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HABITAT SUITABILITY INDEX MODELS: BLACK BEAR, UPPER GREAT LAKES REGION

Fish and Wildlife Service

U.S. Department of the Interior

MODEL EVALUATION FORM

Habitat models are designed for a wide variety of planning applications where habitat information is an important consideration in the decision process. However, it is impossible to develop a model that performs equally well in all situations. Assistance from users and researchers is an important part of the model improvement process. Each model is published individually to facilitate updating and reprinting as new information becomes available. User feedback on model performance will assist in improving habitat models for future applications. Please complete this form following application or review of the model. Feel free to include additional information that may be of use to either a model developer or model user. We also would appreciate information on model testing, modification, and application, as well as copies of modified models or test results. Please return this form to:

Habitat Evaluation Procedures Group
U.S. Fish and Wildlife Service
2627 Redwing Road, Creekside One
Fort Collins, CO 80526-2899

Thank you for your assistance.

Species ______________ Geographic Location ______________________________

Habitat or Cover Type(s) ______________________________

Type of Application: Impact Analysis ____ Management Action Analysis _____
Baseline _____ Other ______________________________

Variables Measured or Evaluated ______________________________
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____
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Was the species information useful and accurate? Yes ____ No ____

If not, what corrections or improvements are needed? ____________________
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____
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Were the variables and curves clearly defined and useful? Yes ____ No ____

If not, how were or could they be improved? ______________________________

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Were the techniques suggested for collection of field data:

Appropriate? Yes ____ No ____
Clearly defined? Yes ____ No ____
Easily applied? Yes ____ No ____

If not, what other data collection techniques are needed? ______________

____

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Were the model equations logical? Yes ____ No ____
Appropriate? Yes ____ No ____

How were or could they be improved? ______________________________

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Other suggestions for modification or improvement (attach curves, equations, graphs, or other appropriate information) ______________

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Additional references or information that should be included in the model:

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Model Evaluator or Reviewer ________________________ Date ____________

Agency ____

Address ____

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Telephone Number Comm: ____________________ FTS ____________________

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September 1987

HABITAT SUITABILITY INDEX MODELS: BLACK BEAR, UPPER GREAT LAKES REGION

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PREFACE

This document is part of the Habitat Suitability Index (HSI) model series [Biological Report 82(10)], which provides habitat information useful for impact assessment and habitat management. Several types of habitat information are provided. The Habitat Use Information section is largely constrained to those data that can be used to derive quantitative relationships between key environmental variables and habitat suitability. This information provides the foundation for the HSI model and may be useful in the development of other models more appropriate to specific assessment or evaluation needs.

The HSI Model section documents the habitat model and includes information pertinent to its application. The model synthesizes the habitat use information into a framework appropriate for field application and is scaled to produce an index value between 0.0 (unsuitable habitat) and 1.0 (optimum habitat). The HSI Model section includes information about the geographic range and seasonal application of the model, its current verification status, and a list of the model variables with recommended measurement techniques for each variable.

The model is a formalized synthesis of biological and habitat information published in the scientific literature and may include unpublished information reflecting the opinions of identified experts. Habitat information about wildlife species frequently is represented by scattered data sets collected during different seasons and years and from different sites throughout the range of a species. The model presents this broad data base in a formal, logical, and simplified manner. The assumptions necessary for organizing and synthesizing the species-habitat information into the model are discussed. The model should be regarded as a hypothesis of species-habitat relationships and not as a statement of proven cause and effect relationships. The model may have merit in planning wildlife habitat research studies about a species, as well as in providing an estimate of the relative suitability of habitat for that species. User feedback concerning model improvements and other suggestions that may increase the utility and effectiveness of this habitat-based approach to fish and wildlife planning are encouraged. Please send suggestions to:

Resource Evaluation and Modeling Section
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BLACK BEAR (*Ursus americanus*)

HABITAT USE INFORMATION

General

The prevailing characteristic of black bear (*Ursus americanus*) habitat is forest cover interspersed with small clearings and early stages of forest succession (Herrero 1979; Hugie 1979). The black bear's original range essentially coincided with forested regions throughout North America (Pelton 1982). The local status and density of the species in its current range varies from abundant to only remnant populations surviving in islands of relatively inaccessible habitat (Cowan 1972; Maehr and Brady 1984). Black bears exhibit variation in habitat use and population dynamics both within and among geographic regions (Reynolds and Beecham 1980). The black bear's ability to inhabit a broad diversity of physiographic and vegetative associations is partly due to its ability to hibernate during winter periods of food scarcity (Hamilton and Marchington 1980). Climate, soil, and topography influence the quantity, quality, and distribution of food, which is the major determining factor of home range size; daily, seasonal, and annual movements; and use of vegetative associations (Jonkel and Cowan 1971; Amstrup and Beecham 1976; Garshelis and Pelton 1980; LeCount 1980; Reynolds and Beecham 1980; McArthur 1981; Elowe 1984; Rogers 1987). The productivity of a black bear population is a function of habitat quality and is independent of density (Bunnell and Tait 1981; Rogers 1987). Knowledge of factors that limit black bear populations is essential for proper management of the species and its habitat (Rogers 1976).

Food

Black bears are opportunistic omnivores whose diet is dominated by easily digested vegetative foods (Rogers 1976; Herrero 1978, 1979). They are highly adapted for living on fruits, nuts, acorns, insects, and other small items that are high in nutrients and low in cellulose (Rogers 1987). The black bear's omnivorous food habits have frequently, but incorrectly, led to the conclusion that an adequate food supply will be available to the species even if few high quality, preferred foods are available (Rogers 1976; Herrero 1979). However, black bears are limited by a poor ability to digest cellulose and to capture large vertebrates (Rogers 1987). Bears cannot efficiently digest cellulose, due to their lack of a cecum and rumen, and they avoid plants high in this material (Mealey 1975; Rogers 1976; Dierenfeld et al. 1982). Green vegetation is consumed mainly during the early sprouting, pre-flowering, or early flowering stages when protein is high, cellulose is low, and many of the nutrients are still available in plant fluids, which are easily digested (Mealey 1975; Herrero 1979; Rogers 1987). Plants in this stage of growth are found mainly in spring, although a few succulents, legumes, and other plants are consumed later in summer, especially in years when fruits and nuts are scarce (Tisch 1961; Poelker and Hartwell 1973; Rogers 1987). Animal matter normally composes only a small portion of the diet but can compose the bulk of the diet for short periods. Colonial hymenopterans (ants, wasps, and bees) are the most commonly eaten animal food and may compose over half the diet in late spring and early summer when vegetation is maturing and berries are not yet ripe (K.V. Noyce, Minnesota Department of Natural Resources, Grand Rapids; letter dated June 22, 1987; L.L. Rogers and G.A. Wilker, North Central Forest Experiment Station, Ely, MN, unpubl. data). Carrion is scarce over much of the black bear's range (Rogers 1987). Predation on vertebrates is uncommon and involves mainly the capture of newborn deer (*Odocoileus* spp.) (Ozoga and Verme 1982), moose (*Alces alces*) (Chatelain 1950; Franzmann and Schwartz 1980; Wilton 1984), and elk (*Cervus elaphus*) (Schlegel 1976); nestling birds (Rowan 1928); spawning fish (Frame 1974); or animals whose escape is hampered (Barmore and Stradley 1971; Cardoza 1976). Crops, orchard fruits, and feral fruits such as apples (*Malus* spp.), are localized and sometimes important supplements to natural foods. Consumption of agricultural crops typically increases during periods of poor production of natural foods (Lindzey et al. 1976; Rogers 1976; Hamilton 1978; Elowe 1984).

The annual cycle of plant growth and fruiting dictates the black bear's annual cycle of feeding and habitat use because most of the diet is plant material (Ewer 1973; Johnson and Pelton 1980). Black bears must fulfill their nutritional needs for the entire year in a 5- to 8-month period throughout much of their range (Beeman and Pelton 1980). After emergence from dens in spring, black bears generally remain lethargic until newly sprouting vegetation is available (Johnson and Pelton 1980; Rogers 1987). Black bears gain weight rather slowly on the spring and early summer diet of vegetation and insects (Jonkel and Cowan 1971; Pelton and Burghardt 1976; Beeman and Pelton 1980). Weight gain is most rapid when soft mast and hard mast become available in summer and fall, respectively (Rogers 1976, 1983, 1987; Alt et al. 1980). Soft mast is high in sugars and other carbohydrates, and hard mast is high in fats and protein (Roehl 1984). These foods enable recovery of energy deficits incurred during winter and spring (Jonkel and Cowan 1971; Rogers 1987).

