

PREDICTING BLACK BEAR HABITAT SELECTION FROM FOOD ABUNDANCE UNDER 3 FOREST MANAGEMENT SYSTEMS

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Abstract: Food is considered to be a primary influence on black bear (*Ursus americanus*) habitat selection, however relative abundance of foods among habitats is rarely quantified. We measured seasonal food abundance within 17 habitats in the central Adirondack Mountains of New York and used food abundance indices to predict habitat selection. Managed habitats provided the highest abundance of spring foods and summer fruit. Nonmanaged and uneven-aged managed hardwood habitats provided the highest amounts of beechnuts (*Fagus grandifolia*), a primary fall food. Analysis of habitat-use data from 5 adult female black bears monitored during 1989-91 suggested that habitat selection was greatly influenced by food abundance. Seasonal shifts in habitat use were related to changes in food resources. Bears used habitats with high food abundance more than expected and habitats with low food abundance less than expected ($P = 0.05$). Habitat diversity within a bear home range appears to be beneficial. Management implications are discussed.

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Habitat selection by individuals should reflect availability of basic necessities, such as food, water, and cover. Seasonal changes in black bear habitat use have been widely documented and are primarily attributed to variation in food availability (Lindzey and Meslow 1977, Landers et al. 1979, Hugie 1982, Novick and Stewart 1982, Elowe 1984, Grenfell and Brody 1986, Pelchat and Ruff 1986, Young and Beecham 1986, Unsworth et al. 1989, Hellgren et al. 1991). Rarely have these studies quantified variation in food abundance among habitat types. Arimond (1979) quantified fruit production by 5 genera in high and low density forests in northeastern Minnesota. Noyce and Coy (1990) estimated abundance and productivity of 22 common fruit species in 11 habitat types in northcentral Minnesota. Estimates of fruit abundance were not related to bear habitat use in either study.

Evidence suggests that net energy intake is related to fitness in black bears. In northeastern Minnesota, Rogers (1987) found that females with access to high energy food reproduced at a younger age and produced larger litters at shorter intervals. In western Massachusetts, Elowe and Dodge (1989) documented litter production by 26 of 28 females feeding on high fat and carbohydrate mast prior to denning, but no reproduction by bears with low carbohydrate fall diets. Failures of important food crops reduced bear survival and fecundity in Montana, Alaska, Minnesota, and Tennessee (Jonkel and Cowan 1971, Hatler 1972, Rogers 1976, Eiler et al. 1989). Starvation was identified as a significant mortality factor among cubs and yearlings in Minnesota (Rogers 1987).

Natural selection should favor individuals that maximize foraging efficiency. Foraging in habitats containing large amounts of food endows individuals with a selective advantage over those foraging in habitats containing smaller amounts of food. Habitat selection by individuals should reflect this variation in food abundance. This study was designed to quantify food abundance in various habitat types, allowing us to predict black bear habitat selection. We hypothesized that black bears select habitats with higher food abundance.

The terms "habitat use" and "habitat selection" are often used interchangeably in the literature. For the purpose of our research, we made a distinction between the terms. "Habitat use" is the end product of the "habitat selection" process. If selection of particular habitats over others is a behavioral decision made by bears, rigorous experimentation would be required to document the behavior. Therefore, our research quantified habitat-use patterns, allowing us to make inferences about habitat selection.

Many factors affect plant food abundance, including forest type, forest management, and fire. Forest management and fire were reported to be positive influences on bear food production in many regions, although potential negative impacts were noted (Lindzey and Meslow 1977, Novick and Stewart 1982, Zager et al. 1983, Young and Beecham 1986, Clark et al. 1987, Unsworth et al. 1989, Noyce and Coy 1990). A primary objective of this study was to examine the value of managed, nonmanaged, and burned forests in the central Adirondacks for providing important black

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bear foods.

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STUDY AREA

The study area was located near Newcomb in the central Adirondack Mountains of New York. Research was centered on Archer and Anna Huntington Wildlife Forest (HWF) and adjacent public and private lands. The HWF is a 6,000 ha research station operated by the State University of New York, College of Environmental Science and Forestry. To the north and east of HWF were private paper company properties and to the south and west were New York State Forest Preserve lands.

The region was mountainous, with elevations ranging from 475 m to 1150 m above sea level. The land area was >95% forested and was interrupted by numerous lakes, ponds, wet meadows, and swamps. Human habitation was low, with most dwellings occurring in Newcomb or along Route 28N, a single highway bisecting the area. Paved roads were uncommon, however seasonal dirt roads were numerous on private property. Vehicular use of dirt roads was limited by locked gates on most private lands, and it was prohibited by the "wild forest" or "wilderness" status of most state lands.

The climate was generally cool and moist. Between 1940 and 1989, mean annual temperature on HWF was 5°C, mean July temperature was 18°C, and mean January temperature was -9°C. Average annual rainfall was 107 cm and average annual snowfall was 290 cm. Continuous snow cover usually extended from early December to late March. The frost-free growing season ranged between 90 and 120 days (HWF unpubl. data).

Soils were of glacial origin and were extremely varied. Most soils were glacial tills with limited outwash or organic soils. They were generally shallow

(<1.2 m), boulder-strewn, poorly- to well-drained, and of moderate fertility (Somers 1986).

Forest species composition was dominated by northern hardwoods, primarily sugar maple (*Acer saccharum*), beech, and yellow birch (*Betula alleghaniensis*). Common associates were red maple (*Acer rubrum*), white ash (*Fraxinus americana*), black cherry (*Prunus serotina*), paper birch (*Betula papyrifera*), quaking aspen (*Populus tremuloides*), big-tooth aspen (*P. grandidentata*), eastern hemlock (*Tsuga canadensis*), and white pine (*Pinus strobus*). Common understory species were witchhobble (*Viburnum alnifolium*), striped maple (*Acer pensylvanicum*), red raspberry (*Rubus ideaus*), bunchberry (*Cornus canadensis*), and Canada mayflower (*Maianthemum canadense*).

Conifer forests generally occurred above 750 m where soils were shallow and dry, and in poorly drained sites at lower elevations. Red spruce (*Picea rubens*) and balsam fir (*Abies balsamea*) were the dominant species. Common associates were paper birch and mountain-ash (*Sorbus americana*) at high elevations; and eastern hemlock, white pine, and paper birch at low elevations. Extremely saturated sites were dominated by black spruce (*Picea mariana*), tamarack (*Larix laricina*), and northern white-cedar (*Thuja occidentalis*). Mixedwood stands occurred as transitions between hardwood and conifer forests.

