mixed-conifer.

Physiography. Many significant differences between use and availability of physiographic characteristics were found (Tables 1, 4). Bears selected against benches for feeding, beds, and dens. Females without cubs also avoided benches. Canyon walls were selected by females for denning, and also if they were not accompanied by cubs. If females had cubs, selection against canyon bottoms occurred. Ridgetops were avoided for use as bed and den sites.

Significant differences in use versus availability of different slope classes were recorded (Tables 1, 4). Zero to 19% slopes were avoided by bears without cubs and for bed and den sites. Bears with cubs used 0–19% slopes in proportion to availability. Bears also used 0–19% slopes, as available, for feeding. If females did not have cubs, they selected for 40–59% slopes. In winter, females selected slopes that were >60% for denning.

Feeding Sites. Bears generally used habitat components as available for feeding sites (Tables 1, 2, 3). No use was documented in grass/forb areas, and all other structural stages of RO3WILD were used as available except for selection against seedling/sapling areas. Bears fed in areas that had significantly greater horizontal visibility (102 ft) than bed sites (73 ft) or den sites (68 ft) (Fig. 3), and also avoided canopy cover less than 40% (Tables 1, 2).

Bed Sites. Bears generally selected more dense cover and steeper terrain to bed in than for feeding. Beds sites had significantly more cover in canopies greater than 6 ft high than feeding or den sites (85%, 67%, and 57% cover, respectively) (Fig. 3). Areas used by bears for bedding also had significantly greater canopy cover (81%) than feeding sites (71%). Bears selected for areas with canopy cover >60%, and against canopies <40% for bedding (Tables 1, 2). Ninety-one percent of the bed sites had >60% canopy cover. Old-growth was selected for, whereas all other RO3WILD structural stages were avoided for bedding.

Table 2. Relative selection of vegetative characteristics by 12 female black bears in east-central Arizona, 1987-1989. A minus (-) indicates use less than available (P ≤ 0.1); an equal sign (=) indicates use as available; a plus (+) indicates use greater than available (P ≤ 0.1).

	ALL BEARS n=129	WITH CUBS n=62	W/O CUBS n=67	FEEDING n=89	BEDS n=22	DENS n=18
CANOPY:						
Single	-	=	=	=	=	=
Double	-	=	=	=	=	=
Multi-storied	=	=	=	=	=	=
Uneven-aged	=	=	=	=	=	=
% CANOPY COVER:						
0-39	-	-	-	-	-	=
40-59	=	=	=	=	-	=
>60	+	=	=	=	+	=
LOGGING HISTORY:						
Logged	-	=	-	=	-	-
Unlogged	+	=	+	=	+	+
RO3WILD[a]:						
Grass/Forb		No random or use sites				
Seedling/Sapling	-	-	-	-	-	-
Pole Timber 5-11.9 dbh	=	=	-	=	-	-
Immature Saw Timber 12-15 dbh	=	=	=	=	=	-
Mature Saw Timber >15 dbh	=	=	=	=	-	-
Oldgrowth	+	=	+	=	+	+

[a]Modified after Byford et al. (1984)

Table 3. Relative selection of four vegetation types by 12 female black bears in east-central Arizona, 1987-89. A minus (-) indicates use less than available (P ≤ 0.1); an equal sign (=) indicates use as available; a plus (+) indicates use greater than available (P ≤ 0.1).

	ALL BEARS n=129	WITH CUBS n=62	W/O CUBS n=67	FEEDING n=89	BEDS n=22	DENS n=18
Spruce-Fir	-	-	-	-	=	-
Ponderosa Pine	-	-	-	-	-	=
Mixed-conifer	+	+	+	+	+	=
Meadow	-	-	-	-	-	-

Seventy-seven percent of the bed sites were located in old-growth. Bears selected for the middle third of a slope for bedding (Tables 1, 4). Bed sites were located on significantly steeper slopes (41%) than feeding sites (26%).

Den Sites. Areas used by bears for denning were in steep, well-wooded areas. Dens in the White Mountains were located inside live trees, dug-out root systems, burn scars at the base of trees, rock outcrops, and in fallen, hollow trees. Of 18 dens, one-third were in upright trees ($\bar{x}$ dbh = 44.1 in). Bears appeared to show no preference for any canopy cover category for denning (Tables 1, 2). Old-growth was selected for, and all other RO3WILD structural stages were avoided for denning. Seventy-eight percent of the dens were in mixed-conifer, with 89% occurring in old-growth. Bears selected steep slopes for den sites (Tables 1, 4). Dens were found on significantly steeper slopes than bedding or feeding sites (58%, 41%, and 26% slope, respectively).

Table 4. Relative selection of physiographic characteristics by 12 female black bears in east-central Arizona, 1987-89. A minus(-) indicates use less than available (P ≤ 0.1); an equal sign (=) indicates use as available; a plus (+) indicates use greater than available (P ≤ 0.1).

	ALL BEARS n=129	WITH CUBS n=62	W/O CUBS n=67	FEEDING n=89	BEDS n=22	DENS n=18
LANDFORM:						
Canyon Bottom	=	-	=	=	=	=
Canyon Wall	+	=	+	=	=	+
Draw	=	=	=	=	=	=
Ridgetop	=	=	=	=	-	-
Bench	-	-	-	-	-	-
Meadow	=	=	=	=	=	=
% SLOPE:						
0-19	-	=	-	=	-	-
20-39	=	=	=	=	=	-
40-59	=	=	+	=	=	=
>60	=	=	=	=	=	+
POSITION ON SLOPE:						
Upper 1/3	=	=	=	=	=	=
Mid 1/3	=	+	=	=	+	=
Low 1/3	=	-	=	=	=	=
DISTANCE TO ROADS (ft.)[a]:						
0 to 600	-					
>600	+					

[a] Only data from aerial locations were used.

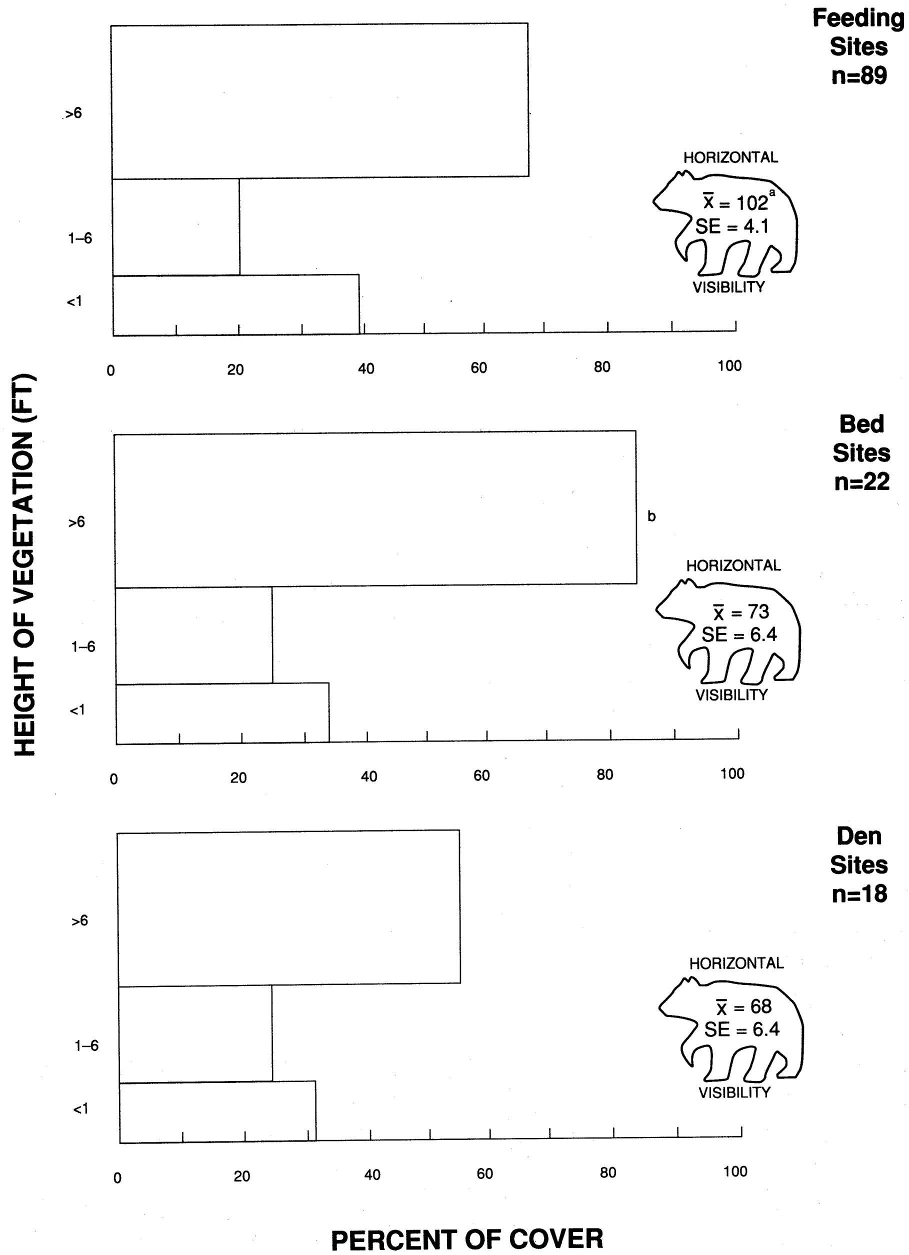


Figure 3.
Percent vegetation cover at three height categories, and horizontal visibility (ft) of female black bear use sites in the White Mountains, Arizona, 1987–89. Cover measured less than 6 ft may include rock and dead and down material.