Hard mast is scarce in the northern coniferous forest region that composes the northern portion of the black bear's range in North America. Thus, nutritious fall foods are scarce for bears, and weight is gained primarily from a diet of fruit in summer. Hard mast is generally more abundant in the eastern deciduous forest, which enables bears to gain weight rapidly in fall. The additional period of fall growth enables bears in the East to achieve more growth per year, become heavier, reproduce at an earlier age, reproduce at shorter intervals, and produce more cubs per litter (Alt et al. 1980; Kordek and Lindzey 1980; Rogers 1987). Similar differences also occur between eastern and western habitats (Bunnell and Tait 1981). A further indication of the importance of hard mast is that annual variations in hard mast production in a given region cause major annual differences in black bear reproductive success, habitat use, and movements (Jonkel and Cowan 1971; Garshelis and Pelton 1980; Kellyhouse 1980; Elowe 1987; Rogers 1987). Pregnant females give birth only if they reach and maintain an adequate state of nutrition prior to the denning period (Rogers 1976). Of females >5 years of age in Minnesota, 33% produced cubs following years of scarce food, 44% did so following years of moderate food availability, and 59% reproduced following years of abundant food (Rogers (1976). Food supply influences the growth and development of black bears more during their first year than at any other time in their life (Rogers 1976). More than 90% of cub and yearling mortality in Minnesota was attributed directly to a scarcity of high quality natural foods. Better nourished bears developed more rapidly, whereas lightweight bears suffered greater mortality (Rogers 1987).

Black bears that find abundant food may become obese and abandon available food earlier than usual to retire to dens (Matson 1946; Rogers 1987). In northern Minnesota, obese bears commonly retire to dens in September and early October (Rogers 1987). Less-fat bears in Minnesota or elsewhere may retire just as early if nutritious food is unavailable or, if food is available, will continue to feed until it becomes unavailable later in fall or early winter (Jonkel and Cowan 1971; Herrero 1978, 1979; Johnson and Pelton 1980; Tietje and Ruff 1980; Rogers 1987). Generally, fall food abundance is determined by fall mast abundance. Black bears in Maine denned earlier than expected as a result of a poor beechnut (Fagus grandifolia) crop (Lamb 1983). Black bears that fed on acorns (Quercus spp.) in Ontario denned later than nonacorn feeders (Kolenosky and Strathern 1986). In more southern ranges, bears with low stored body fat remained active throughout the winter, feeding on corn (Zea mays) and other foods (Carpenter 1973; Matula 1974; Hamilton and Marchington 1980).

Localized failure in mast production, or a regional scarcity of key fall foods, results in longer distances for foraging, increased likelihood of depredation on crops, and attraction to human-related food sources such as dumps and residential areas. These factors precipitate a higher occurrence of bear/human interaction (Harger 1967; Bray 1974; Rogers 1976, 1987; Rogers et al. 1976; Hugie 1979; Landers et al. 1979; Beeman and Pelton 1980), and a greater possibility of cannibalism (Tietje et al. 1986). Human-related mortality of black bears in Wisconsin was greatest when natural foods were scarce (Rogers 1976). Failures in late summer-fall foods, primarily blueberries (Vaccinium spp.) and red oak (Q. rubra) acorns, correlated with marked increases in bear damage to farm crops, livestock, and apiaries. The number of bears killed as a result of such activities exceeded 100 animals only in years in which berry and acorn production was <25% of the normal fall crop.

The availability and nutritional quality of food were thought to be the primary influence on the distribution and social relationships of adult black bears in Minnesota (Rogers 1977, 1987). The black bear's ability to successfully exploit a wide variety of habitats across its extensive North American range can be partially attributed to its adaptable social behavior. Although mature females are territorial and mature males are normally solitary, the species is adaptable in that individuals become integrated into social hierarchies and feed in aggregations where preferred foods are locally abundant (Herrero 1978, 1979; Rogers 1987). This adaptation permits the maximum exploitation of foods that are clumped in distribution or available for only short periods of time (Rogers 1987).

Water

Water must be readily available and well distributed throughout the year if black bears are to use an area in an unrestricted manner (Hugie 1979). Black bears drink frequently when feeding on vegetation, nuts, or insects but seldom when feeding on berries (Rogers and Wilker, unpubl.). They wallow to cool off on hot days in all seasons (Kellyhouse 1980; Rogers and Wilker, unpubl.). Heat stress may be a factor preventing full utilization of forest openings on sunny days (Jonkel and Cowan 1971; Rogers 1980).

Wetland and riparian habitats are used for cooling and provide essential seasonal foods (Landers et al. 1979; Alt et al. 1980; Kellyhouse 1980; Reynolds and Beecham 1980; Elowe 1984; Young 1984), den sites (Landers et al. 1979; Hamilton and Marchington 1980; Manville 1983, 1986), escape and security cover (Lindzey et al. 1976; Landers et al. 1979; Manville 1983; Smith 1985), and travel corridors (Kellyhouse 1980; Elowe 1984).

Cover

In broad terms, preferred black bear habitat is forest interspersed with numerous openings and small clearings that provide a high degree of edge and diversity in vegetative associations (Herrero 1979; Hugie 1979). With the exception of mast producing trees, the most productive forest areas are relatively open stands or openings (Hugie 1979). Closed canopies provide security and escape cover but typically support a reduced understory that produces little fruit. Habitat use patterns often reflect the distribution of available food resources (Amstrup and Beecham 1979; Landers et al. 1979). The search for food is the ultimate reason behind many of the black bear's movements and use of vegetative associations (McArthur 1981; Rogers 1987).

Throughout the black bear's range, habitat is characterized by relatively inaccessible terrain, dense understory, and abundant food resources predominated by hard and soft mast (Pelton 1982). The combination of adequate food and extensive inaccessible terrain typically equate to a relatively large geographic area with a variety of cover types and vegetative associations (Landers et al. 1979). The disappearance of large, relatively uninhabited, tracts of land and ensuing conflicts with human interests is the primary reason behind the decline of black bear populations in the eastern portion of the species' range (Cowan 1972; Cardoza 1976; Pelton and Burghardt 1976; Collins 1978; Raybourne 1978; Willey 1978; Lentz et al. 1980; Manville 1983). Habitat loss, as a result of human habitation and conversion of forested and wetland cover types to agriculture, has forced bears to inhabit smaller geographic areas, with a resulting decline in the overall bear population (B.W. Conley 1978; R.H. Conley 1978).

In the lower peninsula of Michigan, white cedar (*Thuja occidentalis*), balsam fir (*Abies balsamea*), black spruce (*Picea mariana*), and tamarack (*Larix laricina*) dominated wetlands were used year-round (Manville 1983). Lowland brush [e.g., willow (*Salix* spp.), alder (*Alnus* spp.)] and hardwood communities, as well as upland hardwoods including aspen (*Populus* spp.), must be available in relatively large blocks to insure provision of black bear habitat requirements and maintenance of populations. Conifer-dominated wetlands contained 68% of the dens found (Manville 1986).

Oak-hickory (Carya spp.) and mixed mesophytic forests with dense understories are primary black bear habitats over much of the southeastern United States (Pelton and Nichols 1972; Pelton 1982). In the coastal plains of the Southeast however, black bears are associated with a combination of Carolina bays (palustrine wetlands within elliptical depressions), hardwood swamps, and sand ridges (Landers et al. 1979). Escape cover may be the most critical habitat component in this region, due to the density of the human population. The best escape cover in this region is hardwood swamps, but this habitat provides significant food only in early spring [arrow arum leaves (Peltandra virginica)] and early fall [black gum (Nyssa sylvatica) mast] (Landers et al. 1979). Carolina bays dominated by mixed pine communities and shrub bogs (Shartz and Gibbons 1982) provide the great majority of the annual diet and receive the greatest amount of use (Landers et al. 1979; Hamilton and Marchington 1980). The clearing of these bays and the conversion of surrounding oak and longleaf pine (P. palustris) ridges to slash pine (P. elliottii) plantations results in reduced mast production and probably increases the black bear's dependence on the wetland hardwood communities (Landers et al. 1980; Williamson et al. 1980). Wetland hardwood communities, however, contain fewer foods and have more frequent failures in mast production, which results in increased winter activity, increased emigration, poor physical condition, and greater contact with humans (equating to higher mortality) (Williamson et al. 1980).

