BLACK BEAR HABITAT USE IN TAHOE NATIONAL FOREST, CALIFORNIA

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Abstract: Four radio-collared female black bears (*Ursus americanus*) were located 545 times during 1979 and 1980. We evaluated bear habitat use in relation to dominant vegetation, canopy closure, crown diameter, and rotten log density by comparing use to availability. Use of dominant vegetation types by bears was disproportionate to availability in all seasons, reflecting seasonal food availability. Wet meadows, hardwood, and manzanita habitats were seasonally preferred by bears, and we suggest that protection of these habitats is necessary to maintain the local bear population.

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Timber harvest and associated activities alter wildlife habitat considerably. Timber production and wildlife production may be compatible if habitat requirements of animals are considered during the planning and implementation of forest management and production activities (Thomas 1979). The Wildlife Habitat Relationships (WHR) Program was initiated by the U.S. Dep. Agric., For. Serv. to provide a comprehensive data base to be used in integrating wildlife habitat needs with timber management (Verner and Boss 1980). The black bear was identified as a wildlife species whose habitat needs we know little about. Our study was undertaken to describe the habitat needs of black bears in the northern Sierra Nevada within the framework of the WHR Program. Concurrently with this habitat use study, we intensively investigated bear food habits in the area (Grenfell and Brody 1983); this allowed us to examine the relationship between food habits and habitat use.

Hal Salwasser assisted with study design and data analysis. Don Koch trapped the bears and assisted with telemetry monitoring while conducting his own research. B. Dobbas, J. Ferreira, R. Imai, L. Phillips, S. Prater, J. Ranlett, T. Rosefield, L. Sitton, and J. Vincenty provided additional field assistance. W. Spencer assisted in data analysis. Earlier drafts of this manuscript were substantially improved by comments from R. Barrett, D. Garshelis, and J. Verner. The research was supported by Fed. Aid in Wildl. Restor. Proj. W-52-R, Job IV.2.

STUDY AREA

The study area is comprised of the upper reaches of the North Fork and Middle Fork of the American River, and of the Rubicon River on the west slope of the Sierra Nevada range, approximately 11 km west of Lake Tahoe. Elevations range from 1,110 to 2,560 m. The topography is typical of the northern Sierra Nevadas—sharp ridges divided by steep canyons and gorges.

WHR vegetation types (Salwasser and Laudenslayer 1982) in the study area are mixed conifer, red fir (*Abies magnifica*), lodgepole pine (*Pinus contorta*), montane hardwood, montane hardwood-conifer, montane riparian, montane chaparral, manzanita (*Arctostaphylos* sp.), and wet meadow (Table 1). The majority of the area was closed to hunting, and Koch (1983) estimated bear density in the area at the time of the study to be 1 bear per 3.5 km^2.

Land is partitioned, checkerboard fashion, between private and public ownership. The public land is administered by the Tahoe National Forest, Foresthill Ranger District. The study coincided with the beginnings of intensive harvest of mature softwood stands on Forest Service and private lands.

METHODS

Four adult females were selected for study because adult female bears have relatively small home ranges and are generally acknowledged to be the most important reproductive component of bear populations. Bears were captured in culvert traps, immobilized with sernalyn, ear-tagged, fitted with collar transmitters (159 Mhz), and released. Animal locations were monitored with a 2-element hand-held Yagi antenna, receiver, and digital signal processor.

Radiotracking commenced in early May and terminated in early November of 1979 and 1980. During 1979 each bear was located 4 or 5 times per week, every other week. In 1980 each bear was located 1–3 times each day for 5 days each week. An approximately equal number of locations was obtained in each 6-hour segment (0900–1500, 1500–2100, 2100–0300, 0300–0900) in the diel period.

Direction from observer to transmitter was determined by the loudest signal, and the animal was

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Table 1. Composition of WHR habitat types in the Tahoe National Forest study area (Salwasser and Laudenslayer 1982).