[a] Significantly different from bed and den sites ($P \leq 0.05$).
[b] Significantly different from feeding and den sites ($P \leq 0.05$).

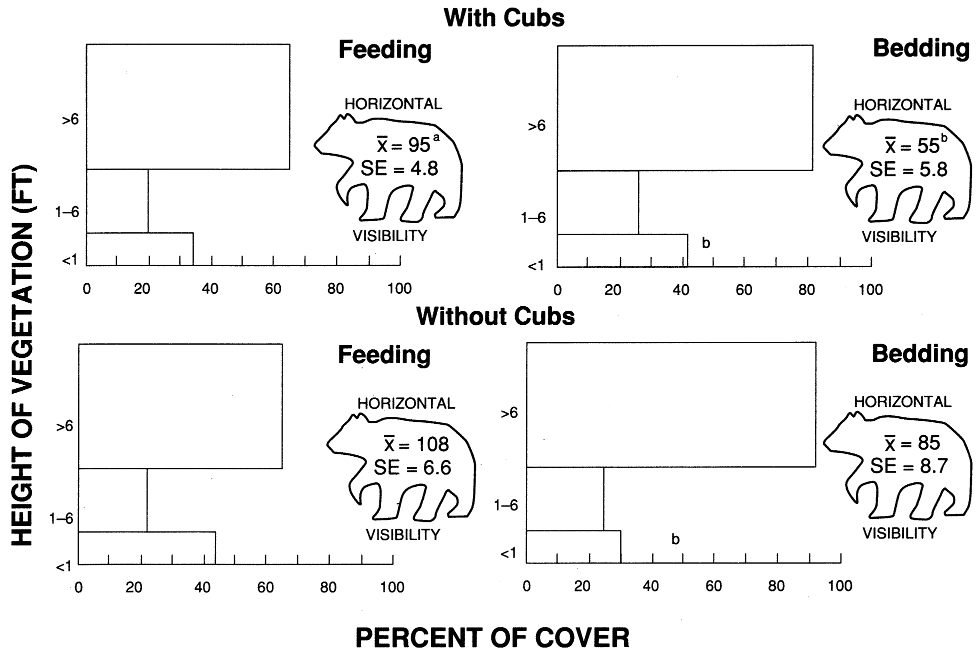


Figure 4.
Percent vegetation cover at three height categories, and horizontal visibility (ft) of female black bear feeding and bed sites when cubs were present or absent in the White Mountains, Arizona, 1987–89. Cover measured less than 6 ft may include rock and dead and down material.

[a] Significantly different from feeding sites without cubs ($P \leq 0.05$).
[b] Significantly different from bed sites without cubs ($P \leq 0.05$).

Females With and Without Cubs. Presence of cubs altered female selection for some site characteristics. The middle third of a slope was selected for, and the lower third was avoided, if cubs were present (Tables 1, 4). Generally, feeding sites of females with cubs present were less open than sites used by females without cubs. Females with cubs also avoided areas that had canopy cover less than 40% (Tables 1, 2). Half of the variables that were significantly different between females with or without cubs at feeding sites dealt with cover less than 6 ft high (total deciduous regeneration, shrub <1 ft, rock <1 ft, dead and down <1 ft, deciduous <1 ft, grass 1–6 ft, and deciduous 1–6 ft). Horizontal visibility was usually less at feeding sites when cubs were present ($\bar{x}$ = 95 ft) than when cubs were absent ($\bar{x}$ = 108 ft) (Fig. 4).

Female bed sites also appeared to be less open when cubs were present. Cover <1 ft high was significantly greater at beds when cubs were present, and horizontal visibility was significantly less ($\bar{x}$ = 55 ft versus $\bar{x}$ = 85 ft) (Fig. 4).

Diet

Seventy-six fresh scats were collected between May 1988 and September 1989. Analysis showed that grasses, insects, seeds, and vertebrates were eaten throughout the period of May to September (Fig. 5). Insects appeared in 88% of the scats, grasses in 51%, vertebrates in 21%, and seeds were in 17%. In this study, vegetable material did not exceed 65% of the total scat content while insects usually were >50% of the content (Fig. 5). Overall importance values (I) (LeCount et al. 1984) showed that insects were highest (I = 78.8) followed by grasses (I = 31.2), vertebrates (I = 11.9), and seeds (I = 5).

Some spring and summer patterns were apparent in food consumption (Fig.5). Grass consumption peaked in spring, decreased

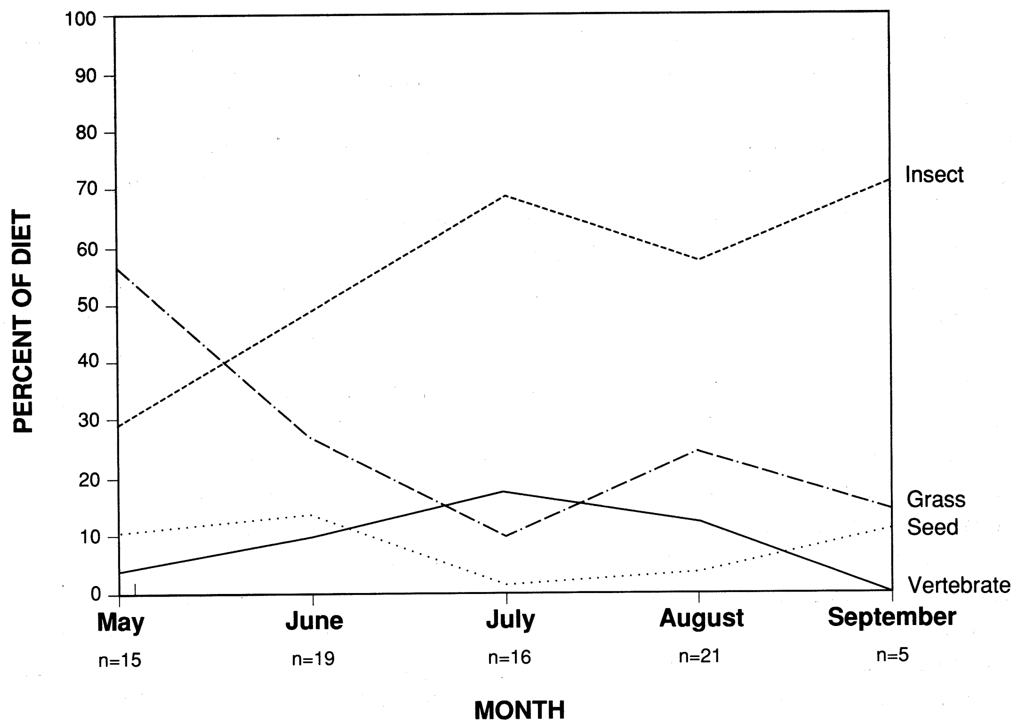


Figure 5.
Black bear mean monthly use of major food types in the White Mountains, Arizona, 1987–89 (n = 76).

during the dry, early summer, and increased again during the late summer wet season. As plant consumption decreased, animal consumption increased. Insects appeared to be the principal food for bears from June through September. Insects eaten included ants (Formicidae), bees (Apidae), wasps (Vespidae), and beetles (Tenebrionidae). Vertebrate consumption increased in June and July when young animals were most vulnerable. Vertebrate items consisted of rodents, cervids, birds, and bear. Seeds were consistently eaten, though in low quantities. The primary seeds eaten were acorns (*Quercus* sp.), squawroot (*Conopholis mexicana*), and gooseberry (*Ribes pinetorum*).

Some evidence of predation was found during this study. Cervid remains probably were obtained as carrion, but two instances of probable bear predation were observed. In August 1988 a bear was observed feeding on a freshly killed elk (*Cervus elaphus*). In July 1989, a female bear and two cubs were seen eating a freshly killed deer (*Odocoileus sp.*) fawn. Bird remains found in scats indicated that nestlings were eaten. Junco (*Junco sp.*) nests and other ground-nesting birds were observed throughout the study area, and bears probably encountered the ground nests while foraging. Most bear hair in the scat probably was due to the bears grooming themselves (LeCount et al. 1984); however, some scats and events implied predation. Scats collected at a cub mortality site in May of 1989 indicated that two cubs were killed and eaten by a bear. In June of 1989, examination of a bear carcass and the feeding behavior of bears indicated that an adult female was killed and eaten by a bear. No bovid remains were found in any scats, and no bear predation on cattle was observed or reported on the study area even though cattle were abundant.

Home Range and Movements

Data on 16 radio collared bears (4 M, 12 F) were used for home range analysis. Home range sizes were determined using aerial locations only. From July 1986 through August 1989 ($\bar{x}$ locations per bear = 49; range 14–76), 787 aerial locations were obtained. Home range size for females averaged 38.2 mi^2 (SD 17.9; range 15–67 mi^2); whereas, male home ranges were much larger, with an average of 209.2 mi^2 (SD 54.2; range 153–261 mi^2).