In Florida, much of the fertile upland habitat has been converted to agriculture. The remaining habitat is largely lowland, which is important as escape cover. In southern Florida, black bears are most commonly associated with "impenetrable" thickets, vine-choked bays, and "bay galls" (Williams 1978). Forested wetlands and cyrilla (Cyrilla racemiflora) swamps provide important habitat in central Florida and the panhandle, respectively (Williams 1978). The conversion of mast producing flatwoods and hardwood communities to slash pine plantations and the winter burning of understory growth decreases black bear habitat quality (Maehr and Brady 1984).

In portions of the northeastern United States where the human population is moderate to high, black bear habitat is largely restricted to mountains. Prime habitats are associated with beech, maple (Acer spp.), birch (Betula spp.), and coniferous forests (Pelton 1982). In the less populous areas of northeastern Pennsylvania, the primary cover is provided by numerous small forested wetlands surrounded by upland hardwoods (Hugie 1979; Alt et al. 1980). Forested and shrub-dominated wetlands compose only 5% of the land but support 70% to 80% of the bears (Hugie 1979). These wetlands are being drained, cleared, or flooded, however, reducing the quantity and quality of bear habitat.

Reproduction

Birth and early maternal care of cubs takes place in dens during hibernation, usually in January. Tree cavities are preferred maternal den sites (Jonkel and Cowan 1971; Johnson et al. 1978; Lentz 1980; Lentz et al. 1980; Rogers 1987). The benefits of tree dens include decreased vulnerability to predation, lower probability of human disturbance, lower probability of flooding by rain or meltwater, and greater thermal protection, which permits more energy to be allocated to parturition and lactation (Johnson et al. 1980; Lentz et al. 1980; Pelton et al. 1980). Preferred dens in Tennessee were cavities 6 to 17 m above ground in large-diameter (average dbh = 97.1 cm) trees in mature stands of northern and lowland hardwood forest types (Pelton et al. 1980; Johnson and Pelton 1981). Eastern hemlock (*T. canadensis*), oak, and maple were most commonly used (Pelton and Burghardt 1976). In Georgia, 72% of dens were in hollow trees, typically chestnut (*Castanea* spp.), chestnut oak (*Q. prinus*), or southern red oak (*Q. falcata*) (Lentz et al. 1980). Landers et al. (1979) reported that all standing hollow trees in their North Carolina study area showed signs of having been investigated by black bears, but most of them contained water and were unsuitable as dens. The authors speculated that the scarcity of suitable tree dens explained why some bears "denned" on the ground surface.

Areas containing abundant, well distributed tree dens may serve as important maternity denning areas and centers from which juvenile bears may disperse (Johnson and Pelton 1981). Watersheds in Tennessee that contained the most tree dens had a higher proportion of adult females and a higher density of bears than did other watersheds (Johnson and Pelton 1981). Tree dens may afford an extra margin of protection necessary to maintain viable populations in islands of dwindling or marginal habitat (Pelton and Burghardt 1976; Johnson and Pelton 1981). Extensive logging on short rotations will decrease the availability of preferred den sites due to the elimination of snags, down trees, and large, mature trees (Lindzey and Meslow 1976). A decrease in preferred sites does not necessarily cause a decline in bear numbers, however, because the black bear is flexible in its use of dens.

In second growth forests that do not contain large, hollow trees bears spend the winter and give birth in caves, rock crevices, burrows, slash piles, and downfall as well as other forest debris (Erickson et al. 1964; Jonkel and Cowan 1971; LeCount 1980; Rogers 1980, 1987; Lamb 1983; Elowe 1984). Black bears have also used culverts (Barnes and Bray 1966) and basements (Jonkel and Cowan 1971) as den sites. Exposure and slope or aspect of den entrances apparently does not influence selection of den sites (Lindzey and Meslow 1976; Elowe 1984). Some bears even hibernate and give birth to surviving cubs in nests on the ground surface (Erickson et al. 1964; Rogers 1987). In second growth forests in northeastern Minnesota, a lack of elevated tree dens did not significantly reduce overwinter survival (Rogers 1981, 1987). Less than 1% of the bears died overwinter. Winter flooding was not a problem, and winter disturbances by humans or domestic dogs were uncommon. However, a mother and newborn cubs were killed by wolves (*Canis lupus*) in a surface den (Rogers and Mech 1981). There was no evidence that den sites were limiting in the study area at current levels of human disturbance (Rogers 1987). The need for den security to avoid people or dogs is minimized in the snowy northern States because human use of the forest is minimal in winter, and most existing use is confined to roads and trails. Young (1984) also concluded that den sites were not limiting in his Idaho study area where 60% of the dens were in caves and rock crevices. In milder regions, however, winter flooding of nonelevated maternal dens can increase cub mortality during rain or thaws. Alt (1984) reported drownings of cubs in ground dens in Pennsylvania, and Johnson and Pelton (1980) reported that adults abandoned dens after hard rains in Tennessee.

In mild regions, hibernation periods are shorter and the bears achieve a less profound state of hibernation (Rogers 1987). In response to more moderate winter weather and increased availability of food, the black bear's length of hibernation generally decreases southward throughout its range. Some bears, especially subadult males, remain more or less active all winter and do not excavate dens or insulate them with vegetative material to the extent that northern bears do (Taylor 1971; Hamilton and Marchington 1980). Adult males in Tennessee were less likely to use elevated tree dens than were females and subadults of both sexes (Johnson and Pelton 1981). Adult males tend to be the last to enter dens (Lindzey and Meslow 1976; Tietje and Ruff 1980).

Although black bears may make extensive movements throughout the summer and fall, they typically return to their established home range to den. Ninety-seven percent of females and 87% of males monitored in Minnesota returned to their home ranges to establish dens subsequent to extensive summer and fall wanderings (Rogers 1987). Only a small percentage of dens is reused (Tietje and Ruff 1980; Alt and Gruttaduria 1984; Rogers 1987); however, they often are established within a relatively small area of the home range from year to year (Rogers 1987).

Interspersion and Composition

Black bear home ranges normally contain the resources required to satisfy the physical needs of the species, and the area is familiar, so the resources are efficiently used (McArthur 1981). Although black bear home ranges overlap between sexes (Novick 1979; Reynolds and Beecham 1980), the home ranges of males are substantially larger than those of females and may contain portions of numerous female home ranges (Landers et al. 1979; Alt et al. 1980; Reynolds and Beecham 1980; Rogers 1987). The home ranges of male bears often overlap extensively (Jonkel and Cowan 1971; Young 1977; Rogers 1987). Minimum home range overlap for male bears in Idaho was 54% to 100%, whereas female ranges overlapped 34% to 89% (Reynolds and Beecham 1980). Home ranges among female black bears in Alberta were largely exclusive, with only about 12% overlap (Fuller and Keith 1980). Extensive overlap was found on Vancouver Island, which had the densest population studied (Lindzey and Meslow 1977a,b).

Black bear home ranges vary based on age, sex, season, population density, and the overall ability of an area to meet the year-round requirements of the species (Pelton 1982). Males are more mobile than females (Erickson 1964; Amstrup and Beecham 1976; Rogers et al. 1976; Young 1977; Kohn 1982). Although some subadult females disperse, the majority establish home ranges near their birthplace (Elowe 1987; Rogers 1987). Sows tolerate subadult females within their territories and often avoid the area in which a subadult establishes her territory (Jonkel and Cowan 1971; Rogers 1987). All female cubs that survived to adulthood in Massachusetts established territories within the territories of the maternal sows (Elowe 1987). Males normally disperse from the natal home range at 1 to 3 years of age regardless of food availability, presence or absence of other males, or whether or not their mother is still alive (Rogers 1987). Nuisance bears frequently are dispersing subadult males, which may move ≥219 km before settling (Rogers 1976, 1987; Lentz et al. 1980).