WHR habitat type	Major overstory species		Major understory species	
Mixed conifer	Ponderosa pine	*Pinus ponderosa*	Deerbrush	*Ceonothus integerrimus*
	Douglas-fir	*Pseudotsuga menziesii*	Whiteleaf manzanita	*Arctostaphylos viscida*
	Incense-cedar	*Libocedrus decurrens*	Greenleaf manzanita	*A. patula*
	Red fir	*Abies magnifica*		
	White fir	*A. Concolor*		
	Sugar pine	*P. lambertiana*		
Red fir	Red fir		Pipsissewa	*Chimaphila menziesii*
			Wintergreen	*Pyrola picta*
			Greenleaf manzanita	
Lodgepole pine	Lodgepole pine	*P. contorta*	Forbs	
Montane hardwood	Canyon live oak	*Quercus chrysolepis*	Deerbrush	
			Whiteleaf manzanita	
			Grasses	
Montane hardwood conifer	Black oak	*Q. kelloggii*	Manzanitas	
	Ponderosa pine			
	Douglas-fir			
	Incense-cedar			
	Canyon live oak			
Montane riparian	Thinleaf alder	*Alnus tenuifolia*	Forbs	
	Willows	*Salix spp.*		
Montane chaparral	Huckleberry oak	*Q. vaccinifolia*		
	Manzanitas			
	Snowbrush	*Ceonothus cordulatus*		
	Bittercherry	*Prunus emarginata*		
	Chinkapin	*Castanopsis sempervirens*		
Manzanita	Manzanitas			
Wet meadow			Grasses	
			Forbs	

located by triangulation using 3–5 bearings taken less than 5 min apart. The angular error of the telemetry receiving system was ± 5°. Error arcs were drawn to arrive at error polygons delineating 95% confidence limits on animal locations (Springer 1979). Areas of error polygons used in the habitat use analysis ranged from 1.2 to 6.1 ha.

We considered 4 habitat attributes in our evaluation of bear habitat use, including WHR habitat type, canopy closure, crown diameter of commercial conifers, and rotten log density. Because our goal was to be able to integrate bear habitat needs with forest management, we examined habitat attributes that are routinely inventoried and recorded by the Forest Service, and used by them in formulating specific forest management plans. WHR habitat categories followed those previously described by Salwasser and Laudenslayer (1982) and were identified from Forest Service soil and vegetation maps. Canopy closure categories of 0–19%, 20–39%, 40–69%, and 70–100% were identified from Forest Service timber stand inventories. Crown diameters, also identified from Forest Service inventories, were grouped into the following categories: < 1.5 m, 1.6–3.8 m, 3.9–7.4 m, 7.5–12.2 m, and > 12.2 m. Rotten log densities were identified from Forest Service fuel inventories in the following categories: 2.5–13.5 metric tons/ha, 25.8–37.9 metric tons/ha, 38.0–49.0 metric tons/ha, and > 49 metric tons/ha. Fuel inventories were available for only about a third of the study area.

The categorical value of each of the 4 habitat variables was recorded for each bear location obtained by telemetry. If more than 1 WHR type was enclosed by an error polygon, the fractional area of each was visually estimated to the nearest tenth. The center of the error polygon was used to identify the values of the other habitat variables.

Annual home ranges for each bear were calculated using error polygon centers and the harmonic mean technique (Dixon and Chapman 1980). The isoline of the 95th percentile of the harmonic mean distance deviations was taken to be the home range boundary (Spencer and Barret 1983). Percent similarity (Brower and Zar 1977) of the WHR habitat types among the 4 annual home ranges was calculated. Because there was extensive overlap among the home ranges of the 4 collared bears a composite home range was constructed by overlaying all 4 annual home

ranges and delineating the resulting perimeter. The availability of each category of each habitat variable within the composite black bear home range was determined from vegetation, fuels, and timber stand maps (Mosby 1980).

Habitat selection was determined by comparing the proportion of each category of each variable used by the bears with the proportion available in the composite home range using chi-square tests. In the chi-square tests the proportion of a category available was multiplied by the total number of telemetry locations to arrive at the expected number of telemetry locations. Additionally, preference indices and associated 95% confidence limits (Strauss 1979) were calculated for each category of each variable. Positive values of the index indicated that the category was used in greater proportion than it was available, negative values of the index indicated that the category was used in smaller proportion than available. The relative preference by bears for each category within each variable was determined by the rank of the respective preference indices. Relative preferences were calculated on a seasonal basis; discriminant analysis of the habitat use data was used to determine the dates that best delimited seasonal differences.