Most bears made seasonal movements off the study area. Males generally made more movements and moved greater distances than females. Male excursions averaged 21 mi (SD 2.8; range 17–24 mi) and females averaged 9 mi (SD 2.2; range 4–7 mi). These movements began in late July and August, with most bears returning to their general home range areas by late September. In 1989 atypical movements by two adult females were documented. These movements were abnormally long (40 and 55 mi), but were made within the time frame of normal seasonal movements.

Females with cubs had restricted movements from mid-April to mid-June. Movements, and areas of use, of females that lost cubs before June 15 increased rapidly following cub loss. Home ranges of females successfully rearing cubs gradually increased to the female's normal use area after June 15.

Human Activities

Timber Harvest. Bears generally selected for unlogged and avoided logged sites (Tables 1, 2). All dens were found in unlogged areas. Fifty-six percent of feeding sites also were found in unlogged areas, although both logged and unlogged sites were used as available. Bears selected for unlogged versus logged forest for bedding. Seventy-seven percent of beds were in unlogged areas. Eighty-six percent of beds were at the base of large trees ($\bar{x}$ dbh = 30.3 in). Only 2 of 19 trees used as beds were less than 25-in dbh. Sixty-eight percent of bed trees were >28-in dbh.

Females with cubs used logged and unlogged areas as available, whereas females without cubs selected for unlogged sites and avoided logged sites (Tables 1, 2). Seventy-nine percent of use sites without cubs were in unlogged areas, but only 51% of the sites with cubs were in unlogged forest.

Roads. Mapping roads showed that the study area contained 336 miles of road (Fig. 6). Road density averaged 2.4 mi/mi^2 (Range 0–9.5 mi/mi^2), with 85% of all sections containing roads. Analysis of aerial locations within the two delineated zones showed that bears avoided areas 0 to 600 ft from roads, and selected for areas >600 ft from roads (Tables 1, 2).

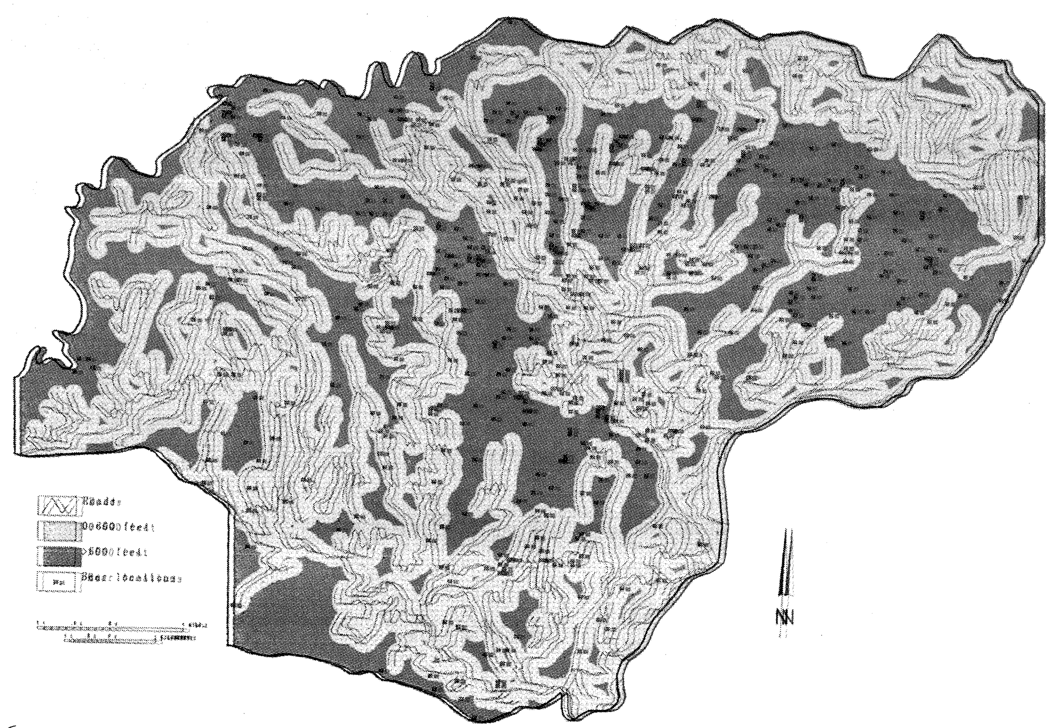


Figure 6.
GIS generated map showing two road zones and female black bear locations within the White Mountain study area, Arizona, 1987–89.

DISCUSSION

Habitat Selection

Food and cover have both been identified as factors strongly influencing black bear habitat selection. Reynolds and Beecham (1980) found that black bear habitat selection in west-central Idaho was related to food availability, as did Grenfell and Brody (1986) in California. Young and Beecham (1986) found a strong correlation between bear locations and phenology of key bear foods in northern Idaho and believed bears selected habitat types that provided the best available food and cover. Lindzey and Meslow (1977) found that black bears in Washington used only the edges of clearcuts that did not provide adequate cover, even though food was more abundant within the clearcuts. Similar observations were made in Idaho (Unsworth 1984). In north-central Arizona, Mollohan et al. (1989) felt that bears selected habitat on the basis of cover first, and food second. This study, in east-central Arizona, substantiates the findings of Mollohan et al. (1989). Adult female black bears appeared to actively select for certain vegetation types, physiographic features, and vegetative characteristics, with selection being related to cover requirements first, and food second.

When random ponderosa pine and mixed-conifer sites were compared, no differences were found in the number of forage plants available—a finding similar to Mollohan's (1987a) in north-central Arizona. Although numbers of insects and vertebrates were not measured, subjective observations of availability of these two food items while doing field work indicated that they appeared to be found in similar supplies in the two vegetation types. Therefore, bears appeared to have relatively equal food supplies in each vegetation type. The amount of horizontal and vertical visibility in each type, however, differed. Ponderosa pine had less cover, and horizontal visibility was much greater than in mixed-conifer (Figs. 2,7). These measurements reflect the more open growth pattern of ponderosa pine stands in the Southwest. The only ponderosa pine sites used by bears (9 of 129) were those that were structurally similar to mixed-conifer sites and, therefore, atypical of ponderosa pine in general (Fig. 2). Bears selected for canopy cover in excess of 60% (Tables 1, 2), and for horizontal visibility of approximately 100 ft or less for all purposes (feeding, bedding, denning) (Fig. 3). This need for thick cover probably explains why old-growth forest was selected for, and grass/forb meadows and seedling/sapling stands were avoided (Tables 1, 2). Black bears are not an obligate old-growth species, but on the study area the

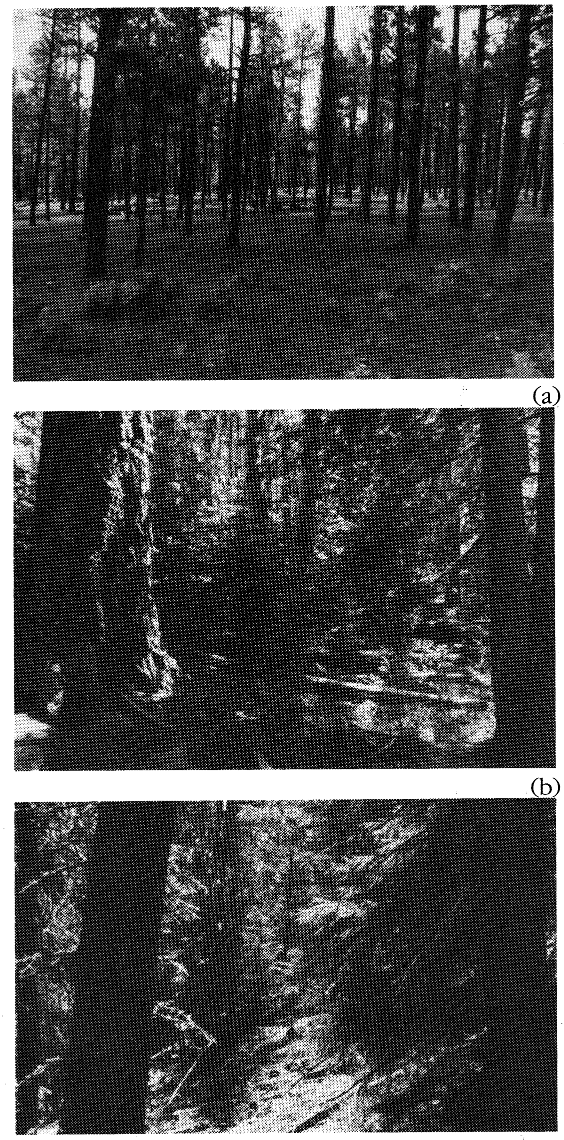

(a) (b) (c)

Figure 7.
Typical canopy cover and horizontal visibility in (a) ponderosa pine, (b) mixed-conifer, (c) and spruce/fir vegetation types on the White Mountain study area, Arizona, 1987–89.

greatest vertical and horizontal cover was found in old-growth sites.