Movements of females with cubs may be restricted for up to 4 months after leaving the den (Lindzey and Meslow 1977). Their small size, restricted mobility, and requirement for frequent periods of rest probably contribute to the restricted activity of sows with cubs in early spring (Garris and Pelton 1984). Sows with cubs show an increase in activity and movements from spring through fall. In Minnesota, sows with cubs-of-the-year foraged outside of their established home ranges as frequently as did females without cubs (Rogers 1987). The longest recorded movements by females were those of two sows with cubs-of-the-year. Annual home ranges of females with cubs in Pennsylvania were larger (45 km^2) than those of solitary females (20 km^2) (Alt et al. 1976, 1980). In Pennsylvania, movements increased from spring through summer with maximum movements in September. Late summer movements lasted from a few days to more than a month, leading bears as far as 35 km outside their usual home ranges. In Minnesota, mothers with cubs traveled up to 107 km outside their usual home ranges, and adult males traveled up to 200 km outside their usual home ranges (Rogers 1987). In both States, bears normally returned to their usual ranges as the time for hibernation approached.

The value of an area as black bear habitat is directly related to the availability of food, water, concealment, and escape cover (Hugie 1979). Ideal food conditions correspond to a high degree of interspersion of cover types containing foods for all seasons of activity. Norton (1981) reported that black bears in Wisconsin showed no strong habitat preferences but were found most often in areas composed of a diversity of cover types. Use of cover types was attributed chiefly to the availability of food. The greatest number of adult male black bears captured in an Arkansas study were in the portion of the study area that had the greatest diversity in habitat components (Smith 1985).

Behavioral, nutritional, and human influences govern black bear population density (Rogers 1987). On a populationwide scale, density appears to be limited by human-related mortality and by reproductive failure and starvation resulting from a lack of nutritionally adequate foods. The territorial system of black bears does not appear to be rigid but fluctuates in response to the distribution and abundance of food resources (Rogers 1987). During periods of food scarcity, bears will forage over a greater area (Pelton and Burghardt 1976; Rogers 1987). The intensity and extent of movements is directly related to food availability. Poor mast production results in black bears moving farther from established summer ranges in search of food (Pelton and Burghardt 1976; Rogers 1976, 1987). Concentrations of seasonally available foods provide the stimulus for extensive movement, especially during late summer and fall.

Table 1 provides a summary of estimated black bear home ranges and densities within major vegetative associations in the eastern United States. Home ranges vary due to food supply, quality, and distribution; season; sex; and age, making direct comparisons among study results difficult. Nevertheless, differences remain due to regional variation in the distribution and abundance of food (Lindzey and Meslow 1977b; Rogers 1987). Jonkel and Cowan (1971) concluded that greater diversity of topography, climate, and vegetation resulted in smaller black bear home ranges in Montana than in eastern deciduous forest habitats.

Special Considerations

Timber harvest. Timber harvest can have positive or negative impacts on black bears and their habitat. Logging practices help maintain essential diversity in vegetative communities and can increase or maintain the productivity and abundance of key food plants. In Washington, berry producing shrubs were more productive and seven to eight times more abundant in logged areas than in nonharvested forest (Lindzey and Meslow 1977b). Similarly, in Minnesota, berry production in mixed upland stands that had been thinned to <800 trees/ha was nearly twice (70 kg/ha vs. 35 kg/ha) that found in stands with more than 1,000 trees/ha (Arimond 1979). An area that was burned after harvest produced 356 kg/ha, with blueberries being the dominant species (Arimond 1979). Jonkel and Cowan (1971) found increased production of berries following selective harvest in the spruce-fir forest of Montana. The early stages of forest succession in Michigan produce more chokecherries (*Prunus virginiana*), pin cherries (*Prunus pensylvanica*), blackcap raspberries (*Rubus occidentalis*), blueberries, and serviceberries (*Amelanchier* spp.) than do more mature forests (Manville 1983). Regeneration and growth of understory and seral vegetation varies with site, aspect, and elevation even though silvicultural prescriptions may be identical (Kellyhouse 1980; Irwin and Hammond 1985).

Despite the abundance of food in some logged areas, black bears may avoid the centers of those areas because of the absence of forest cover for shade and escape (Jonkel and Cowan 1971). McCollum (1973) found a dramatic decline in use of clearcuts beyond 183 m of forest cover. Hugie (1982) reported little use beyond 125 m of forest cover. J. Kesel (U.S. Fish and Wildlife Service, Seney, MI; pers. comm.) however, saw a mother with four cubs feeding in an oat (*Avena sativa*) field nearly 400 m from forest cover. In Montana and California, avoidance of clearcuts was not noticeable after 10 years of regrowth (Jonkel and Cowan 1971; Kellyhouse 1980). In Washington, black bears preferred 14- to 23-year-old clearcuts over clearcuts 5 to 12 years old or those older than 38 years (Lindzey and Meslow 1977b). Cover strips penetrating into clearcut areas will enhance the use of open areas by black bears (Lindzey and Meslow 1976), especially mothers with cubs (Herrero 1979).

Table 1. Summary of estimated home range size and density of black bears (am = adult male; af = adult female; sm = subadult male; sf = subadult female; afc = adult female with cubs). Estimates of home ranges are not comparable within or between regions due to variations in methodology and sample size. Habitat association follows Ecoregion descriptions of Bailey (1980). Individual references provide more precise descriptions of habitat and vegetative associations.

Region	Estimated home range or density	Habitat association	Reference
<u>Great Lakes</u>			
Michigan, upper peninsula	average minimum annual home range am 38.9 km^2	Northern hardwoods-fir forest	Erickson (1964)
Michigan, upper peninsula	11 bears/100 km^2	Northern hardwoods-fir forest	Erickson et al. (1964)
Michigan, lower peninsula	average home range am 150.4 km^2 af 68.9 km^2	Northern hardwoods forest	Manville (1983)
Minnesota	early summer range am 75 km^2 22 bears (including cubs)/100 km^2	Spruce-fir forest	Rogers (1987)
Minnesota	17 bears (excluding cubs)/100 km^2	Spruce-fir forest	Garshelis (1986)
Wisconsin	22 bears/100 km^2	Northern hardwoods forest	Norton (1981)
Wisconsin	minimum home range am 71.5 km^2 af 13.7 km^2 26 bears/100 km^2 (in prime range)	Northern hardwoods forest	Kohn (1982)

(Continued)

Table 1. (Continued)

Region	Estimated home range or density	Habitat association	Reference
Southeast			
Arkansas	mean home range am 116.0 km^2 af 12.0 km^2 sm 148.0 km^2 sf 9.0 km^2	Southern floodplain forest	Smith (1985)
Great Smoky Mountains National Park	mean home range am 42.0 km^2 af 15.0 km^2	Appalachian oak forest	Garshelis (1978)
Louisiana	minimum home range am 64.1-168.0 km^2 af 17.6- 21.8 km^2	Southern floodplain forest	Taylor (1971)
North Carolina	average range of activity am 9.1 km^2 af 5.0 km^2 sm 4.3 km^2	Southern mixed forest (coastal plain)	Landers et al. (1979)
Northeast			
Maine	average home range af 40.9 km^2	Northern hardwoods-spruce forest	Hugie (1982)
Maine	average home range af 24.7 km^2	Northern hardwoods-spruce forest	Lamb (1983)
Maine	31 bears/100 km^2	Northern hardwoods-spruce forest	McLaughlin & Matula (1984)

(Continued)

Table 1. (Concluded)