RESULTS AND DISCUSSION

Four adult female black bears were radio-located 545 times during 1979 and 1980. Annual home range size averaged 3,640 ha, with extensive overlap among all 4 home ranges. The similarity of WHR habitat composition among the ranges was 54% (Brower and Zar 1977). Much of the dissimilarity was due to the absence of montane hardwood (which consists primarily of canyon oak [*Quercus chrysolepis*]) from the home ranges of 2 bears (4887 and 5093) and the absence of pure manzanita stands from the home ranges of 2 bears (4887 and 4843) (Table 2). Some canyon live oak and manzanitas occur in those home ranges but were not mapped as dominant WHR habitats. The composite home range was 5,495 ha and consisted of 47% mixed conifer, 21% montane chaparral, 10% red fir, 6% montane riparian, 4% manzanita, 4% lodgepole pine, 3% montane hardwood, 3% montane hardwood-conifer, and 2% wet meadow.

The most appropriate dates for delimiting seasonal differences in habitat use were den emergence (usually in Apr) to 31 July (spring), 1 August to 14 September (summer), and 15 September to the onset of hibernation (usually in November) (fall). The use of WHR habitat types by bears was disproportionate to availability in all seasons ($P < 0.05$). Disproportionate use of canopy closure classes was evident only in the spring ($P < 0.01$). Use of crown diameter classes was disproportionate only in the summer ($P < 0.05$). One hundred and twenty-eight of the radiolocations were in the area for which we had fuel inventories; these data indicated disproportionate use of rotten log density classes only in the spring ($P < 0.05$).

Spring Habitat Use

The only WHR habitat type used significantly more than expected in the spring was the wet meadow type (Fig. 1). Lodgepole pine and montane riparian types were positively selected also but not at the 95% level. The spring diet of bears in the area was dominated by grasses and forbs (Grenfell and Brody 1983), which are most abundant in wet meadows. Wet meadows frequently grade into riparian and lod-

Table 2. WHR habitat composition of annual home ranges of 4 female black bears in Tahoe National Forest, 1979 and 1980.

WHR habitat type	Bear identification number							
	4843		4877		4887		5093	
	Ha	%	Ha	%	Ha	%	Ha	%
Mixed conifer	1,653	41	815	25	1,313	53	2,634	54
Montane hardwood	210	5	95	3	0	0	0	0
Montane conifer-hardwood	274	7	536	17	70	3	352	7
Red fir	242	6	690	22	99	4	694	14
Montane riparian	177	4	130	4	159	6	313	6
Lodgepole pine	278	7	57	2	295	12	83	2
Montane chaparral	1,113	28	471	15	461	19	752	15
Manzanita	0	0	344	11	0	0	24	1
Wet meadow	85	2	22	1	84	3	34	1
Total area	4,032		3,160		2,481		4,886	

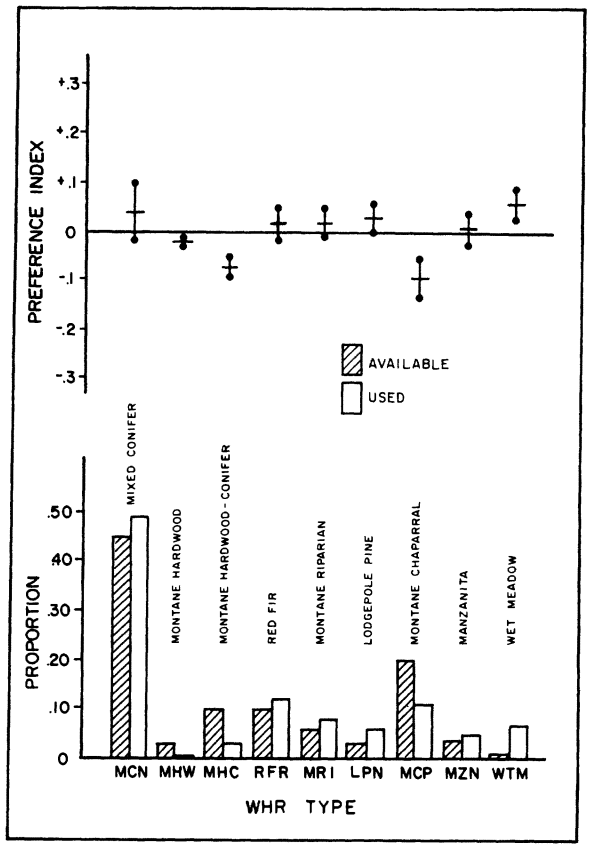

Fig. 1. Spring use of WHR habitat types by 4 female black bears in Tahoe National Forest, 1979–80. Vertical lines bisecting preference indices represent 95% confidence limits.