Nonforest wetlands were associated with lakes, ponds, and streams. Common woody species occurring in wetlands were alder (*Alnus* spp.), willow (*Salix* spp.), leatherleaf (*Chamaedaphne calyculata*), and *Spiraea* species. Common nonwoody species were sphagnum-moss (*Sphagnum* spp.), sedge (*Carex* spp), royal fern (*Osmunda regalis*), and jewelweed (*Impatiens biflora*).

Forest fire and timber harvesting affected forest composition. Intense forest fires occurred throughout the central Adirondacks between 1903 and 1910 and burned significant portions of the study area. From about 1885 to 1910, white pine and spruce sawlogs were extracted from conifer and mixedwood stands. Pulpwood logging for conifers continued into the early 1950s.

After the 1930s, most forest management focused on hardwood species. Selective cutting, usually with a 30-38 cm diameter limit, was the most widely used method for harvesting stands, resulting in uneven-aged structures. Private lands and several stands on HWF were managed using this uneven-aged system, generally with a 15-year cutting cycle. This cutting cycle was interrupted beginning about 1965, when hardwood

stands were cut more heavily to salvage beech trees infected with beech bark disease. The 15-year cutting cycle was resumed as stands matured.

Beginning in 1966, a system of even-aged management was employed on HWF to regenerate mature stands. Approximately 1,360 ha of hardwood and mixedwood stands were harvested using a 2-cut shelterwood method. A site preparation treatment using herbicides to control beech understory was applied to most of these stands prior to cutting (Sage 1983). Shelterwood overstories were generally removed 5-10 years after the initial cut, however some were left remaining for experimental reasons. This management resulted in even-aged seedling/sapling stands with high stem densities and multiple species that ranged from 3 to 24 years of age (Kelty and Nyland 1981).

Approximately 25% of the study area was part of the state-owned Forest Preserve, where logging is prohibited. Most of these stands were uncut or were cut prior to 1920. However, selective logging occurred on some stands as late as 1958, before they were acquired by New York State.

METHODS

Food Abundance

We sampled the distribution and abundance of black bear food plants across the study area July-September 1989-91. Costello (1992) characterized bear foraging habits in this study area from analysis of scats and stomachs collected 1988-89 ($n = 358$) and from observations of foraging bears or bear sign during 1988-91. We wished to sample all bear foods, except those eaten in trace amounts. Therefore, we included all species identified by observation and those present in ≥ 2 scats/season (Table 1). Costello (1992) identified 3 foraging seasons based on plant phenology and recognizable shifts in food utilization: spring (den emergence-15 July), summer (16 July-31 August), and fall (1 September-den entry). We used the same seasons and separated foods based on the season of greatest use. Blackberry (*Rubus allegheniensis*) was designated a summer food and a fall food, because its ripening dates fell well into each season (R.W. Sage, Adirondack Ecological Center Spec. Rep. No. 15).

Sampling transects included 5-25 plots placed approximately 150 m apart by pacing. We recorded forest type (hardwood, mixed, lowland conifer, and upland conifer) and management type (nonmanaged, uneven-aged, even-aged) for each plot. We judged approximate time since logging in the field and verified age by consulting cutting maps and records. We

determined fire history from historical records and observable differences in species composition and size. Single, randomly-spaced plots were sampled in nonforested wetland habitats.

We measured basal area of all trees ≥ 11.3 cm diameter at breast height (DBH) using a 5-factor angle gauge. We measured DBH of beech, black cherry, pin cherry (*Prunus pennsylvanica*), and aspen. We counted saplings (1.4-11.2 cm DBH) by species on a circular 40.5-m² (0.01-acre) plot and measured DBH for pin cherry stems. Four 1-m² plots were placed 3.6 m (radius of sapling plot) from plot center and equidistant from each other. We recorded presence of plant species < 2 m tall in each plot. A rating of scarce (1-5 stems/m²), common (6-10 stems/m²), or abundant (> 10 stems/m²) was recorded for raspberry. A visual estimate of percent coverage of grass/sedge (Poaceae/Cyperaceae) in each plot was recorded.

We sampled raspberry fruit production in July 1989. We randomly placed 105 0.25-m² plots in 10 raspberry patches. Fruit-producing stems, nonproducing stems, and fruit were counted for each plot. Mean number of fruit/stem was calculated and used with stem data to estimate fruit abundance/area.

We also surveyed pin cherry fruit production in July 1989. We randomly selected 55 trees from 6 stands of varying age. After felling, we counted total fruit and measured DBH. Simple linear regression analysis was used to relate fruit production to DBH. The resulting equation (Costello 1992) was used with density data to estimate fruit abundance/area.

We estimated beechnut abundance/area using a model relating beechnut production to DBH and beech bark disease (Costello 1992). Black cherry fruit abundance/area was estimated from basal area using values obtained from Bjorkbom (1979).

Data were summarized by habitat type. Habitat types were assigned based on forest type, management type, stand age, and fire history. Habitats logged > 24 years prior to sampling were combined with undisturbed habitats and classified as nonmanaged, because only minor changes in structure and composition resulted from limited selective cutting (Richards and Farnsworth 1971).

Within each habitat, mean basal area/ha, mean number/ha, and mean occurrence were calculated for trees, saplings, and herb and shrub species, respectively. For balsam fir, white ash, and aspen, only size classes judged to be used by bears were used in analyses (Table 1). For example, use of white ash saplings was frequently observed, however no evidence that bears fed on large trees was found (Costello 1992).

Table 1. Black bear food plants sampled in the central Adirondack Mountains, New York, 1989-91.