Region	Estimated home range or density	Habitat association	Reference
Northeast (continued)			
Massachusetts	average home range am 318.0 km^2 af 28.0 km^2	Northern hardwoods-spruce forest	Elowe (1984)
New York	6 bears/100 km^2 (Adirondak range)	Northern hardwoods-spruce forest	McCaffrey et al. (1976)
	5 bears/100 km^2 (Catskill range)	Northern hardwoods forest	
Pennsylvania	average home range am 196.0 km^2 af 20.0 km^2 sm 37.0 km^2 afc 45.0 km^2	Northern hardwoods forest	Alt et al. (1976)
Pennsylvania	average home range am+sm 196.0 km^2 af 38.0 km^2	Northern hardwoods forest	Alt (1977)
Pennsylvania	average total home range am 173.0 km^2 af 41.0 km^2	Northern hardwoods forest	Alt et al. (1980)

Human influence: roads, residences, farms, and human attitudes. Roads also have positive or negative impacts on black bears. Relatively low use logging, service, and other dirt roads are used as travel routes (Manville 1983; Young 1984), and the roadsides are used as feeding areas (Grenfell and Brady 1983; Lamb 1983). Roadside vegetation produces fruit (Manville 1983) and often includes edible greens such as clover (*Trifolium* spp.), dandelions (*Taraxacum officinale*), peavine (*Lathyrus* spp.), and vetch (*Vicia* spp.) (Jonkel and Cowan 1971; Rogers and Wilker, unpubl.). Black bears in Great Smoky Mountains National Park showed no avoidance of limited access roads, frequently crossing them or using areas adjacent to them (Carr and Pelton 1984). Bears seem attracted to roads but avoid traffic (Miller 1975; Brown 1980). Roads used by black bears in northeastern Minnesota typically were unimproved logging roads with traffic of <3 vehicles/day. An improved gravel road (Forest Service Road 173) and a paved highway (Minnesota Highway 1) were each used by more than 1 vehicle/hour and were rarely used for travel or feeding although bears readily crossed them. The bears became habituated to traffic sounds and fed in forest cover within 100 m of the highway but rarely used open areas within full view of passing vehicles. Roads through feeding areas can limit use of those areas, which can be important if feeding areas are limited (Kellyhouse 1980). Exceptions occur, however. In Minnesota, a mother and three yearlings ate grass daily beside a highway from 3 to 10 May 1972, retreating into forest cover at the approach of each vehicle. A mother and cubs denned in forest cover approximately 100 m from the same highway. In Michigan, two subadults became panhandlers beside U.S. Highway 41 on the Keweenaw Peninsula in 1968.

Major highways can impede black bear movements (Miller 1975; Brown 1980; Brody 1984; Brody and Pelton, in press), and highways account for perhaps 100 road kills each year in the Upper Great Lakes Region. Minnesota road kills average 51/yr, with lower averages reported in Wisconsin (B.E. Kohn, Wisconsin Department of Natural Resources, Rhinelander; pers. comm.) and Michigan (J. Stuht, Michigan Department of Natural Resources, Lansing; pers. comm.). Road kills are confined primarily to paved roads with heavy, fast-moving traffic, and the number of road kills depends partly upon the density of those roads and the amount of traffic. For example, Pennsylvania road kills average about 150/yr (G.L. Alt, Pennsylvania Game Commission, Moscow; pers. comm.), three times the number in Minnesota, despite comparable bear populations. The difference is attributed to more roads and more traffic in Pennsylvania.

Road access can increase the chances of people or dogs disturbing maternal dens in winter. Cubs, born in January, depend on their mother's body for warmth and soon die if the mother must leave, exposing the cubs (Smith 1946; Alt, pers. comm.; Rogers and Wilker, unpubl.). Few dens, however, are disturbed in northern forests. Winter recreation is confined mainly to roads, snowmobile trails, and ski trails. Logging operations affect <1% of the forest per winter. There is no evidence that den disturbance, hinderance of travel, or road kills are serious enough problems to significantly reduce black bear survival, growth, or reproductive success in the Upper Great Lakes Region.

The major negative impact of roads on black bears is that roads provide easy access for hunting and poaching. Legal hunting is not considered a road problem because this can be controlled through hunting regulations. Well managed, sustained yield hunting has not been shown to jeopardize black bear populations. Where poaching is a problem, however, road density is a major factor in population viability. Stone and Brody (1986) considered road densities >0.75 mi/mi^2 to make forest areas unsuitable as bear habitat in areas where there is a deeply rooted tradition of killing bears over hounds, regardless of season or hunting regulations. [This kind of unregulated killing is not a serious problem in the Upper Great Lakes Region, however, where bears persist at higher road densities.] For example, in northeastern Minnesota, approximately 34 bears (27-41 bears) persisted in a 168 km^2 area where road density was 2.3 km/2.5 km^2 (1.45 mi/mi^2) (Rogers and Wilker, unpubl.). The roads were mainly logging roads and there were no permanent human residents. During 9 years of study, only two bears were killed illegally in that area. Most of the bears were in dens during the rifle deer season when human use was highest (Rogers 1987). Mortality was similarly low in the Boundary Waters Canoe Area Wilderness, a 4,403 km^2 area used by nearly 180,000 visitors a year.

Permanent residents and campground managers were less tolerant of black bears than were recreationists. Although campers and hikers generally coped with bears as part of their wilderness adventure, permanent residents were more prone to shoot them. Unregulated, human-caused deaths were studied in an 88 km^2 area that contained three resorts, two campgrounds, and approximately 35 homes distributed along 17 miles of Highway 1 in northeastern Minnesota (Rogers, unpubl.). Despite the sparse human population, at least 31 marked bears (12 males, 19 females) were killed or otherwise removed from that population during 9 years of study; 26 were killed for being nuisances or within sight of homes, two were killed by vehicles, and two were translocated and killed elsewhere. An unknown number of unmarked bears was also killed. A conservative estimate of nonhunting, human-related deaths for the 9 years was 40, or 1 death per 9 years for each unit of human habitation. (Each resort or campground was counted as one unit.)

Although the amount of land occupied by the homes, campgrounds, and resorts in the above study was negligible, the amount of land needed to support a bear population sufficient to compensate for the killings around them was 154 km^2 (60 mi^2). This was calculated as follows. The average number of unregulated, human-caused deaths around those sites was 4.44 per year. If the allowable mortality for sustained yield in that part of Minnesota was 13% (D.L. Garshelis, Minnesota Department of Natural Resources, Grand Rapids; pers. comm.), the population required to supply those 4.44 bears per year was 34 (100/13 x 4.44 = 34.15). At a density of 1 bear per 4.5 km^2 (1.75 mi^2) (Table 1), the 34 bears would require a living area of 154 km^2 (60 mi^2) (1.75 x 34 = 60). This amounts to 3.9 km^2 (1.5 mi^2) of habitat required per human habitation, which is the area within a radius of 1.1 km (0.7 mi).

Where houses are grouped together bears are attracted primarily to the garbage of the outermost houses. Bears often concentrate at trash canisters at the edges of the towns, usually within 100 m of forest cover but occasionally farther into the towns. The bears commonly are killed or translocated. Data for Ely, Minnesota, a town of approximately 4,000 people, show that eight bears were killed and 22 were translocated during 1980-1987

(Garshelis, pers. comm.; F.W. Thunhorst, Minnesota Department of Natural Resources, Ely; pers. comm.). More were shot and not reported. A conservative estimate of the actual number shot during the 8 years is 24 (Thunhorst, pers. comm.). The fates of the 22 translocated bears are unknown. The estimate of 24 deaths represents an average of three bears per year. If the allowable mortality rate is 13%, a population of 23 bears would be required to supply those three bears per year. At 4.5 km^2 (1.75 mi^2) per bear, that population would require 104 km^2 (40 mi^2) of habitat. The impact of Ely on the surrounding bear population may be approximated as neutralizing population growth for a radius of 5.7 km (3.6 mi) beyond the city limits.