Little use was found in spruce/fir (6 of 129 sites). We believe, however, that this lack of use is not a function of the vegetation type, but rather of the bears sampled. Spruce/fir has been found to be an important habitat component in other areas of North America (Jonkel and Cowan 1971, Young and Ruff 1982), and in the White Mountains of Arizona it varied little structurally from mixed-conifer (Figs 2, 7). Therefore, it appears that spruce/fir should have been used similarly to mixed-conifer. One possible reason that it was not, may have been related to the fact that the spruce/fir portion of the study area (Fig. 1) received heavy hunting pressure, before and during the study, because of its proximity to paved State Highway 666 and improved Forest Service Road 25. This hunting pressure may have eliminated many adult females (LeCount 1990) that had spruce/fir within their home ranges, leaving few animals to be captured and monitored for habitat use in these areas. A second reason might have been greater recreational use along these highly traveled roads. The number of vehicles traveling these roads per day was not determined, but our subjective observations indicated that it was much higher than elsewhere in the study area. More people were also observed parking their vehicles along these roads and hiking into the surrounding forest. This human activity within spruce/fir areas might also have discouraged some females from using this vegetation type. However, in the two instances of bears having undisturbed spruce/fir areas within their home ranges, use of this vegetation type was observed. In addition, the frequency of bear sign observed in spruce/fir areas was similar to that found in mixed-conifer, as was the number of males captured. If more adult females had been available for monitoring in spruce/fir areas, we believe we would have documented greater use of this vegetation type.

Bears also showed a preference for security in their selection of physiographic characteristics. Bears generally used steep slopes (>20%), except for some feeding activity, and when females were accompanied by cubs (Tables 1, 4). Beds rarely were found on slopes <20%, with steep canyon walls (>60%) being preferred for bedding and den sites. Similar use of steep timbered slopes for bedding and denning was found in north-central Arizona by Mollohan et al. (1989) and in west-central Idaho (Unsworth 1984).

Feeding Sites

In selecting sites for feeding, bears generally selected habitat in proportion to availability, as long as criteria for protective cover were met. Bears seemed reluctant to venture into areas where cover <6 ft high allowed them to be seen much over 100 ft (Fig. 3), and avoided grass/forb and seedling/sapling structural stage areas (Tables 1, 2). Sites that seemed to meet feeding criteria were found in both logged and unlogged areas, but it appeared that areas exhibiting canopy cover below 40%, and horizontal visibility much over 100 ft (Tables 1, 2, Fig. 3) were avoided. Mixed-conifer forests were important for feeding (Fig. 8). Eighty-five percent of the feeding sites were in mixed-conifer forest, and normally within 0.15 mi of water. Similar use of mixed-conifer for feeding was described by Mollohan et al. (1989) in coniferous forest areas of north-central Arizona.

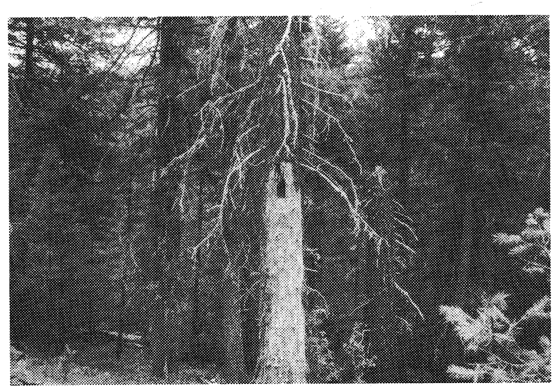


Figure 8.
Feeding site in mixed-conifer forest on the White Mountain study area, Arizona, showing bear feeding sign on tree and density of surrounding cover.

Bed Sites

Bed sites were quite different from feeding sites (Fig. 3). As found by Mollohan et al. (1989), bears generally selected steep terrain with thick cover for bedding. Bears bedded on canyon walls where slopes averaged 41% and selected for the middle one-third of the slope (Tables 1, 4). This portion of the slope provided the least disturbance because most human and bear activity occurred either along the ridge tops or canyon bottoms.

Areas chosen for bedding generally had over 80% canopy cover, and horizontal visibility averaged 73 ft (Figs. 3, 9). This vertical and horizontal cover represents significantly higher canopy cover and less horizontal visibility than that found at feeding sites, but is similar to bed sites described in north-central Arizona by Mollohan et al. (1989) and in Idaho (Young and Beecham 1986). This thick overstory provided dense shade at all bed sites suggesting that these sites may have been selected not only for the protective cover they provided, but also for thermal cover during the day.

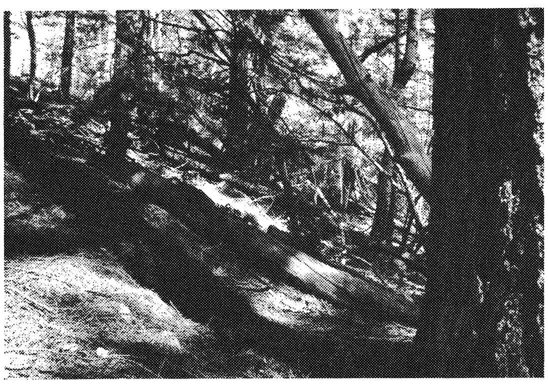


Figure 9.
Typical bed site at base of large tree in mixed-conifer forest on the White Mountain study area, Arizona, showing dense horizontal cover surrounding bed.

Large trees were found at 86% of all bedding sites (Fig. 9). As described by Mollohan et al. (1989) and Herrero (1983), bears prefer to bed at the base of large trees (>30-in dbh), thereby obtaining vertical and horizontal cover provided by the tree plus the protection that can be gained by climbing the tree in times of danger.

Because of the need for thick cover and large trees for bedding, only certain portions of the study area appeared to be suitable. Bears selected for unlogged, old-growth (Tables 1, 2), mixed-conifer forests (Table 3), with dense canopy cover (Fig. 3). The canopy cover above 6 ft was significantly greater at beds than at feeding or den sites (Fig. 3). This relatively thick cover provided a cool daytime resting environment. Beds occurred on slopes >60% and within 0.15 mi of water. Ridgetops and logged areas were avoided for bedding (Tables 1, 2, 3). The only logged areas used for bedding(5 of 22 sites) had been logged over 10 years before the study with group selection cuts that left a good component of trees in excess of 30-in dbh. Similar use of steep, thick, timbered sites for bedding has been described by other investigators (Unsworth 1984, Mollohan et al. 1989).

Den Sites

Most dens (78%) were found in mixed-conifer areas. Generally, den sites were on steep slopes (>60%) with canyon walls being selected most often (Tables 1, 4). A similar use of steep thick-forested areas for denning also has been reported by Johnson (1978), Beecham et al. (1983), LeCount (1983), Wathen et al. (1986), and Schwartz et al. (1987).

Large trees played an important role in den site selection. Some dens were found in association with rock outcroppings, but 61% of all dens were in association with large trees (Fig. 10). Some of these dens were in hollow logs or dug under the roots of fallen trees, but 55% of all tree dens were found in live standing trees that had an average dbh of 44.1 in. Dens in live trees were found either near the base of the tree, in hollow fire scars, or in natural cavities 20 to 30 ft above the ground. This preference for large trees for den sites probably explains why bears selected for old-growth forest and against all other structural stages and logged areas for denning (Tables 1, 2). Under recent past and current logging operations conducted on the study area, large mature trees have been targeted for cutting, primarily with overstory removal harvest. Trees in excess of 40-in dbh remain only in unlogged areas.

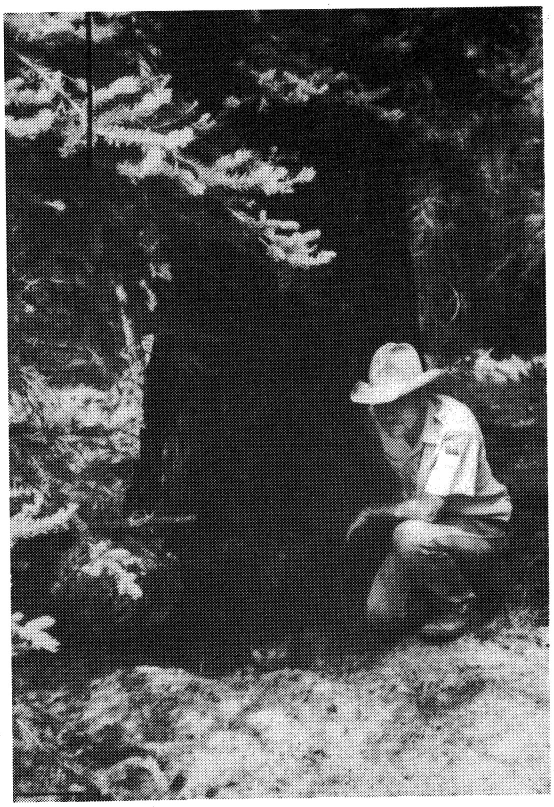


Figure 10.
Typical den site in a hollow fire scar at the base of a large (40+ in dbh) Douglas fir occupied by an adult female and two yearlings on the White Mountain study area, Arizona, 1989.

Females With and Without Cubs

Predation of black bear cubs by other bears appears to be a major cause of cub mortality on the study area, and elsewhere in Arizona (LeCount 1984, 1987, 1990). Therefore, females with cubs are not only faced with having to find nutrition for themselves and their offspring, but also they must find sites that provide cubs protection from other bears and disturbance by man. They appear to do this by selecting for thick timbered areas.