Common name	Scientific name	Portion consumed	Data on use (Costello 1992)	Size class sampled (cm DBH)
Spring				
Aspen	<i>Populus</i> spp.	new leaves	$n > 10^a$	≥ 11.3
Balsam fir	<i>Abies balsamea</i>	new shoots	$n = 12$ (1%) ^b	1.4-11.2
Dewberry	<i>Rubus</i> spp.	fruit	$n = 5$ (<1%) ^b	
Grass/sedge	Poaceae/Cyperaceae	leaves	$n = 139$ (48%) ^b	
Helleborine	<i>Epipactis latifolia</i>	leaves	$n = 2^a$	
Jack-in-the-pulpit	<i>Arisaema triphyllum</i>	roots	$n = 2^a$	
Strawberry	<i>Fragaria</i> spp.	fruit	$n = 2$ (<1%) ^b	
White ash	<i>Fraxinus americana</i>	new leaves	$n > 10^a$	1.4-11.2
Wood fern	<i>Dryopteris</i> spp.	leaves	$n = 6$ (1%) ^b	
Summer				
Beaked hazelnut	<i>Corylus cornuta</i>	fruit	$n = 5$ (1%) ^b	
Blueberry	<i>Vaccinium</i> spp.	fruit	$n = 13$ (2%) ^b	
Pin cherry	<i>Prunus pennsylvanicus</i>	fruit	$n = 6$ (2%) ^b	≥ 1.4
Red raspberry	<i>Rubus ideaeus</i>	fruit	$n = 65$ (42%) ^b	
Shadbush	<i>Amelanchier</i> spp.	fruit	$n > 10^a$	≥ 1.4
Wild sarsaparilla	<i>Aralia nudicaulis</i>	fruit	$n = 17$ (7%) ^b	
Fall				
American beech	<i>Fagus grandifolia</i>	fruit	$n = 19$ (26%) ^b	≥ 11.3
Apple	<i>Malus</i> spp.	fruit	$n = 36$ (27%) ^b	≥ 1.4
Arrowwood/wild raisin	<i>Viburnum</i> spp.	fruit	$n = 2$ (<1%) ^b	
Blackberry	<i>Rubus allegheniensis</i>	fruit	$n = 2$ (<1%) ^b	
Black cherry	<i>Prunus serotina</i>	fruit	$n = 2$ (1%) ^b	≥ 11.3
Mountain-ash	<i>Sorbus americana</i>	fruit	$n = 2^a$	≥ 1.4
Winterberry	<i>Ilex verticillata</i>	fruit	$n = 18$ (10%) ^b	

^a Data from observations of foraging bears or bear sign 1988-91 (n = no. of observations).

^b Data from 355 scats and 3 stomachs collected during spring (n = 174), summer (n = 103), and fall (n = 81) of 1988-89 (n = no. of scats or stomachs collected during season containing food, number in parenthesis = % volume during season).

Mean number of fruit/ha was estimated for raspberry, pin cherry, black cherry, and beech. Mean percent coverage was calculated for grass/sedge. Significant differences in mean values were found using analysis of variance (ANOVA). Habitats having means that were not significantly different were pooled and a single mean was calculated.

We aspired to generate seasonal food abundance indices for each habitat that combined tree, sapling, occurrence, and fruit production data. To permit comparison of these various types of data, values were converted to a scale of 0-1 for each species. A value

of 1 was assigned to the habitat having the highest abundance of a given food and its abundance in other habitats was scaled relatively.

When each food was given a maximum value of 1, information regarding abundance of a species relative to other species was masked. For example, mountain-ash and beech would each receive a value of 1 in the habitat with highest abundance. However, mountain-ash is a rare species and beech is very common. To account for this, we multiplied each abundance value by a factor of 1-4, depending on its percent occurrence on plots in the habitat(s) rated 1. Species found on 1-25% of plots

were multiplied by 1, those found on 26-50% by 2, those found on 51-75% by 3, and those found on 76-100% by 4. These factored values were summed to produce seasonal food abundance indices for each habitat.

Habitat Use

Bears were trapped in steel culvert traps or foot snares May-July, 1989-91. They were immobilized with a 5:1 mixture of ketamine hydrochloride and xylazine hydrochloride, administered by jab pole or dart pistol. A lower premolar was removed for age determination (Willey 1974). Tooth sectioning and age determination were performed by NYSDEC personnel. Selected bears were fitted with radio-transmitter collars. All were released at the capture site.

We attempted to relocate radio-collared bears every 1-5 days by triangulation using hand-held, 2- or 4-element yagi antennas and a scanning receiver (Advanced Telemetry Systems Inc., 470 1st Ave. No., Box 398, Isanti, MN 55040). Aerial telemetry was used when bears were out of ground telemetry range and was conducted from a fixed-wing airplane using 2 aircraft-mounted, 4-element yagi antennas. Telemetry was conducted between dawn and dusk. Previous studies found that black bears were primarily diurnal and crepuscular (Amstrup and Beecham 1976, Garshelis and Pelton 1980).

Habitat types were delineated from forest management records, HWF forest type maps, aerial photographs, and U.S. Geological Survey (USGS) 7.5-minute orthophotoquads. Accuracy of designations was confirmed from vegetation sampling data. Habitat boundaries were digitized using EasyCad2 computer software (Montooth and Vening 1990).

We used Locate II computer software (Nams 1990) to analyze radio-telemetry data. This program plotted an error ellipse for each fix (calculated from average angle error) superimposed on the digitized habitat map. We determined habitat type for each fix by assigning the habitat encompassing the largest area within the error ellipse. If 2 habitats encompassed 50% of the ellipse, both were assigned and weighted by 0.5. Fixes with the dominant habitat encompassing <40% of the ellipse were discarded.

Differences between habitat use and habitat availability were determined using Chi-square and Bonferroni Z-tests (Neu et al. 1974). We calculated 95% convex polygon home ranges for each bear using program HOME RANGE (Ackerman et al. 1989) and formed a composite. Availability of habitats was determined within this composite home range.

RESULTS

Food Abundance

Nineteen food species were encountered during vegetation sampling. Species identified by Costello (1992), but not encountered were helleborine (*Epipactis latifolia*), apple (*Malus* spp.), and winterberry (*Ilex verticillata*). Data from 399 sample plots were summarized for 17 habitat types.

Abundance of grass/sedge did not differ among any habitats except the nonforested wetland ($P = 0.05$, $n = 399$), where percent coverage was nearly 20-fold higher.

Abundance of raspberry, pin cherry, and beech fruit differed by habitat, but black cherry abundance did not ($P = 0.05$, $n = 399$) (Table 2). Highest raspberry and pin cherry abundance was found in even-aged managed habitats cut ≤ 16 years prior to sampling. Raspberry abundance was also high in most uneven-aged managed habitats. Nonmanaged habitats had the lowest abundance of raspberry and pin cherry.

In contrast, beechnut abundance was highest in nonmanaged hardwood habitats, especially the 86-year-old burned habitat. Uneven-aged managed hardwood habitats had slightly lower abundance, but means did not differ from the nonmanaged (unburned) hardwood habitat ($P = 0.05$, $n = 399$). Beechnut abundance was lowest in mixedwood, conifer, and even-aged managed habitats.