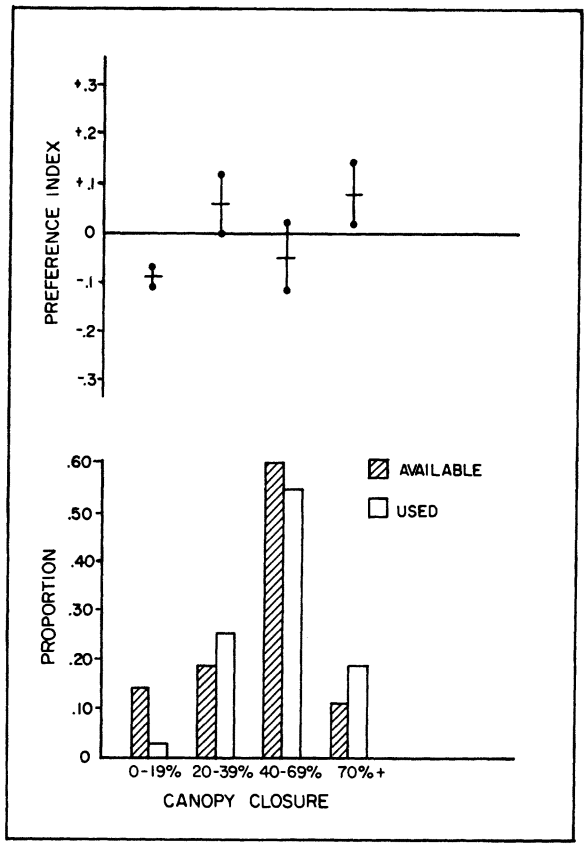

Fig. 2. Spring use of canopy closure classes by 4 female black bears in Tahoe National Forest, 1979–80. Vertical lines bisecting preference indices represent 95% confidence limits.

gepole pine habitats, so that grasses and forbs are abundant in these habitats also. Thus both the presence of seasonally preferred foods and physical juxtaposition with wet meadows may account for the high spring use of montane riparian and lodgepole habitats.

Montane hardwood, montane hardwood-conifer, and montane chaparral were all used less than expected during the spring. These types are essentially devoid of grass or forb ground cover, and the lack of forage may have made these habitats relatively unattractive to bears in the spring.

Bears used closed canopy stands in significantly higher proportion than expected during the spring and open canopy stands less often than expected (Fig. 2). The preference indices for canopy closure classes may also relate to the relative abundance of grasses and forbs. Shrubs dominate the understory of open canopy stands, precluding an abundance of grass or forbs. Closed canopies intercept too much light for brush understory species to thrive but produce ideal conditions for a moderate ground cover of grass and forbs. Important exceptions to this occur in the 1st few years after clear-cutting or fire, when the canopy is open but there has not been sufficient time for brush to develop, and in meadows, where the open canopy and thick grass and forb groundcover is maintained by edaphic factors rather than light regime. Wet meadows were excluded from analysis of canopy cover for this reason.

During the spring bears were located in areas containing 13.6–25.7 metric tons of rotten wood per hectare significantly more frequently than expected and located in areas of higher rotten wood density less frequently than expected (Fig. 3). The infrequent use of areas of high rotten wood density may reflect the possibility that a ground cover of dead wood precludes the establishment of grasses or forbs, so that only areas of low rotten wood density produce abundant spring bear food.