Conversion of forest to farmland makes areas unsuitable for bears long before all the forest is destroyed. Bears are attracted to corn, oats, fruit, beehives, or livestock, and are shot. As a result, farms have a negative influence on the surrounding bear population and serve as "sinks." In northwestern Wisconsin, 86 bears were reported shot for agricultural depredations in 1986, with the actual number killed being higher (B.E. Kohn, Wisconsin Department of Natural Resources, Rhinelander; pers. comm.). The area is 20% farmland with 200,720 ha (2,007 km^2) of cropfields, mostly corn (Kohn, pers. comm.). The allowable kill for sustained yield in that region is 16%, and the bear density is 1 bear/7.7 km^2 (Kohn, pers. comm.). The amount of bear habitat required to produce the 86 bears on a sustained yield basis is 4,175 km^2, approximately twice the area of the farmland. Thus, for a bear population to be maintained in that area, 6,182 km^2 (2,007 km^2 + 4,175 km^2) of land are needed. These data suggest that a bear population would be difficult to maintain without substantial immigration if more than 33% of the land were converted to agriculture. The actual percentage is probably <33% because the kill figure of 86 is conservative.

Data from Minnesota further suggest that conversion of more than 33% of forested land to agriculture is incompatible with maintenance of viable black bear populations. The southern extent of the bear range is limited by transition into agricultural lands. Where farms compose more than a third of the area, bears have become so few that nuisance complaints are infrequent, but where farmland composes 10% to 30% of the land in northern Pine County, nuisance complaints persist, showing a substantial bear population that perhaps is bolstered by immigration from extensive nonagricultural land to the north and east (Garshelis, pers. comm.).

The high mortality among bears around residences, towns, and farms may explain, in part, why negative correlations are found between road density and bear density (G. Radde, Minnesota State Planning Agency, St. Paul; pers. comm; J.W. Edde and S. LaValley, U.S. Forest Service, Ironwood, MI; letter dated December 8, 1986). The higher road densities tend to coincide with agricultural or built-up areas, reduced forest cover, and higher permanent human populations. Radde (pers. comm.) found that where human density or agriculture led to road densities of 3.2 km/2.5 km^2, bear density was zero, or nearly so. Edde and LaValley (1986) found a similar negative correlation in Michigan's upper peninsula. They compared road density and bear kill in 53 townships and found the two parameters to be inversely, but not significantly ($P<0.2$), correlated.

Black bears are adaptable and, to an extent, can persist in the presence of humans (Pelton 1982). In most situations, however, the absence of adequate refuge will result in local populations succumbing to the intolerance of humans (Hugie 1979; Beecham 1980; Lentz et al. 1980). Sanctuaries assume greater importance with increasing human-related mortality (Hugie 1979; Lentz et al. 1980). Without nearby sanctuaries to produce dispersing subadults, bear numbers will decline where human-related mortality exceeds black bear reproductive rate. Norton (1981) suggested that areas with minimum disturbance that are >50 km^2 may dictate future bear densities in Wisconsin. Hugie (1979) recommended that effective refuge areas must: (1) be large enough (e.g., >100 km^2) to support a group of bears; (2) correspond to natural rather than political boundaries (e.g., drainages or forested wetlands rather than townships); (3) contain adequate resources to meet year-round needs; (4) contain a viable bear population in order to ensure adequate productivity; and (5) have easily recognizable boundaries. Lindzey et al. (1976) stated that the continued existence of viable black bear populations in Pennsylvania depends on the existence of retreat areas such as forested wetlands, refuges closed to hunting, and areas of light hunting pressure.

Habitat management. A variety of management options can improve black bear habitat or mitigate impacts on it. Habitat improvement ranges from silvicultural prescriptions that enhance understory food production to limiting human access and protecting sensitive areas from hunting (Lindzey and Meslow 1977b; Hugie 1979; Kemp 1979; Lawrence 1979; Pelton 1979; Kellyhouse 1980; Pelton et al. 1980; Elowe 1984; Young 1984; Irwin and Hammond 1985; Rogers 1987). Some activities may be applicable only to specific geographic regions or may not be financially or politically acceptable. The concepts, however, may be useful in identification of alternatives for enhancement or maintenance of black bear habitat.

a. Forest management. Although clearcuts are generally beneficial as a result of the growth of seral food producing vegetation, their size and configuration influence use by black bears. Clearcuts should be of a size and shape that results in the furthest distance from forested escape cover being ≤250 m. Irregular boundaries, islands of standing timber, and corridors of timber along ridgelines and drainages will offset the negative effects of larger clearcuts by providing escape cover interspersed with open cover types. Linear clearcuts are less detrimental than are rectangular cuts because of a higher edge/area ratio. Clearcuts should be well dispersed and ideally ≤8 ha. Forested stands adjacent to clearcuts should not be harvested until suitable cover is established in the cut area. Leaving scattered mature white pines (*P. strobus*), hemlocks (*Tsuga canadensis*), or other large trees with strong, rough bark enhances habitat for mothers with cubs in spring.

Stands of hard mast producing species, especially oak, should be protected to the fullest extent possible. Silvicultural prescriptions should be oriented toward increased production and diversity of mast producing species.

Timber management should be oriented toward maintaining a diversity of age classes in close proximity. Selective and seed tree prescriptions should be directed toward the preservation and enhancement of preferred food species. Thinning of pine stands as they mature enhances fruit production.

Harvest activities should be scheduled to allow seasonal use by black bears of important cover types. Logging operations should avoid wetlands or low elevation areas during spring when these areas receive greater use by bears. Disturbance in high elevation sites should be minimized in late summer.

Drainage, cutting, or otherwise destroying wetlands, seeps, and riparian areas should be avoided since these sites provide seasonally important foods. Buffer strips of timber should be maintained around these sites to permit continued use by black bears. Roads and log landings should be situated well away from wetlands.

Low intensity site preparation has less impact on food production for black bears than does high intensity activity. Large-scale use of herbicides to minimize competition of seral vegetation with regenerating timber is undesirable due to reduction in food plants. Herbicide kills most or all of the fruit producing species, depending on the kind of herbicide and the amount applied. Hand application of herbicide is preferable to broadcast treatment. Judicious use of herbicides may be used to eliminate unpalatable species, and to create logs as sources of ants. Scarification is generally beneficial for establishment of grasses and forbs but reduces growth of berry producing shrubs, due to damage to root crowns and rhizomes.

Ideally, forest management should maintain or develop from 5% to 25% of the area in nonforested cover types to maximize diversity, productivity, and availability of food producing plants. Forested cover types should be composed of stands in all age classes.

b. Den sites. Forest management should allow for the preservation of large trees and snags as potential den sites. When den trees are identified in intensively managed areas, they should be preserved within a stand of surrounding trees to provide security and allow for replacement of den trees lost through natural attrition. The preservation of den trees may be particularly important in areas of marginal habitat, high human use, and in warmer parts of the region where winter thaws and flooding are potential problems. Preservation or creation of large slash piles may provide additional den sites.

c. Food. Silvicultural prescriptions that enhance mast production should be encouraged in eastern forests. Highly preferred fruit producing shrubs and trees may be planted to enhance their availability and distribution. Important vegetative associations or cover types that are limited in distribution should be preserved or managed to favor increased food production. Examples are northern red oak and mountain ash (*Sorbus* spp.) in Minnesota (Rogers 1987) and black cherry (*Prunus serotina*), oaks, and abandoned apple orchards in Michigan and Wisconsin (S. Shultz, U.S. Forest Service, Marquette, MI; pers. comm.). Livestock grazing should be sharply curtailed or eliminated in clearcuts or sensitive areas [e.g., riparian zones, aspen stands] to enhance availability of black bear foods.

d. Refuge. Timber roads and skid trails should be revegetated, gated, or otherwise closed to restrict human access in areas of marginal bear populations where few females survive to reproductive age.

Forested and scrub/shrub wetlands provide critical escape and refuge cover, particularly in regions of comparatively high human density. These cover types should be preserved and, in some situations, closed to hunting to provide a core area for subadult dispersal and maintenance of the bear population in areas of marginal or declining habitat.

HABITAT SUITABILITY INDEX (HSI) MODEL

Model Applicability

Geographic area. This model was developed for application in the Upper Great Lakes Region, which includes northeast Minnesota, northern Wisconsin, the upper peninsula, and the upper half of Michigan's lower peninsula (Figure 1).

Season. This model was developed to evaluate the quality of year-round black bear habitat.