Abundance of 10 other foods varied by habitat ($P = 0.05$, $n = 399$), but differences among habitats were not found for shadbush (*Amelanchier* spp.), beaked hazelnut (*Corylus cornuta*), blackberry, or mountain-ash. Relative abundance data for all species were used to generate food abundance indices for spring, summer, and fall (Table 3).

During spring, the upland conifer habitat had the highest index, resulting primarily from a substantially greater density of balsam fir saplings. High abundance of grass/sedge, dewberry (*Rubus* spp.), and jack-in-the-pulpit (*Arisaema triphyllum*) contributed to a large index value for the nonforested wetland. Index values among managed habitats ≥ 9 years old were also high. These values were primarily due to considerable quantities of white ash, wood fern (*Dryopteris* spp.), and jack-in-the-pulpit in these habitats. Indices for the burned habitats were low, however the mixedwood burned habitat had a greater mean basal area of aspen than all the other habitats ($P = 0.05$, $n = 399$).

Summer food abundance indices were largely influenced by raspberry and pin cherry abundance, therefore even-aged managed habitats had the highest

Table 2. Estimated fruit abundance (mean no. fruit/ha) within habitats sampled in the central Adirondack Mountains, New York, 1989-91. Means with same letter are not significantly different ($P = 0.05$).

Habitat	<i>n</i>	Red Raspberry	Pin Cherry	American Beech	Black Cherry
Nonmanaged					
Hardwood	56	15,147C	0B	406,629B	3,977A
Mixed	64	9,902C	3,797B	111,691C	25,080A
Lowland conifer	27	8,306C	8,640B	3,559C	12,264A
Upland conifer	7	0C	0B	6,834C	0A
Nonforested wetland	12	14,625C	0B	0C	0A
Even-aged managed					
Hardwood (1-8) ^a	11	732,636A	0B	18,945C	0A
Hardwood (9-16)	16	193,469B	400,804A	42,988C	0A
Hardwood (17-24)	28	111,250B	173,229B	87,505C	23,643A
Mixed (1-8)	8	683,813A	0B	106,640C	6,960A
Mixed (9-16)	22	516,375A	139,291B	3,903C	0A
Mixed (17-24)	18	54,111C	136,346B	122,263C	3,092A
Uneven-aged managed					
Hardwood (1-8)	41	289,232B	30,166B	335,606B	0A
Hardwood (9-24)	13	201,442B	0B	226,501B	0A
Mixed (1-8)	11	374,295B	0B	53,201C	0A
Mixed (9-24)	8	18,281C	116,088B	29,358C	27,620A
Burned and nonmanaged					
Hardwood (86)	37	13,439C	0B	497,122A	11,993A
Mixed (86)	20	36,075C	0B	113,857C	30,383A

^a Years since cut or burned.

indices. A notable exception was the mixedwood burned habitat. This habitat had significantly higher amounts of blueberry (*Vaccinium* spp.) and sarsaparilla (*Aralia nudicaulis*) than all other habitats ($P = 0.05$, $n = 399$).

Three of 5 fall foods did not differ among habitats ($P = 0.05$, $n = 399$), therefore differences in fall indices were due only to variation in beech and arrowwood/wild raisin (*Viburnum* spp.) abundance. Consequently, indices were highest in nonmanaged, burned, and uneven-aged managed hardwood habitats. Abundance of arrowwood/wild raisin was higher in the mixedwood burned habitat than in all other habitats ($P = 0.05$, $n = 399$), resulting in a moderate index value for that habitat, despite its low beechnut abundance.

Habitat Selection

Radio-telemetry data from 5 adult female bears were

used for analysis of habitat use. These animals were selected, because >10 usable fixes were obtained during each season of a given year for each animal. Data from males and subadult females were excluded from analysis because they did not meet this criteria.

A total of 512 fixes were obtained on the 5 females: 476 (93%) from ground telemetry and 35 (7%) from aerial telemetry. Fixes were obtained between 0440 and 2315 hours. More than half of the fixes were obtained before 1100 hours (31%) or after 1500 hours (22%). The remaining 47% were obtained between 1100 and 1500 hours.

Sizes of error ellipses for ground fixes varied dramatically (range 0.0009-2.74 km², $\bar{x} = 0.18$ km²), primarily in relation to the distance of bears from telemetry stations. Six (1%) of 512 fixes were discarded from habitat-use analysis, because the dominant habitat type encompassed <40% of the

Table 3. Seasonal black bear food abundance indices for habitats sampled in the central Adirondack Mountains, New York, 1989-91.

Habitat	<i>n</i>	Spring	Summer	Fall
Nonmanaged				
Hardwood	56	5.17	3.60	5.98
Mixed	64	4.18	3.60	3.63
Lowland conifer	27	4.18	3.60	3.63
Upland conifer	7	7.81	4.05	3.63
Nonforested wetland	12	7.50	3.60	3.63
Even-aged managed				
Hardwood (1-8) ^a	11	4.18	6.96	3.63
Hardwood (9-16)	16	7.12	7.39	3.63
Hardwood (17-24)	28	5.62	4.64	3.63
Mixed (1-8)	8	4.18	6.96	3.63
Mixed (9-16)	22	4.18	6.96	3.63
Mixed (17-24)	18	4.18	3.60	3.63
Uneven-aged managed				
Hardwood (1-8)	41	5.17	4.64	5.98
Hardwood (9-24)	13	7.12	4.64	5.98
Mixed (1-8)	11	4.18	4.64	3.63
Mixed (9-24)	8	6.58	4.05	3.63
Burned and nonmanaged				
Hardwood (86)	37	2.68	4.05	7.09
Mixed (86)	20	4.85	7.34	4.54

^a Years since cut or burned.

error ellipse.

Habitats that did not differ significantly for particular characteristics (e.g., abundance indices, fruit abundance) were grouped, and differences between use and availability of these pooled habitats was determined. In addition, habitats were combined by forest type and management type to determine how these factors affected use.

Spring habitat use differed from habitat availability ($\chi^2 = 47.24$, $df = 8$, $P < 0.0001$, $n = 169$). Habitats having an index of 7.12 and 2.68 were used more than expected and habitats with an index of 5.17 were used less than expected ($P = 0.05$, $n = 169$) (Fig. 1a). Use of the habitat with the highest grass/sedge abundance

(nonforested wetland) did not differ significantly from availability ($\chi^2 = 0.10$, $df = 1$, $P = 0.75$, $n = 169$) (Fig. 1b). Habitat use did not differ from availability by forest type ($\chi^2 = 3.46$, $df = 4$, $P = 0.33$, $n = 169$) (Fig. 1c), but differed by management type ($\chi^2 = 47.23$, $df = 3$, $P < 0.0001$, $n = 169$). Bears used even-aged managed and burned habitats more than expected and nonmanaged habitats less than expected ($P = 0.05$, $n = 169$) (Fig. 1d).