The presence of cubs significantly altered female habitat selection and use. Alt et al. (1980) found that movements of females accompanied by cubs were restricted when cubs were young and then, as they became older, gradually increased. We observed the same behavior with females staying near den sites when cubs were young and gradually expanding their movements as cubs became older. Females accompanied by cubs selected for the middle one-third of the slope and avoided areas near canyon bottoms, whereas females without cubs used slopes in proportion to their availability (Tables 1, 4). Such selection would appear to be beneficial in avoiding both humans and bear disturbance because most human travel was on roads along ridge tops, and bears typically travel along canyon bottoms.

Females with cubs selected the middle of slopes and specific microsites that provided more than the normal amount of cover, primarily in the <6-ft height level. Females with cubs used areas that provided thick cover near the ground. This cover reduced visibility (Fig. 4) making cubs more difficult to find.

Another feature important to females with cubs was the presence of large trees at bed sites. Herrero (1983) pointed out the importance of large trees to females with cubs for escape, protection, play, sleep, and relaxation, and Mollohan (1987b) discussed how crucial large trees were to females and their cubs for bed sites. In this study 86% of all beds were found in association with a large tree ($\bar{x}$ dbh = 30.3 in). When cubs were less than 6 months old, 100% of the beds were found in association with large trees. This is the time period when cubs are the most vulnerable to predation, and when the opportunity to climb a tree in time of danger would be the most advantageous (LeCount 1987, 1990).

Home Range and Movements

Home range, as applied to mammals is "that area traversed by the individual in its normal activities of food gathering, mating, and caring for young" (Burt 1943). Depending on the quality, quantity, and distribution of this food, home range sizes can vary greatly within various portions of a species range. Such variation in home ranges has been well documented for black bears throughout North America with extremes ranging from 1 to 36 mi^2 for females, and 2 to 67 mi^2 for males (Bunnell and Tait 1985). Home range sizes varied from 7 to 11 mi^2 for females and males, respectively, in a very diverse habitat in central Arizona (LeCount et al. 1984), to 40 to 235 mi^2 for females and males in less diverse habitat in north-central Arizona (Mollohan 1987a).

In this study home ranges of adult females averaged 38 mi^2, and males 209 mi^2. These home range sizes are larger than those found in central Arizona, but are similar to those found in other areas of northern Arizona. Also they are somewhat larger than for bears elsewhere in North America, but the 1:5.5 ratio of male to female home range size is similar to that found for most black bears (Bunnell and Tait 1985).

The similarity in home range sizes between the White Mountains and north-central Arizona appears to have been related to similarities in habitat. Both areas primarily were composed of coniferous forest habitat, with the majority of bear use in mixed-conifer forest where two to three forage plants were available to bears while they were on the site (Mollohan 1987a). This average number of forage plants is less than the six items per site found in central Arizona (LeCount et al. 1984), which supports some of the higher bear densities found in the state (LeCount 1990). In north-central Arizona, Mollohan (1987a) found that the coniferous forest habitat was not capable of supporting bears on a year-round basis because of the lack of late summer foods. As a result, every year most bears in north-central Arizona made seasonal movements off the Mogollon Rim to take advantage of hard and soft mast crops that developed at lower elevations (Mollohan 1987a). Similar seasonal movements by bears were observed in the White Mountains.

In late July and early August, both males and females began to move from the study area to lower elevation areas to the south and east. These movements ranged from 4 to 24 mi, with males generally moving farther than females ($\overline{x}$ = 21 and 9 mi, respectively). Several aerial observations, plus scats collected in these areas, indicated bears were taking advantage of juniper berries (*Juniperus sp.*) and acorns from lower elevation oak species (*Quercus sp.*) that did not grow on the study area. These are some of the same food items bears used after moving to lower elevations in north-central Arizona (Mollohan 1987a). Once located in these lower elevation areas, bears continued to feed on these food items until late September or early October, when they moved back to the study area to take advantage of gambel oak acorns that grew at higher elevations. Bears continued to feed on these acorns until they denned. Similar movements by bears to seasonal food supplies have also been reported by several authors (Jonkel and Cowan 1971, Piekielek and Burton 1975, Amstrup and Beecham 1976, Rogers 1977, Kellyhouse 1980, Garshelis and Pelton 1981, Young and Ruff 1982, Mollohan 1987a).

In addition to regular seasonal movements, atypical movements of black bears from the study area also were noted. From 1988–1989 a severe drought occurred in Arizona (Shaffer 1990). By early summer of 1989 abnormal behavior of closely monitored female bears began to indicate that because of this drought food supplies were becoming critically short. Female black bears are very attentive to their cubs (Rogers 1977). However, on four occasions locations of radio collared females with radio collared cubs indicated that mothers were separated from their cubs by several miles and were not located with them for up to 3 days at a time. It is suspected that this behavior was related to females spending more time foraging and, therefore, making more movements than the cubs were capable of making. Observations of these females also showed that rather than feeding for 3 to 4 hours each morning and evening, and bedding throughout most of the day, which was normal behavior for bears in this area, they were feeding almost continually throughout the day. When a bear did bed it was usually for 30 minutes or less and it then resumed foraging. The primary food item taken during this time was insects, which were obtained from under rocks and by tearing apart decaying stumps and logs.

By August, when normal movements to lower elevations took place, all monitored animals moved as usual but the movements of two adult females were abnormally long (40 and 55 mi). Subsequent observations showed that neither of these females had their cubs with them; however, by this time most cubs had lost their "break-away" radio collars and their location was unknown. All bears that moved off the study area returned in a normal manner in late September and October. Observations at winter den sites revealed that of nine monitored females that produced cubs in 1989 (including the two known to be unaccompanied by their cubs in August), only two still had cubs (now yearlings) with them in their dens. Whether the other cubs died, or were abandoned in early fall, could not be determined. Similar cases of extraordinary movements, or cub abandonment, during years of severe food shortages have been reported in California (Riegelhuth 1961) Tennessee (Beeman 1974), and Utah (Fair 1978).

Human Activities

Historically, man's major influence on black bear populations has been due to hunting (Cowan 1972), and the population on our study area was no exception (LeCount 1990). Man can also affect bear populations by making changes in the habitat. In coniferous forests these changes normally are due to timber harvest and its associated road building and fire suppression. All these activities, if not done with bear habitat needs in mind, have the ability to render habitat less suitable or unusable by fragmenting or eliminating it and by making bears more vulnerable to hunting (Mollohan and LeCount 1989). In this study, both logging and roads appeared to affect black bears.

Timber Harvest. Timber harvest can have varying effects on bear habitat. The key to whether these effects are positive or negative appears related to how the timber harvest duplicates natural forest conditions under which bears evolved. Where seral plant communities, and their associated plants that are used by bears for foods, were created by small wildfires, logging strategies such as selective harvest or small patchcuts (clearcuts) were very positive for bears (Lindzey and Meslow 1977, Mealey 1977, Rogers 1977, Zager 1980, Young and Beecham 1986). If food-rich seral stages were not produced, or cutting units were large, black bears might only be able to use the edges (Jonkel and Cowan 1971, Lindzey and Meslow 1977), or avoid them entirely for up to 20 years (Jonkel and Cowan 1971, Kellyhouse 1980, Zager 1980, Unsworth 1984, Young and Beecham 1986).

On our study area, ponderosa pine made up 19% of the vegetation, and only 7% of the bear use was found in this vegetation type. Therefore, except for ponderosa pine stands that structurally resembled mixed-conifer sites (Fig. 2), logging in most ponderosa pine areas probably had minimal effect on bears. This is because, historically, ponderosa pine areas tended to be more open than mixed-conifer sites because pine sites burned about every 6 years (Campbell et al. 1977), as opposed to approximately 22 years for mixed-conifer sites (Dietrich 1983). Therefore, because of a lack of cover, they probably never supported many bears.

Mixed-conifer composed 64% of the study area and was highly selected for by bears (Table 3). Thus, logging in mixed-conifer areas has the potential to greatly affect bear habitat. In the Southwest, the mixed-conifer forest evolved through a series of small lightning-caused wildfires (Dietrich 1983). Following these fires, successional stages varied depending on the site, but normally evolved through grass/forb, shrub, and tree successional stages. In some cases, coniferous tree succession was preceded by long successional stages of oak or aspen (Ronco et al. 1984). Normally, these fires were not intense; therefore, many decaying logs and trees remained in the area. As a result, bear habitat was enhanced by fires through the creation of small clearings containing a diversity of grasses, forbs, and hard and soft mast producers, while retaining much horizontal and vertical diversity with an ample amount of dead and down decaying wood.

Logging has been conducted in the White Mountains since the area was first settled in the late 1800s. Traditionally, this logging occurred in the flatter ponderosa pine areas because such areas were easy to cut, and ponderosa pine had a high market value. By the late 1950s, however, many of the highly productive pine areas had been cut over, and logging activities began to move into mixed-conifer areas where slopes were gentle enough that logs could be removed by tractor skidders. Most logging at this time was light selective cuts (pick and pluck) where large trees were removed creating small openings (≤0.25 acre) (Fig. 11) within uneven-aged, clumpy stands, similar to those created by natural fire. There were also experiments on a few 100- to 200-acre clearcuts in the early 1960s (Fig. 12).