A 2nd important spring bear food in the study area is colonial insects, particularly carpenter ants (*Cam-*

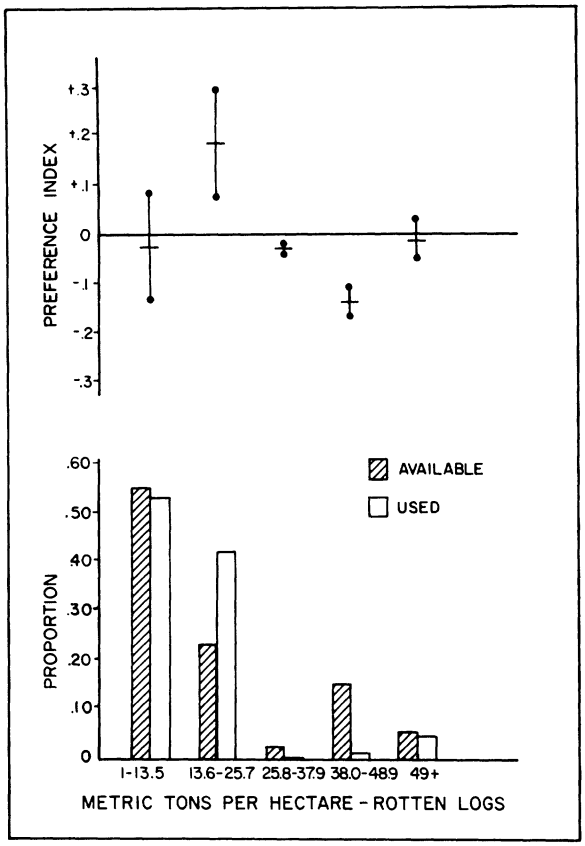

Fig. 3. Spring use of rotten log density classes by 4 female black bears in Tahoe National Forest, 1979–80. Vertical lines bisecting preference indices represent 95% confidence limits.

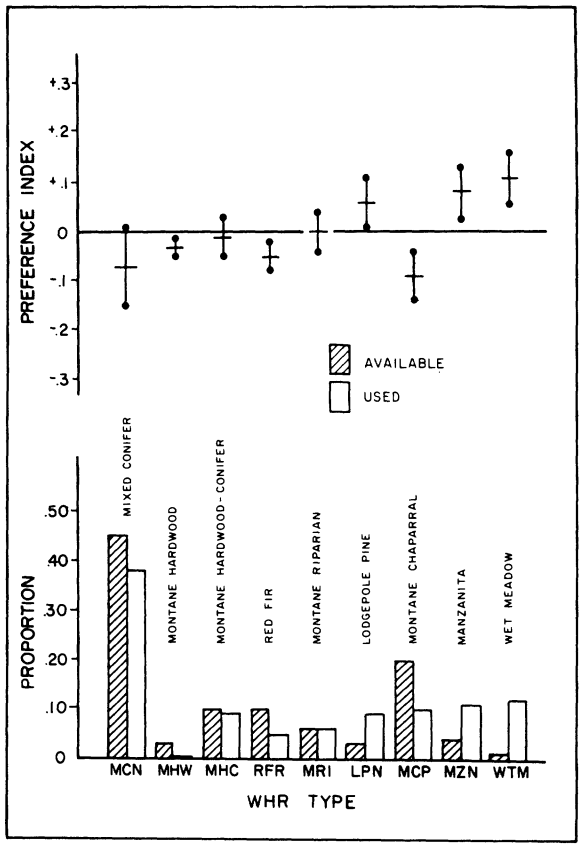

Fig. 4. Summer use of WHR habitat types by 4 female black bears in Tahoe National Forest, 1979–80. Vertical lines bisecting preference indices represent 95% confidence limits.

ponotus spp.), which inhabit downed logs (Grenfell and Brody 1983). It seemed as if the protein in ants would be more actively sought by bears than the relatively ubiquitous roughage of grasses and forbs; thus the relative preference for areas of low rotten log density, and presumably low ant density, was surprising. We did not measure insect density directly, however, so it may be that bears prefer areas of high insect density, but that insect density is independent of rotten log density.

Summer Habitat Use

Lodgepole pine, wet meadow, and manzanita WHR habitat types were used significantly more than expected by bears during the summer; montane hardwood and red fir types were used significantly less than expected (Fig. 4). The only significantly disproportional use of crown diameter classes occurred during the summer, when areas of greater than 7.5 m diameter were used less than expected, and areas of intermediate crown diameter (3.9–7.4 m) were used more than expected (Fig. 5).

As in the spring, summer habitat use can be related to diet. In summer grasses and forbs still make up a substantial portion of the diet, but the majority of the diet consists of manzanita berries (Grenfell and Brody 1983). Mature conifer stands, characterized by large crown diameters, are typically devoid of manzanita understory.