Cover types. This model was developed for application in the following cover types (terminology follows that of U.S. Fish and Wildlife Service 1981): Deciduous Forest (DF), Evergreen Forest (EF), Deciduous Tree Savanna (DTS), Evergreen Tree Savanna (ETS), Deciduous Shrubland (DS), Evergreen Shrubland (ES), Palustrine Scrub/Shrub (PSS), Deciduous Shrub Savanna (DSS), Evergreen Shrub Savanna (ESS), Forested (PFO), and Emergent (PEM) wetlands (wetland terminology follows that of Cowardin et al. 1979).

Minimum habitat area. Minimum habitat area is defined as the minimum contiguous habitat required to support a viable population of black bears in the Upper Great Lakes Region. The concept of a minimum viable population is still being developed for bears. For grizzly bears (*Ursus arctos*), a population of at least 50 adults is generally accepted as the minimum required to avoid serious loss of genetic variability in the short term (Allendorf and Servheen 1986). A population of this size has a 95% chance of survival for 100 years, although smaller populations may persist for long periods (Shaffer and Samson 1985; Allendorf and Servheen 1986).

For black bears, a population of 50 adults would probably include 30 to 40 females, according to sex ratios determined in northeastern Minnesota (Rogers 1987). This many adult females would require 288 to 385 km^2 if their territories averaged 9.6 km^2 each, as was found in northeastern Minnesota (Rogers 1987). Male ranges overlap the ranges of females, and males would be included in this area.

A complicating factor is that 40% of the females and 67% of the males studied in northeastern Minnesota moved up to 107 and 200 km outside their usual ranges when natural foods were scarce. These are longer movements than those recorded in more mountainous terrain where microclimate and vegetation change with elevation. Bears in flatter terrain usually have to travel farther to find similar changes. Thus, bears that live where terrain is relatively flat and natural food crops commonly fail may require larger blocks of unfragmented habitat to avoid conflict with man in years of natural food

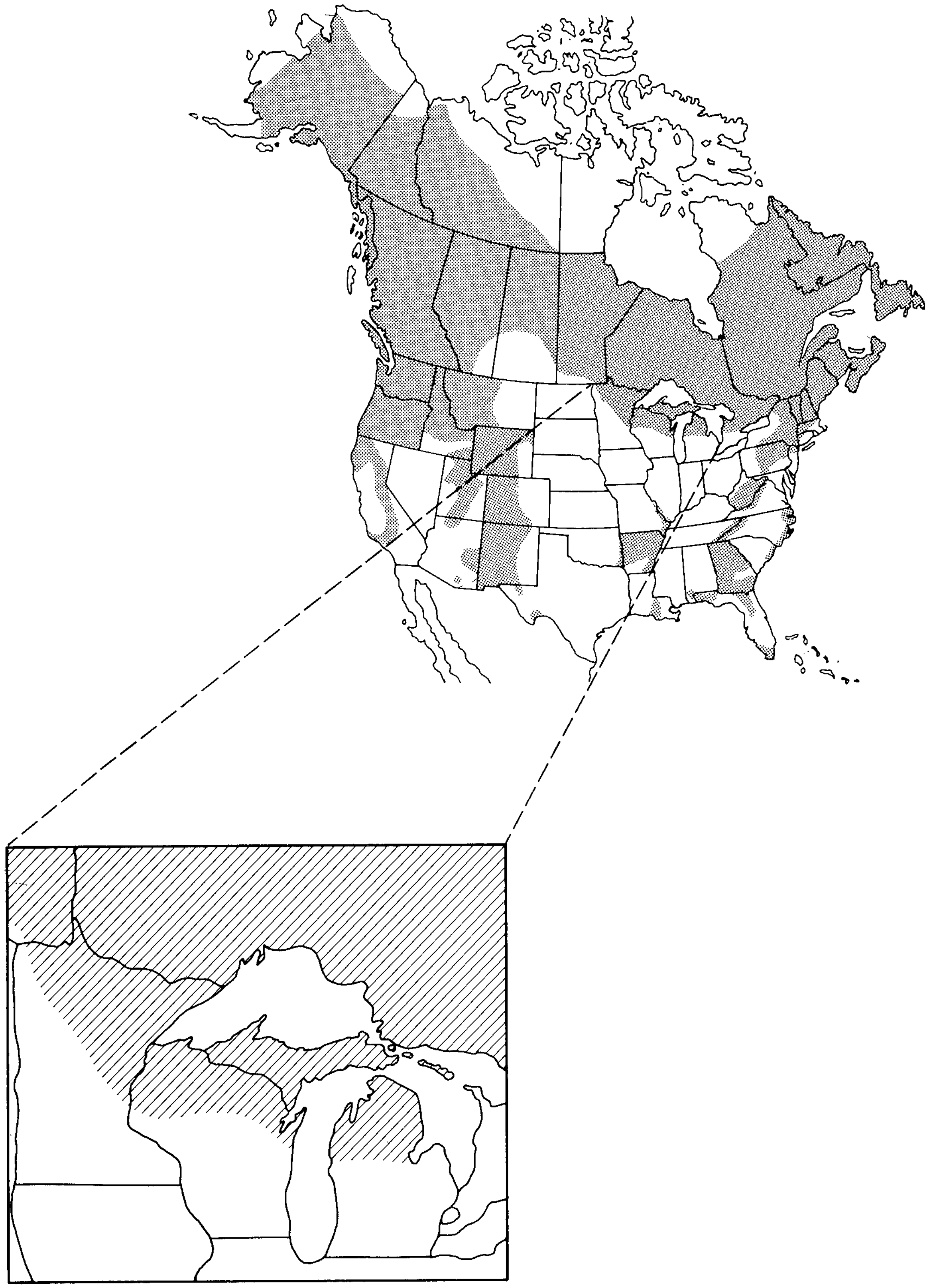

Figure 1. Approximate current distribution of the black bear in North America (modified from Pelton 1982 and Klepinger and Norton 1983) and geographic area (inset) of HSI model applicability.

failure. Elowe (1984) stated that the minimum area needed to fully support 15 breeding females in Massachusetts may be approximately 400 km^2, and, in low mast years, some females may even forage outside this area.

Conversely, smaller blocks of habitat that hold bears should not be disregarded. Small populations sometimes persist for long periods in small enclaves. For example, Stockton Island, which covers only 40 km^2 in Lake Superior, has a population of about eight black bears (R.K. Anderson, College of Natural Resources, University of Wisconsin, Stevens Point; pers. comm.). Lindzey and Meslow (1977a) reported 23 black bears living on an island of only 20 km^2 in Washington. However, in each of these cases, bears traveled to and from the mainland, providing opportunities for the introduction of new genetic material. In mountains of Colorado, Towry (1984) believed that 65 to 78 km^2 was enough to support a viable population. The long-term viability of small populations is not easily assessed.

For this model, 30 female territories, or about 288 km^2 of contiguous habitat is assumed to be sufficient to support a viable population of black bears in the Upper Great Lakes Region where there are barriers to movement outside that area. However, minimum habitat area is influenced by abundance, quality, and distribution of food resources as well as amount of human-related mortality. Larger areas may be required where foods are of low abundance, low quality, or poorly dispersed or where the area contains human population areas that divide the habitat and act as sinks. Conversely, smaller areas may suffice where food diversity, reliability, and abundance are greater than in the northeastern Minnesota area on which these estimates are based. Refuge or sanctuary areas appear to be critical in maintaining black bear populations in regions where human density and hunting pressure are high.

The area to be evaluated using this HSI model is intended to be the female territory, which averages 9.6 km^2 in northeastern Minnesota and probably less in the more fertile portions of the black bear's range farther south. The model is structured around evaluation of the abundance and quality of seasonal foods, cover type composition, and the potential for human-related mortality. Estimation of the abundance and quality of foods also may be applied to the minimum habitat area or to smaller areas as guidance for the enhancement of food resources within individual sites or forest stands.