Figure 11.
Selective cut (pick and pluck) in uneven-aged mixed-conifer on the White Mountain study area, Arizona, showing small (≤ 0.25 acre) opening surrounded by thick uncut areas.

Figure 12.
Unplanted clearcut (*circa* 1965) on White Mountain study area, Arizona, showing lack of regeneration of horizontal and vertical cover 25 years after being logged.

In the early 1980s the type and intensity of cutting on the study area took a dramatic change. An increased emphasis was placed on mixed-conifer areas from a belief that because of the previously light logging activity in this habitat type, a gross imbalance in age classes existed, especially mature sawtimber and old-growth (USDA Forest Service 1987). In addition, these mixed-conifer areas also supported high volumes of lumber. In an attempt to adjust this imbalance, and to meet the Apache Sitgreaves Forest Allowable Sale Quantity targets, logging activity was accelerated, timber volumes available for harvest increased, and both flat areas and steep slopes were logged. The results of these cuts did not duplicate natural fires. Instead, large blocks (50 to 100 acres) of land were converted to habitat structurally similar to ponderosa pine (Fig. 2), and resembled clearcuts more than selective cuts (Fig. 13).

Little bear use was observed in any cut areas where the horizontal cover exceeded 100 ft, or canopy cover was <40%. The localities fitting these descriptions included most areas logged since the early 1980s, whether on gentle or steep slopes. This avoidance appeared to be due to the elimination of cover. In most of these cut areas, horizontal visibility exceeded 100 ft and bears seemed reluctant to venture into them even if food were present. Consequently, such areas were eliminated as bear habitat, and indications are that they will not become usable again until shrub or tree regeneration is sufficient to once again reduce horizontal visibility to approximately 100 ft. Lindzey and Meslow (1977) did not observe use in clearcut areas in Washington for at least 15 years, and in Montana clearcut areas were not used for 10 years (Jonkel and Cowan 1971). The time span needed to regain adequate cover on the study area appears to be even longer.

Areas clearcut on the study area approximately 25 years ago (Fig. 14) showed that, even though planted with coniferous trees following logging, they were currently unused by bears. It appeared this lack of use was not due to a shortage of food but instead to insufficient cover within the relatively large cut area (50–100 acres). Several food items, including grasses and gooseberry, grew abundantly in these areas but canopy closure still did not exceed 40%, and horizontal visibility was greater than 100 ft. Because bears avoided such areas it is assumed that until cover increases, most bears will continue

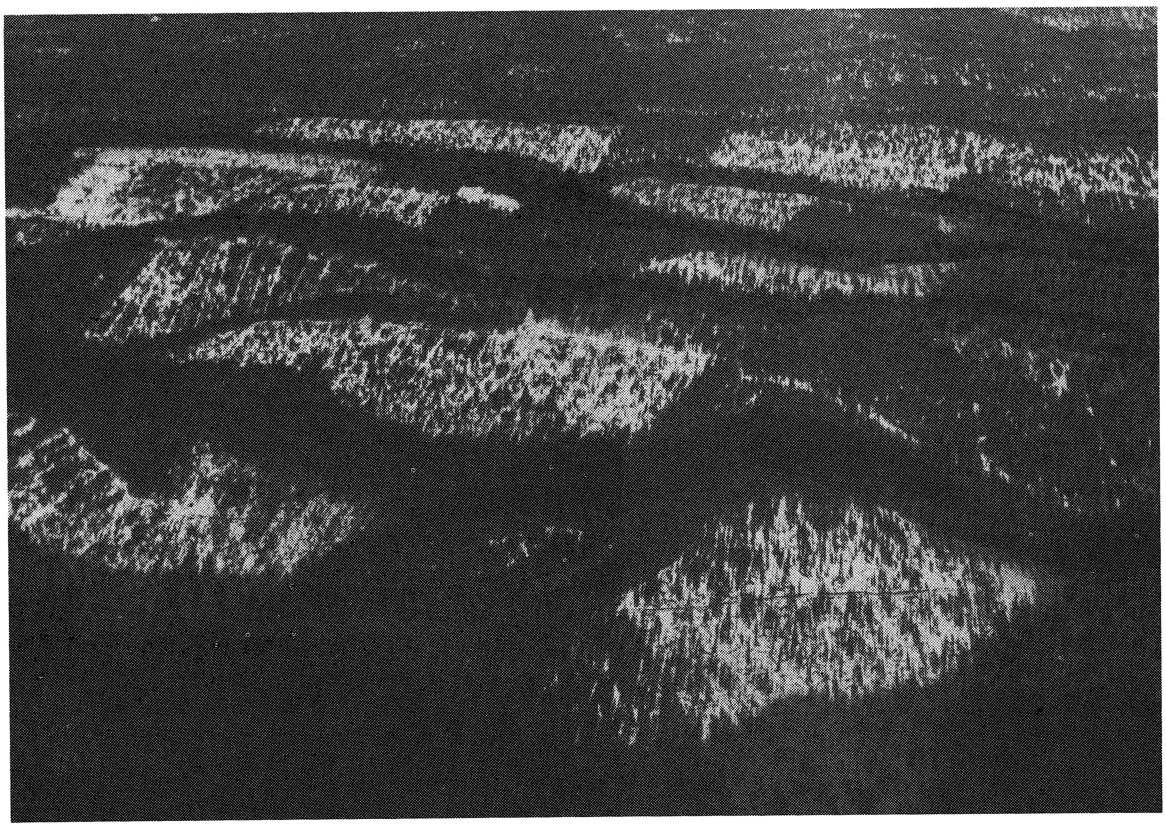


Figure 13.
Aerial photograph showing the degree of timber removal on some timber sales logged since 1980 on the White Mountain study area, Arizona.

to avoid these clearcuts, which in the arid Southwest could be at least another 5 years. This long time span to develop adequate regeneration is of concern because many areas subjected to heavy overstory removal since 1980 structurally resemble clearcuts, even if that were not the intent (Fig. 15). Even with reseeding, most of these areas probably will not become usable bear habitat until around the year 2010; if not reseeded, the length of time could be even greater.

Primarily, bears using logged areas were females with cubs, whereas females without cubs avoided logged areas. This use of logged areas by females with cubs probably is related to the type of food and cover produced by logging. Use was generally restricted to areas that had been selectively cut more than 10 years before the study. These areas retained high canopy cover (>60%), with small (≤0.25 acre) openings surrounded by multistoried uncut forest (Fig. 11). Bears were able to use the grasses and insects found in these openings, yet because the openings were small, they provided good protective cover within the 100 ft distance that bears seemed to prefer for feeding (Fig. 3). Females with cubs probably preferred these sites because the excellent grass, forb, and shrub growth that had

Figure 14.
Clearcut (*circa* 1965) replanted with coniferous trees shortly after logging on the White Mountain study area, Arizona. Note that the amount of vegetation present still provides inadequate cover for bear use.

Figure 15.
Area logged in 1988–89 on the White Mountain Study area, Arizona, showing resemblance to a clearcut even though this was not the intent.

developed in these areas produced both food and cover at the <6-ft height level. Females appeared to seek out these attributes when they were accompanied by cubs (Fig. 4).

Roads. Various responses to roads by black bears have been documented by several observers. Jonkel and Cowan (1971) reported bears in Montana feeding along roads reseeded with orchard grass (*Dactylis glomerata*), and Manville (1983) reported that Michigan black bears used oil pipeline and lumber roads as travel routes. In Idaho both Young and Beecham (1986) and Unsworth (1984) found males, and females without cubs, feeding near roads, but all bears avoided roads for bedding. Both investigators speculated that the reason for avoidance of roads was because of lack of security cover for bedding.

In this study we observed bears feeding near roads, but they appeared to avoid bedding close to roads. Data collected from 336 aerial locations indicated that most animals selected for areas >600 ft from roads, and against areas <600 ft (Tables 1, 4, Fig. 6). Only one bed was located within 600 ft of a road, and it was found in an area that had been selectively logged approximately 10 years before this study.

Whether the data were indicative of a real avoidance of roads, or an avoidance of a combination of factors associated with roads, could not be determined. Bears also avoided slopes of <20% for bedding, where many of the roads on the study area were located, and logged areas, which were common along roads (Fig. 16). Thus, the avoidance of roads we observed could have been due to these other factors. We do believe, however, that because roads primarily are constructed for timber removal, they do indirectly affect bears by reducing cover to a point where some areas become unusable, especially for bedding. Areas farther from roads receive less logging, provide better security, possess steeper slopes, and appear to be preferred by bears.

Another effect of roads is hunter access. Manville (1983) and Jonkel and Cowan (1971) reported that bear vulnerability was increased as hunter access increased. A similar finding was made in north-central Arizona where high bear vulnerability was documented in an area that contained an average of 1.9 mi of road/mi^2, and only 11% of all sections were roadless, as opposed to lower vulnerability in an area with an average of 1.3 mi of road/mi^2 and 34% of all sections roadless (Mollohan and LeCount 1989). Road density on our study area resembled the latter of these two situations. Road density averaged 2.4 mi/mi^2, with some sections containing over 9 mi of road. Only 15% of all sections were roadless. The 336 mi of road on the study area afforded hunters excellent access and appeared to contribute to the high mortality rate of bears caused by hunters each year (LeCount 1990).