Fall Habitat Use

In the fall bears were located in montane hardwood-conifer and manzanita WHR habitat types significantly more than expected, while the mixed conifer, montane chaparral, and red fir types were used significantly less than expected (Fig. 6). No disproportional use of canopy closure, crown diameter, or rotten log density classes was evident. Habitat use in the fall could again be related to diet. Acorns are the most important fall bear food (Grenfell and Brody

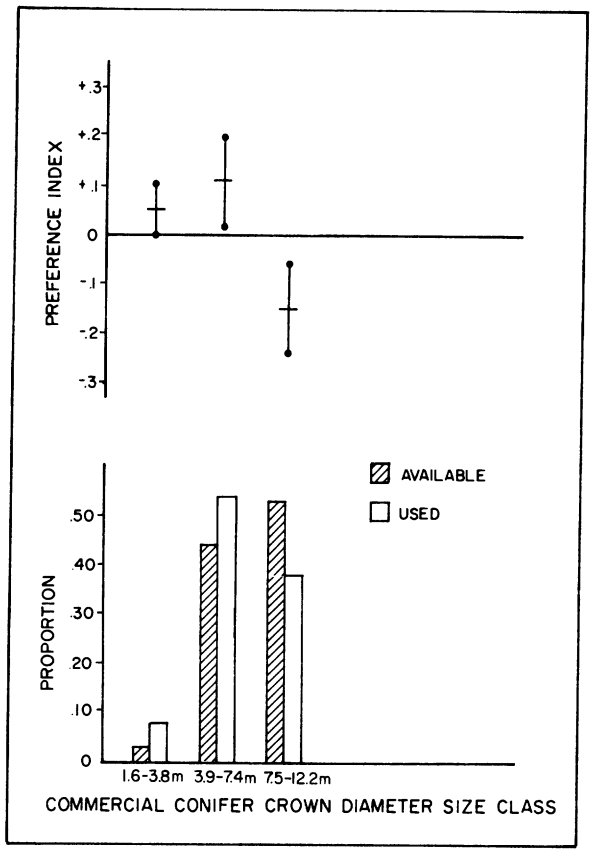

Fig. 5. Summer use of crown diameter classes by 4 female black bears in Tahoe National Forest, 1979–80. Vertical lines bisecting preference indices represent 95% confidence limits.

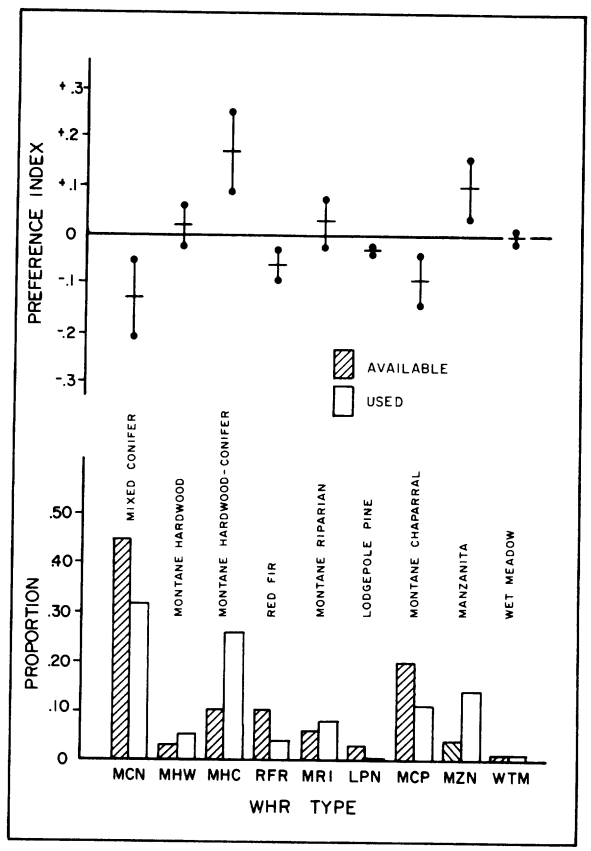

Fig. 6. Fall use of WHR habitat types by 4 female black bears in Tahoe National Forest, 1979–80. Vertical lines bisecting preference indices represent 95% confidence limits.

1983), and oaks are abundant only in the relatively rare hardwood habitats.