Summer habitat use differed from availability ($\chi^2 = 56.79$, $df = 5$, $P < 0.0001$, $n = 120$). Bears used habitats with the highest index (7.39) more than expected and habitats with the lowest index (3.60) less than expected ($P = 0.05$, $n = 120$) (Fig. 2a). When compared to summer fruit (raspberry and pin cherry) abundance, use differed from availability ($\chi^2 = 29.04$, $df = 1$, $P < 0.0001$, $n = 120$). Habitats with high fruit abundance were used more than expected and those with low abundance less than expected ($P = 0.05$, $n = 120$) (Fig. 2b). Use did not differ from availability by forest type ($\chi^2 = 3.20$, $df = 3$, $P = 0.36$, $n = 120$) (Fig. 2c), but differed by management type ($\chi^2 = 34.26$, $df = 3$, $P < 0.0001$, $n = 120$). Even-aged managed habitats were used more than expected and nonmanaged habitats were used less than expected ($P = 0.05$, $n = 120$) (Fig. 2d).

Fall habitat use did not differ from availability when compared to fall indices ($\chi^2 = 1.50$, $df = 3$, $P = 0.68$, $n = 217$) (Fig. 3a) or fall fruit (beechnuts and black cherry) abundance ($\chi^2 = 0.912$, $df = 2$, $P = 0.63$, $n = 217$) (Fig. 3b). Use differed from availability by forest type ($\chi^2 = 9.87$, $df = 3$, $P = 0.02$, $n = 217$), but did not by management type ($\chi^2 = 5.22$, $df = 3$, $P = 0.16$, $n = 217$) (Fig. 3d). Bears used hardwood habitats more than expected and nonforested habitats less than expected ($P = 0.05$, $n = 217$) (Fig. 3c).

Although use of nonmanaged habitats was not significantly different than availability during fall, there was an increase in use of these habitats compared to other seasons. Nonmanaged habitats, as a group, were used more during fall than during spring ($P = 0.05$, $n = 386$) or summer ($P = 0.05$, $n = 337$). In addition, percent use of the nonmanaged hardwood habitat more than doubled during the fall and was significantly higher than its use in spring ($P = 0.05$, $n = 386$) or summer ($P = 0.05$, $n = 337$).

DISCUSSION

Forest type, forest management, and fire profoundly affected the relative abundance of food plants across habitats. Seasonal changes in food abundance within

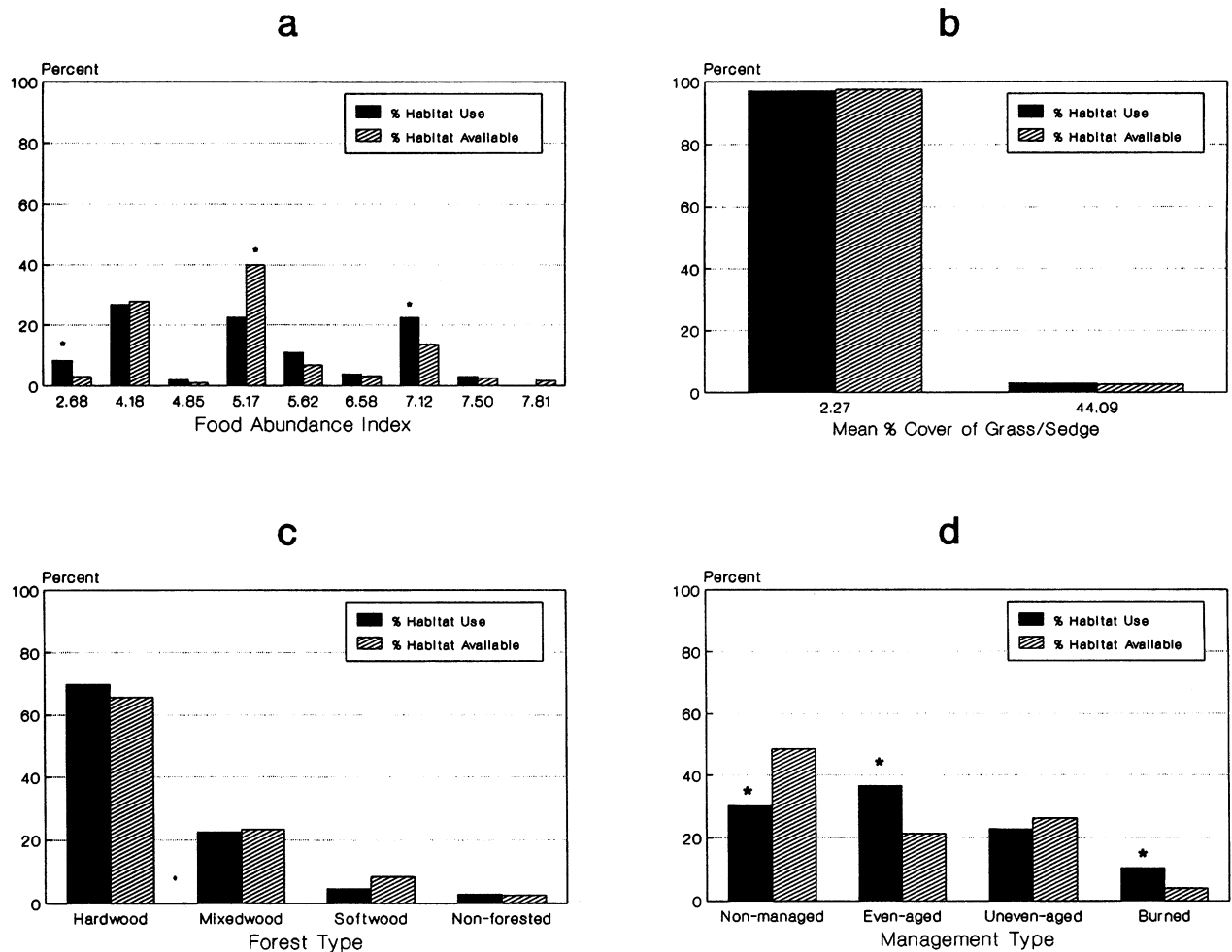


Fig. 1. Spring black bear habitat use compared to habitat availability in the central Adirondack Mountains, New York, 1989-91. Habitats are grouped by food abundance index (a), significant differences in grass/sedge abundance ($P = 0.05$) (b), forest type (c), and management type (d). Habitat-use values denoted with asterisks differ significantly from habitat availability ($P = 0.05$).

habitats were also considerable, thus almost all habitats were valuable during some time of the year.