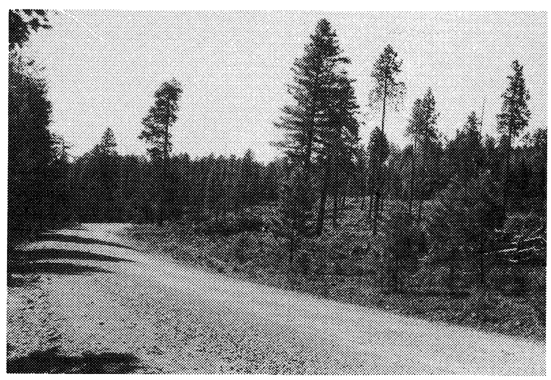
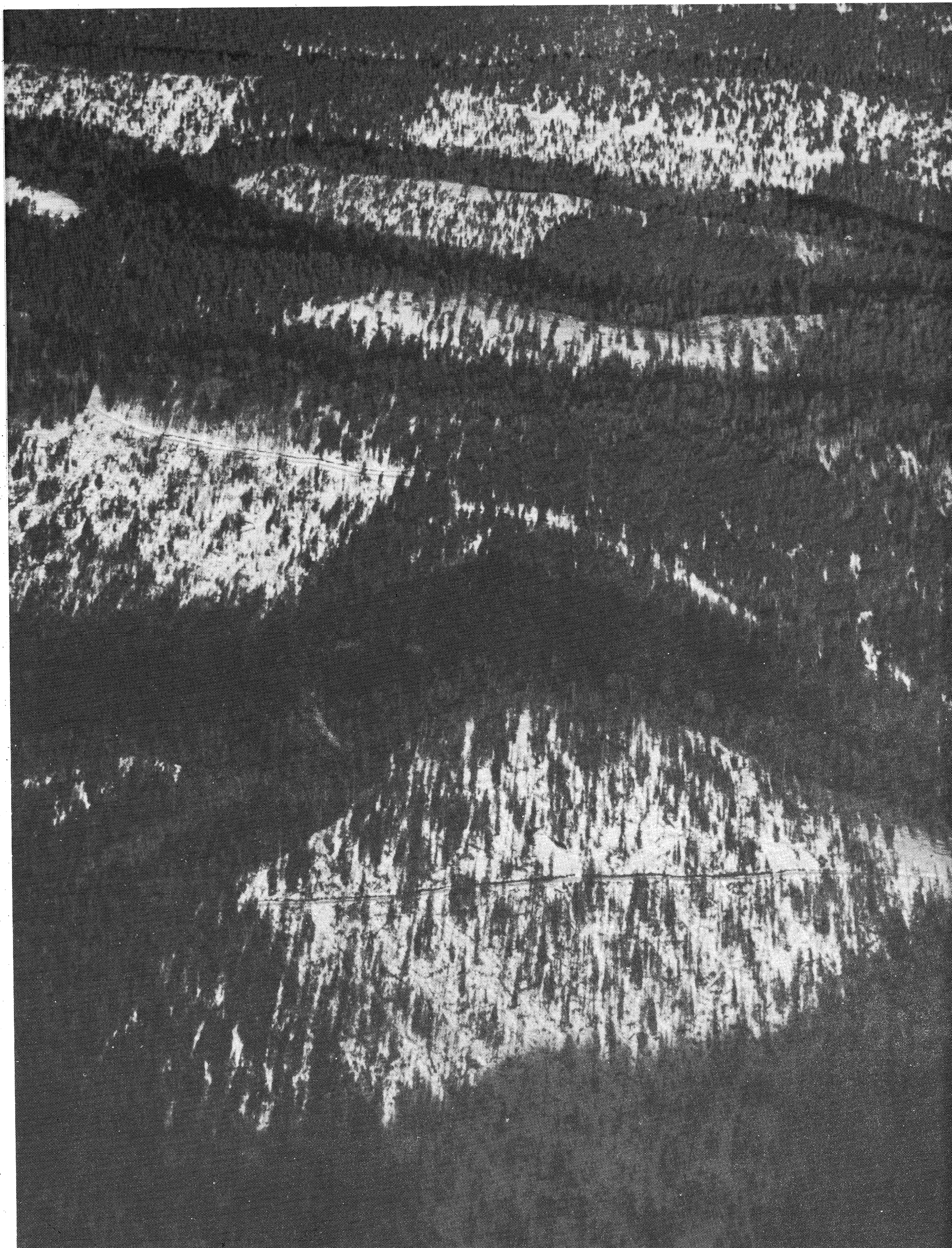


Figure 16.
Area logged adjacent to road in 1989 on the White Mountain study area, Arizona. Note visibility produced by removal of cover.



CONCLUSIONS

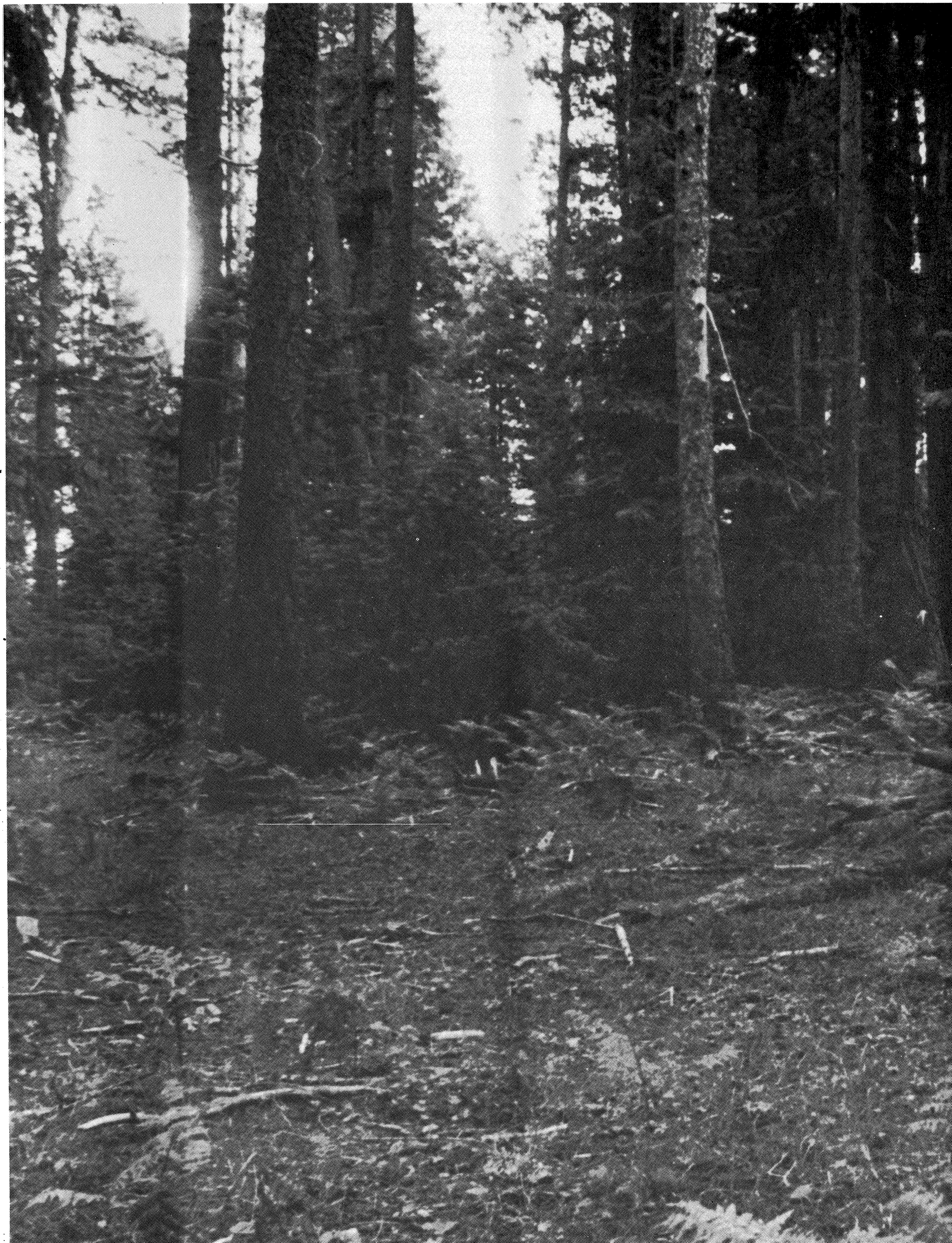
By radio collaring black bears in the White Mountain study area, we were able to observe how they used a variety of habitat types, physiographic features, and array of past timber management treatments. We found that adult female bears were very specific in their habitat selection. They appeared to prefer unlogged, old-growth, mixed-conifer stands characterized by dense (>60%) multistoried canopies and understory cover that reduced visibility below 100 ft. Such sites were usually located on steep slopes (>20%), away from roads, where there was an abundance of large standing trees (>25 in dbh), and a good amount of decaying wood. Such sites appeared to meet all the requirements that most females, whether accompanied by cubs or not, needed for feeding, if cover were adequate to prevent a bear from being seen over 100 ft, and for bedding and denning if horizontal visibility was less than 80 ft.