The nature of hardwood habitat use is somewhat obscured by the fact that we combined both years in the analysis. In 1979 the acorn crop failed (Grenfell and Brody 1983), and consequently we observed very little use of the hardwood habitats but much use of the manzanita habitats by bears in that year. In 1980 acorns were much more abundant, and nearly all of the locations in hardwood habitat types were recorded in that year. Despite little use of hardwood habitats in the fall of 1979, the overall preference index for montane hardwood-conifer was 0.17, the highest index calculated in any season. Other researchers in California and elsewhere have noted the importance of acorns as fall bear food (e.g., Boyer 1976, Rogers 1976, Kelleyhouse 1977, Goldsmith et al. 1981); manzanita berry crops fail much less frequently than acorn crops and provide a reliable secondary fall food source.

CONCLUSIONS

The analytical approach we used describes habitat use patterns and suggests causal relationships but does not neccessarily indicate the importance of particular habitats to bears. Although locational telemetry data provide a measure of how much time an animal spends in a particular habitat, it does not tell what the animal was doing in that habitat or how important that habitat was to the overall fitness of the animal. Similarly, the habitat selection that we observed allows a ranking of habitat preferences, but the rankings were conditional on the particular array of habitats available and do not necessarily reflect the relative importance or substitutability of particular habitats.

Despite the shortcomings of this coarse-grained analysis and small sample size, our study suggests a tight relationship between seasonal habitat use and food habits of bears in Tahoe National Forest. Wet meadows and associated habitats, with grass and

forbs, were preferred in the spring and summer. As manzanita berries ripened in the summer, bears used manzanita habitats preferentially, along with the meadow habitats. Fall habitat preferences varied depending on the quality of the acorn crop. In a year of acorn abundance, bears used hardwood habitats in great excess of availability; in a year of acorn scarcity bears used manzanita habitats most frequently. The WHR types that were consistently least preferred were the red fir and chaparral types, both of which support low densities of bear food plants.

Of the 4 habitat variables we considered, only WHR categories were used disproportionately in each season to a significant extent. Analysis of canopy closure, crown diameter, and rotten log density did not provide much insight into bear habitat relationships. This may have been because bears did not select habitats on the basis of these attributes, or it might have been that bears did indeed select habitats on the basis of these attributes but that the influence that these variables had on habitat selection was confounded by interaction with other variables, or we could not detect the selection with the particular classification schemes we used.

Certainly food availability is a major factor in habitat selection, but other factors we did not attempt to investigate surely influence habitat selection also. Chief among these are social relations within the population and individual variation in resource exploitation tactics.

Management Implications

The wet meadow, hardwood, and manzanita WHR types that were most preferred by bears were also the scarcest habitat types in the area, together making up only between 6% and 30% of individual annual home ranges. In light of the comments in the preceding section, we cannot say that increasing the amount of these habitats available to bears would improve the overall quality of the habitat, but given the relative scarcity of these particular types protection of them is warranted. Meadows, riparian, and hardwood habitats are currently protected by Forest Service policy, but manzanita, when it occurs near or under commercial stands, hinders timber harvest operations and is considered undesirable by foresters.

Chaparral had consistently low preference rank, which was somewhat surprising given the occurrence of bear foods in that habitat. Being of no commercial timber value, and usually occurring on sites unsuitable for commercial conifers, chaparral areas are rarely subject to any management except for occasional controlled burns. Given the relatively large amount of chaparral available, the infrequent use of it by bears, and the infrequent forest management activity, we believe that no specific attention to chaparral is necessary for the sake of bears in the area.

Commercial conifer habitats (mixed conifer and red fir) made up approximately half of each annual home range and were never used in significant excess of their availability. It appears that a responsible timber harvest regime (i.e., moderate to long rotation intervals on a sustained yield basis) poses no special threat to bears as far as food availability is concerned. However, the large amount of commercial timber in the area gives rise to the potential for much more human activity in the area than we witnessed during our study. Detrimental effects of timber harvest on bears are thus most likely to be due to disturbances (e.g., roads, development, noise) that might interfere with exploitation of the habitat by individual bears. Our study did not address these potential impacts, but we believe that they pose potential problems and should be addressed in light of the WHR program goals of integrating wildlife needs with timber management.

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