A variety of foods were available in both hardwood and mixedwood forest types during all seasons, however relative abundance was affected by management and fire. In contrast, lowland conifer, upland conifer, and nonforested habitats displayed a general lack of food plant diversity.

Opening of the canopy after logging created conditions in managed habitats not found in nonmanaged habitats. Increased sunlight encouraged the growth of shade-intolerant shrubs, most importantly raspberry. Increases in soft mast production following cutting was reported for many regions (Rogers 1976, Lindzey and Meslow 1977, Arimond 1979, Clark et al. 1987, Noyce and Coy 1990).

Overstory removal also encouraged the establishment of shade-intolerant trees, such as white ash, pin cherry, aspen, and black cherry. Although black cherry regeneration in even-aged habitats was too young to fruit, high stem densities in these habitats (C.M. Costello, unpubl. data) indicate potential for high production of black cherries in the future (Marquis et al. 1975, Bjorkbom 1979). At age 85, even-aged managed habitats will probably most resemble the burned habitats, which had the highest abundance of aspen (significant) and black cherry (not significant).

Abundance of spring and summer foods was generally lower in uneven-aged managed habitats than in even-aged managed habitats, however bechnut abundance was substantially higher. Uneven-aged managed habitats were of moderate quality during all

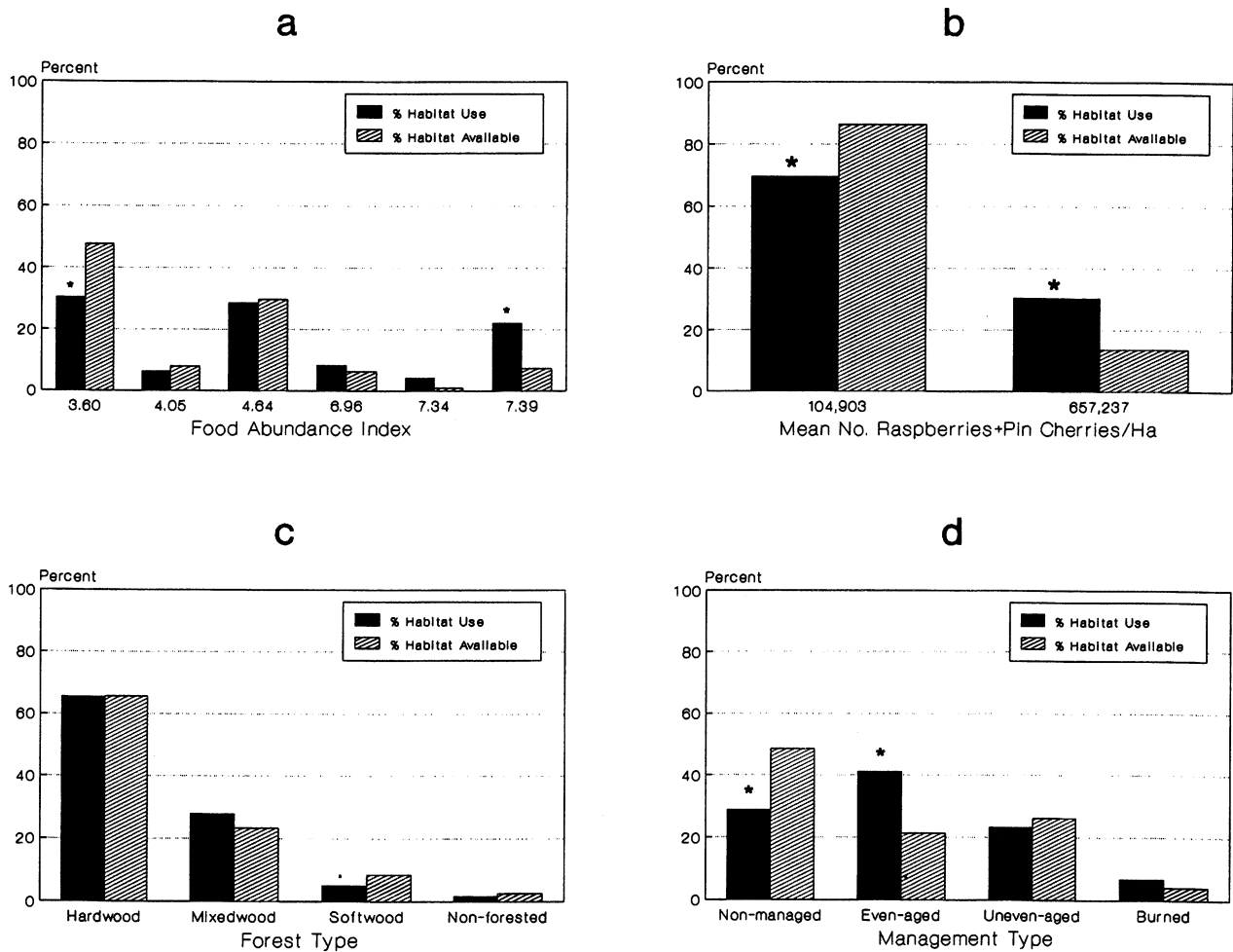


Fig. 2. Summer black bear habitat use compared to habitat availability in the central Adirondack Mountains, New York, 1989-91. Habitats are grouped by food abundance index (a), significant differences in raspberry and pin cherry abundance ($P = 0.05$) (b), forest type (c), and management type (d). Habitat-use values denoted with asterisks differ significantly from habitat availability ($P = 0.05$).

seasons, perhaps making year-round use of these habitats a viable alternative for some bears. Young and Beecham (1986) reported that bears preferred selectively logged areas during spring, summer, and fall in Idaho.

Burned habitats differed from both managed and nonmanaged habitats. The burned hardwood habitat had the highest production of beechnuts, and the burned mixedwood habitat had the highest abundance of aspen, sarsaparilla, blueberry, and *Viburnum* species. If the present composition of trees is an indication of post-fire regeneration, then young burned habitats probably resembled managed habitats, especially those under even-aged management. However, the amount of sarsaparilla, blueberry, and arrowwood/wild raisin

persisting in these habitats, even 86 years after the fire, indicated that conditions created by fire and forest management are not identical. Zager et al. (1983) reported that canopy cover of 6 mast-producing shrubs was generally higher on sites burned 35-70 years prior to sampling than on old-growth or clearcut sites.