As important as what bears selected for, however, was what they selected against. Bears avoided meadows and ponderosa pine areas unless the latter structurally resembled mixed-conifer forest. Except when feeding, bears also avoided gentle slopes (<20%), and roads. The avoidance of roads, especially for bedding, undoubtedly was somewhat interrelated with the flatter areas where most roads were located, but road avoidance seemed plausible because only one bear was found bedded within 600 ft of a road.

All bears showed a strong avoidance of logged areas, especially single- or double-storied stands cut under recent overstory removal harvests, or past clearcuts—both forms of even-aged management. This avoidance seemed to be linked to a reduction in canopy cover below 40% and horizontal visibility increased beyond 100 ft. Most logged areas used by bears were mixed-conifer or spruce/fir stands where relatively light selective "pick and pluck" logging was conducted more than 10 years ago. These cuts resembled natural fire succession in that they created small grassy openings ($\leq$0.25 acre) surrounded by "leave" areas of thick, older-age structured forest, more indicative of harvest under uneven-aged management systems. Most areas logged under recent accelerated high-volume rates during the 1980s, and all clearcuts logged since the 1960s, were found to contain bear foods but appeared to be unusable to bears because of the lack of both vertical and horizontal cover. No bear locations were made in any of these areas even though they were prevalent on the study area.

By ocular examination of regenerating cover in these clearcut areas during other field work, it appeared to us that such logged areas would not be usable by bears for at least 30 years, and then only for feeding. Because the oldest intensively cut areas were approximately 25 years old, we could not determine how many additional years might be needed to re-create habitat that bears could use for both feeding and bedding, but obviously in the arid Southwest, where vegetation grows slowly, the time period will be quite lengthy.

We believe the results of this study indicate that timber harvest in mixed-conifer and spruce/fir portions of the study area over the past decade has largely eliminated bear habitat. Even though the habitat still supports a bear density of one bear/2.7mi^2 (LeCount 1990), it is our belief that if current timber management practices are continued, habitat loss will become extensive enough to result in a definite decline in bear population numbers over the next decade. This, however, does not have to be the case. With proper timber management, bear habitat can be preserved, and in some cases even enhanced.



MANAGEMENT OPTIONS

Based on the data from this study, it is our opinion that timber practices on the study area during the past decade have tended to eliminate black bear habitat because of increased emphasis placed on mixed-conifer and spruce/fir areas. These practices involved extensive removal of mature sawtimber and old-growth forest over large areas (Fig. 13). Overstory cover was reduced below 60%, and horizontal visibility was increased beyond 100 ft, with most trees >25-in dbh being eliminated (Fig. 15). In addition, logging operations, and the associated roads, removed timber from steep slopes (>20%) (Fig. 17) and drainageways (Fig. 18), which are critical areas to bears for travelways, bedding, and denning. Many feeding areas were lost because of reduction in cover and removal of decaying and cull logs (Fig. 19) inhabited by insects, which make up a major portion of the bear diet in the area.

(a)

(b)

Figure 17.
Steep slopes cable logged on the White Mountain study area. Note differences in the degree of timber removal between the area cut in (a) 1984 and (b) 1988.

Figure 18.
Drainageway logged in 1988 on the White Mountain study area, Arizona, showing removal of cover and increased visibility across drainage.

Figure 19.
Area logged in 1988 on the White Mountain study area, Arizona. Note elimination of most dead and down material during postlogging slash removal.

Figure 20.
Stand of usable bear habitat on the White Mountain study area, Arizona, isolated by logging operations in 1987–88.

This accelerated timber removal resulted in a shorter time period between cutting of adjacent stands. This did not allow enough time for previously logged areas to adequately regenerate into usable bear habitat before adjacent stands were cut. The accelerated removal also led to forest fragmentation and isolation of usable habitat (Fig. 20). To reverse this trend in loss of bear habitat, we suggest the following options be given serious consideration when planning future timber management operations in mixed-conifer or spruce/fir habitat in east-central Arizona or west-central New Mexico.

Uneven-Aged Management Systems Appear Far Superior to Even-Aged Management in Meeting Bear Habitat Needs.

In mixed-conifer or spruce/fir areas, small ($\leq$0.25 acre) group selection cuts (pick and pluck) should be employed, rather than techniques that create even-aged stands and tend to reduce horizontal and vertical cover throughout larger blocks of the forest. Selective uneven-aged cutting creates small grassy openings usable by bears, while retaining dense cover and large trees (>25-in dbh) for cover and protection.

Cut Areas Should Retain High Vertical and Horizontal Cover.

Management should be for multistoried rather than even-aged stands. Overstory cover should exceed 60%, and understory vegetation up to 6 ft high should be sufficient to prevent a bear from being observed over 100 ft away. Such areas can be used by bears as feeding sites but not for bedding.

As Recommended by Mollohan (1987a), Stands Should Retain a Minimum of Five Conifer Trees/Acre in Excess of 25-in dbh.

These trees should be surrounded by understory cover with a horizontal visibility of less than 80 ft. Such trees are important to all bears, especially females accompanied by cubs that use them for bedding sites and for cub protection. When these trees die, they also will provide snags and decaying logs containing insects that can be used by bears as food.

Cutting on Slopes Between 20% and 40% Should Be Done in a Manner to Meet All of the Above Criteria.

Bears use such areas for feeding, and adequate cover must be provided or regenerating food supplies will be unusable.

No Logging Should Occur on Slopes Greater Than 60%.

Bears prefer areas with high vertical and horizontal cover on steep slopes for bedding, especially in the middle one-third of such slopes.

During Treatment of Logging Slash, Decaying Logs Should Not Be Destroyed.

Such logs contain insects that are very important to bears. Therefore, they should be left in place or, if movement is necessary during slash treatment, they should be pushed or piled on the edges of untreated areas. Such slash treatment makes insects contained in decaying wood available to bears without their having to move into open areas.

"Cull" Logs Found During Logging Operations Should Not Be Treated With Other Logging Slash.

Such logs will provide the next generation of decaying wood from which bears will be able to forage on insects. Culls should be left in place or, if movement is necessary, they should be pushed or piled on the edges of untreated areas.

When Logging in Drainageways, Leave a Minimum 300-ft Buffer Strip Along Each Side of the Drainageway, Even if Slopes Are Less Than 20%.

Bears use drainageways as travel corridors, and the complete removal of protective cover across shallow drainages makes bears hesitant to cross such areas and increases their vulnerability to hunting. This protection of drainageways will also ensure that water quality standards, and the associated vegetation that is important to bears for food and cover, are maintained.

Most Dens are Located in Steep Mixed-Conifer and Spruce/Fir Areas; therefore, Avoid Logging Such Sites Between April 15 and June 15 to Avoid Disturbing Females With Cubs.

Black bear females establish maternity areas near den sites in the spring and try to avoid other bears, which are potential predators on cubs. Disturbance during this time causes females to try and move their cubs to a more secure area, which increases the chance that they might be found and killed by another bear (LeCount 1987).

Avoid Fragmentation of Usable Habitat.

Leaving suitable habitat for bears is not productive if such habitat is isolated from other usable habitat. All "leave" areas should be interconnected with travel corridors at least 600-ft wide in which horizontal visibility does not exceed 100 ft. The best locations for such travelways are along drainages and across ridge tops where heads of drainages occur opposite each other.

In Mixed-Conifer and Spruce/Fir Forests, Roads Can Have Both Positive and Negative Effects on Bears.

Closed and reseeded roads can be positive by allowing small undisturbed grass areas for feeding. Open roads negatively affect bears by allowing increased hunter access. In addition, a 600-ft area on each side of the road is rendered largely unusable for bedding. This combined 1200-ft width amounts to a loss of approximately 150 acres of bear habitat for each mile of open road. Road density should be reduced to at least that recommended by Mollohan (1987a) of no more than 1.3 mi of road in any section of bear habitat. No new permanent roads should be constructed without the elimination of an equal mileage of existing permanent road, and temporary roads should be closed and reseeded with grasses as soon as logging operations are completed.

Attempts Should Be Made to Restrict Road Construction to Slopes Less Than 20%. Such Areas Are Less Expensive for Road Construction, are More Stable Sites, and Avoid Areas of High Bear Use.

If roads are needed on slopes ranging from 20% to 40%, only temporary roads should be built that will not be opened until needed for log removal and will be closed immediately after logging is completed. No roads should be constructed on slopes >60%.

Existing Old-Growth Should Be Retained.

In mixed-conifer and spruce/fir habitats, bears showed a very strong selection for old-growth areas on slopes >60%, especially for bedding and denning. As many of these sites as possible should be retained in old-growth, or developed in old-growth, to assure that bedding habitat is not lost and that bear habitat does not become fragmented.

Design Timber Harvest Plans to Promote a Mosaic of Different Age Cuts.

Following group selection logging, there is a period of at least 10 years before bears appear to use logged areas, even for feeding. In clearcuts, and intensively logged stands, this time span is increased to 30+ years. Timber management plans should take into consideration the time periods that bear habitat is unusable as a result of a various timber operations. Timber sales adjacent to areas previously cut should be planned to allow an appropriate amount of time to pass to ensure that these logged areas have become usable for bears.

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Key Words: black bear, *Ursus americanus*, habitat selection, diet, home range, logging.

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