Analysis of habitat-use data suggested that habitat selection by bears in this region was greatly influenced by food abundance. Seasonal shifts in habitat use corresponded with changes in food resources.

Grass and sedge constituted nearly 50% of the volume of spring scats collected during 1988-89 (Costello 1992). Nonforested wetlands provided the greatest amount of grass/sedge, but bears used this habitat only in relation to its availability. Bears did not

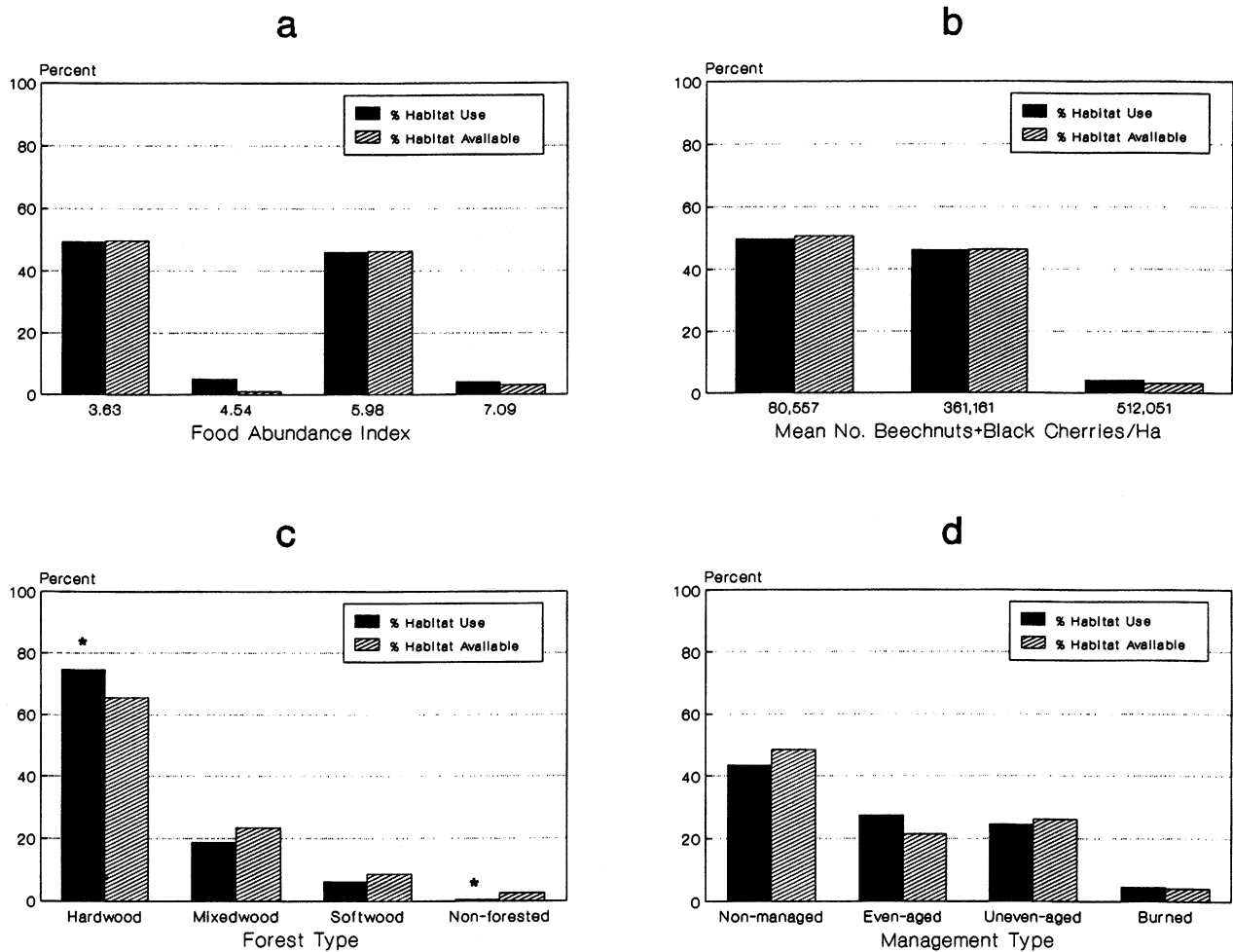


Fig. 3. Fall black bear habitat use compared to habitat availability in the central Adirondack Mountains, New York, 1989-91. Habitats are grouped by food abundance index (a), significant differences in beechnut and black cherry abundance ($P = 0.05$) (b), forest type (c), and management type (d). Habitat-use values denoted with asterisks differ significantly from habitat availability ($P = 0.05$).

use the upland conifer habitat at all during the spring season, despite its high index value. Balsam fir constituted over half of the abundance index value for upland conifer, and abundance of other species was moderate to low. Balsam fir was used minimally by bears during 1988-89, accounting for only 1% of spring scat volume (Costello 1992). This indicates that habitat selection based on fir abundance alone may not be beneficial to bears. Habitat selection based on diversity of foods may be more advantageous. We found that bears used managed hardwood habitats ≥ 9 years old more than expected, and these habitats provided an abundance of grass/sedge equal to most other habitats as well as maximum quantities of white ash, jack-in-the-pulpit, and wood fern.

Bears also used the burned hardwood habitat more than expected during spring, although its spring food index was low. High use of this habitat may be explained by its high fall index value. After an excellent beechnut crop in 1988, beechnuts were found in 40% of spring scats in 1989 (Costello 1992). The burned hardwood habitat had the highest beechnut abundance of any habitat type. The digestible and high-energy nature of hard mast compared to most other spring foods (Eagle and Pelton 1983, Hellgren et al. 1989) may favor utilization of beechnuts during spring, even following relatively poor fall production.

Raspberry fruit was the primary summer food during 1988-89, constituting over 40% scat volume during both years (Costello 1992). Evaluation of fruit crops based

on visual observation showed that raspberry production was high each year from 1988 to 1991 (Costello 1992). Stable production of fruit across years indicates it may be an important part of the summer diet each year. Pin cherry appears to be secondary to raspberry in importance, due to its lower productivity and yearly variation in abundance (Costello 1992). Pin cherry fruit constituted a small percentage of summer scats during 1988-89, however extensive use was observed in 1991 when the crop was plentiful (Costello 1992). Although several other fruit species were consumed during summer, abundance of these 2 species most notably affected habitat selection. Clearly, managed habitats, especially those resulting from even-aged management, were most valuable for providing summer fruit. Bears largely avoided nonmanaged habitats during this season, probably in response to the lack of soft mast.

Scat analysis data from 1988-89 and observations during 1990 and 1991 indicated that beechnuts were the primary fall food for bears in this region (Costello 1992). High use of hardwood habitats was observed during fall, but habitat selection based on food availability or management type was not indicated. Movement to hardwood habitats providing beechnuts during fall has been reported for Maine black bears (Hugie 1982, Schooley 1990).

During fall, 31% of fixes were located in the nonmanaged hardwood habitat. This percentage represents the highest use of any single habitat during any season. It also represents a two-fold increase in use of this habitat from spring or summer levels. However, use was not significantly different from availability. This habitat comprised the largest portion of the composite home range (28%). McLellan (1986) reported that use versus availability analyses rarely find common habitats selected for, even if they are used often. He recommended that the potential importance of these habitats be recognized. The high beechnut abundance in the nonmanaged hardwood habitat, coupled with its high percent use by bears, indicates that this habitat is important in this region for beechnut foraging. Numerous observations of "bear nests" in areas where radio-collared bears were located support this conclusion.

Significant differences in black cherry abundance were not found in our survey, preventing us from differentiating habitats on the basis of black cherry abundance. Costello (1992) observed extensive consumption of black cherries during the fall seasons of 1990 and 1991, when cherries were plentiful. Few

trees were found without bear sign. Availability of black cherry undoubtedly influences bear movements, however a preponderance of black cherry in any particular habitat was not apparent in our study area.

Apple and winterberry volume in fall scats was fairly high during 1988-89, but nearly all scats containing these foods were collected from a single abandoned homestead during 1989. Little evidence of consumption was observed in 1990 or 1991 (Costello 1992). The fact that neither species was encountered during habitat sampling verifies the limited availability of these foods. Apples are principally available only along roads where human habitation has occurred. Winterberries are found primarily along lakeshores and streambanks. This limited distribution probably means that apples and winterberries are consumed heavily by some bears, but rarely eaten by most bears.

Bears do not forage continuously, and other activities must also govern habitat selection. Mollohan et al. (1989) concluded that habitat selection in Arizona forests was based first on cover and secondarily on food. Little use of open wetlands was observed during our study, even during spring when food abundance was high. Although summer food abundance was nearly equal in younger versus older managed habitats, those cut 1-8 years ago were used less than those cut 9-24 years ago. It is possible that use of these habitat types was underestimated, because of their small patch sizes and the resolution of our telemetry data. However, it is equally possible that availability of escape and/or thermal cover may be a factor in habitat selection, and these habitats were lacking adequate cover. Lindzey and Meslow (1977) reported that bears avoided clearcuts ≤ 11 years old, even though soft mast was more abundant than in other habitats. They suggested that older clearcuts were used more often, because they offered bears cover as well as food. More information should be gathered about the cover requirements of bears in the Adirondacks.

Hamer and Herrero (1990) documented the use of summits and upper-elevation ridges by courting pairs of grizzly bears (*Ursus arctos*). These areas were not feeding habitat and bears evidently reduced food intake during the courting period. Mating activities were not directly observed during our study, but radio-relocation of male and female bears in close proximity was documented. In many cases, these pairs were located at relatively high elevations, suggesting a possible link to the observed behavior of grizzly bears. Information regarding mating, nursing, and cub-rearing habitat requirements is needed.

MANAGEMENT IMPLICATIONS

Availability of many habitat types within a home range appears to be beneficial to bears in this region. Habitat interspersed provides bears with foods during all seasons and may ensure the availability of alternative foods during years of mast failure.

Conifer forests and nonforested wetlands displayed a general lack of plant food diversity, and bears generally avoided these habitats. In contrast, a variety of foods were available in both hardwood and mixedwood forests. Relative abundance of these foods was profoundly affected by management and fire; and habitat selection by bears appeared to be influenced by this variation. Therefore, we encourage the integration of the 3 forest management systems for optimal black bear habitat management in areas like the Adirondacks. Modifications of current fire suppression procedures to allow some fires to occur may also contribute to long-term species and habitat diversity.

Nonmanaged forests favor the growth of shade-tolerant species. The most important of these to bears is American beech. Protection of forests with abundant mature beech should be a management priority in the Northeast, especially with the loss of beechnut production associated with beech bark disease (Costello 1992).

Extensive tracts of state-owned forest are protected in the Adirondack Park, assuring availability of nonmanaged forests to black bears. Goals in future land acquisition by New York State call for the purchase of lands which would connect and expand existing Forest Preserve parcels. This would result in large blocks of undisturbed forest lacking the habitat diversity of our study area. Our results suggest that this may not be the best alternative for black bears, as important spring and summer foods would be extremely limited in these blocks.

Uneven-aged forest management is commonly used in the Northeast for production of paper fiber, timber, and other wood products. Results of this study indicate that this management system is very compatible with black bear foraging needs. Small openings created by canopy removal permit establishment of shade-intolerant species, such as strawberry (*Fragaria* spp.), white ash, and raspberry. The presence of beech in the residual overstory, coupled with favorable light conditions for beech growth in the understory, also results in high beechnut abundance.

Currently, use of even-aged regeneration methods in hardwood and mixedwood forests is rare in the Adirondacks and relatively limited in the Northeast. However, the abundance and diversity of food plants

resulting from this management system, as well as its high yield of commercially valuable species (Kelty and Nyland 1981) make it an appealing option for forest managers in this region. The initial establishment of raspberry shrubs in great numbers is followed by the growth of pin cherry and white ash saplings. This 2-step development ensures that stands remain valuable to bears even after the initial "flush" of growth associated with cutting. Data suggest that aspen, black cherry, and beech may also be abundant in older stands resulting from even-aged management. However, silvicultural practices, such as site preparation, weeding, and thinning that discriminate against beech (such as those employed on HWF) should be avoided where beechnut availability is a priority.

Results of this study illustrate the difficulty in interpreting habitat-use data, especially with use versus availability analyses. Studies of habitat selection based on bear movements alone, without knowledge of habitat quality, may not render the information needed for optimal habitat management. We believe quantification of habitat quality parameters, such as food availability, is vital to understanding bear habitat selection.

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