Verification level. The habitat requirements and associated variables identified in this model are the result of a modeling workshop held to define characteristics that influence habitat quality for black bears in the Upper Great Lakes Region. The model is a hypothesis of species-habitat relationships based on pertinent research and the experience of the workshop participants. The model can be used to identify impacts on black bear habitat and to identify management actions that may mitigate losses in habitat quality. Workshop participants were as follows:

Lynn Rogers, U.S. Forest Service, North Central Forest Experiment Station, St. Paul, MN

Jerry W. Edde, U.S. Forest Service, Ottawa National Forest, Ironwood, MI

Donald M. Elsing, U.S. Forest Service, Hiawatha National Forest, Escanaba, MI

Earl Flegler, Michigan Department of Natural Resources, East Lansing, MI

Jim Fossum, U.S. Fish and Wildlife Service, Green Bay, WI

Jim Hammill, Michigan Department of Natural Resources, Crystal Falls, MI

Jon Haufler, Department of Fisheries and Wildlife, Michigan State University, East Lansing, MI

John Hendrickson, Michigan Department of Natural Resources, Baraga, MI

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Larry Visser, Michigan Department of Natural Resources, Houghton Lake Heights, MI

Modifications and improvements have been made in this model subsequent to reviews, suggestions, or data provided by the following: Douglas Blodgett, Vermont Fish and Game; Kenneth D. Elowe, Utah Division of Wildlife Resources; Roy D. Hugie, Bio/West; Steve LaValley, U.S. Forest Service; Edward L. Lindquist, U.S. Forest Service; Dennis Marten, Virginia Commission of Game and Inland Fisheries; Craig R. McLaughlin, Maine Department of Fisheries and Wildlife; Steven Stringham, Wildwatch; Bruce E. Kohn, Wisconsin Department of Natural Resources; David L. Garshelis and Karen V. Noyce, Minnesota Department of Natural Resources; Robert E. Radtke, Wini B. Sidle, and Greg Wilker, U.S. Forest Service.

Model Description

Overview. Black bear habitat quality in the Upper Great Lakes Region is chiefly a function of the quantity, quality, and distribution of food. Different foods are available in various cover types by season. Early spring foods are dominated by grasses and other herbaceous vegetation primarily associated with wetland or lowland cover types. As this vegetation matures in late spring, ants become a larger part of the diet. Preferred ant species are found primarily in upland openings. Upland openings also are the primary producers of most species of berries and fruits eaten in summer. Upland forest communities, including hardwoods and mixed stands of hardwood and coniferous species, are the primary producers of hard mast and late ripening berries important in the fall diet.

Carrion, feral fruits, and agricultural crops are not addressed in the habitat portion of the model. Carrion availability is limited mainly to spring when a few bears feed on winter-killed ungulates. Carcasses generally are limited to localized winter deer yards, however, and many of the carcasses are eaten by winter scavengers before bears emerge from dens. Carrion is considered a relatively unimportant food source for most bears on an annual basis. Feral fruits such as apples may be an important food source in regions with numerous abandoned orchards and should be taken into account by managers in such regions. Over much of the region this food source has much less influence on habitat quality than does native foods. Agricultural crops such as corn are commonly eaten by bears where available; however, because agricultural land use is a human activity that usually reduces bear habitat and because crops that attract bears commonly are associated with population losses due to shooting or translocation, agricultural crops are considered to have a negative influence on the quality of black bear habitat. Agricultural land use is considered in the section on human intolerance.

This model is structured around the evaluation of spring, summer, and fall foods and is based on the assumption that all three categories of seasonal foods must be available in order to provide optimum availability of food. The model is composed of three major components: (1) variables that estimate the abundance and quality of seasonal foods within specific cover types; (2) variables that are used to estimate the cover type composition within an evaluation area; and (3) a variable that is used to estimate the influence of human disturbance on black bear habitat quality.

The availability and distribution of seasonal foods dictates black bear movements and use of vegetative associations and appears to be the most important component of habitat. Water is important for drinking and at times thermal regulation. Ideally, surface water should be available and well distributed (e.g., every 1.3 km^2). Water becomes less important when succulent berries and fruits are available. Due to its normal abundance, the availability and distribution of surface water has been assumed not to be a limiting habitat feature in the Upper Great Lakes Region and therefore is not addressed in this model.

Black bear den sites have received a great deal of attention in past research. The species is adaptable in its selection and use of dens, surviving and giving birth even in exposed nests on the ground surface. Although hollow trees probably are preferred den sites, bears survive about as well in other dens except where winter flooding or disturbance by humans or dogs cause drowning or abandonment of newborn cubs. Flooding is not a common problem in the Upper Great Lakes Region, and human disturbance is minimal because few people leave forest trails during the snowy winters typical of the region. Potential den sites are assumed to be present if all required cover types, particularly forested cover types, are present in the evaluation area. The problem of human disturbance is addressed in the section on human intolerance.

Similarly, specific escape and security cover requirements (e.g., vegetative density) are not directly evaluated in the model, since the presence of shrub and forested cover types is a mandatory requirement of year-round food availability. The presence of forested and shrub-dominated cover types is assumed to indirectly address the availability of the black bear's cover requirements. Escape and security quality also is addressed through the evaluation of human influence.

Reproductive success and survival in black bear populations has been correlated with the availability of high-energy foods. The output of this model is assumed to correspond to the reproductive success of the resident bear population based on estimates of the abundance and quality of required food resources.

The variables used in this model to evaluate food suitability are primarily based on measures of the density and species diversity of soft and hard mast producing trees and shrubs. These variables are assumed to provide a surrogate measure of the amount of metabolizable energy available to the species within a given area. Theoretically, a more accurate approach for the evaluation of food resources would be to determine metabolic requirements of black bears and the amount of metabolizable energy available within the evaluation area. At the present time, however, an energetics model is not practical since such models require data that are costly and time consuming to collect, and are impractical to measure for the typical biologist or land manager.

Spring food component. Lowland grass and herbaceous vegetation were found to be the black bear's primary early spring foods in northeastern Minnesota (Rogers 1987; Rogers and Wilker, unpubl.) and Massachusetts (Elowe 1984, 1987). Lowland grasses are primarily affiliated with black ash (*Fraxinus nigra*) swamps, tamarack swamps, and other forested or scrub/shrub wetlands, especially alder swamps. Lowland or wetland herbaceous vegetation includes skunk cabbage (*Symplocarpus foetidus*), jewelweed (*Impatiens capensis*), wild calla (*Calla palustris*), fragrant bedstraw (*Galium triflorum*), jack-in-the-pulpet (*Arisaema triphyllum*), and interrupted fern (*Osmunda claytoniana*). In Massachusetts, black bear activities centered around wetlands from spring emergence from dens through the end of July (Elowe 1984). Home ranges appeared to be adjusted to include between 176 and 309 ha of forested or scrub/shrub wetland, which composed 7% to 19% (average 11%) of the home ranges (Elowe 1984). Forested wetlands, beaver (Castor canadensis) impoundments, and riparian areas were used for feeding in spring and for travel corridors in summer. In Minnesota, over half of the food consumed during the 6 weeks following emergence in spring was grass obtained from forested wetlands that composed <1% of the home ranges of the study bears (Rogers and Wilker, unpubl.). Lowland and riparian areas supplied additional spring foods and continued to supply succulents into summer. Spring foods obtained primarily from uplands were aspen and willow catkins, aspen leaves, and ants. Small openings in upland forests became important feeding sites in late spring when forbs sprouted.

In June and early July, when vegetation growth had slowed, bears spent most of their feeding time seeking ants (Noyce, pers. comm.; Rogers and Wilker, unpubl.). Ants in logs and stumps were preferred over those in anthills (Rogers and Wilker, unpubl.). Logs dry enough to house the preferred species were found mainly in upland forest openings. Standing wood (snags, stumps, and upturned roots) housed preferred ants in uplands and forested wetlands (Rogers and Wilker, unpubl.). Ants continued as a major food item until berries ripened in July.

Resting habitats in spring were primarily in the uplands, in close association to lowland feeding areas. Mothers with cubs in northeastern Minnesota sought white pines >50 cm dbh as refuge trees for their cubs. These trees had firm, rough bark that facilitated safety and ease of climbing for the cubs. In Massachusetts, white pines and hemlocks were used (Elowe 1984).

Due to the ephemeral nature of spring foods and the resultant difficulties of sampling, this model does not require direct evaluation of the quantity or quality of herbaceous spring foods. The spring food component of this model is based on the assumption that spring food abundance in the Upper Great Lakes Region will be optimum where forested wetland, forested lowland, and riparian areas compose 7% to 50% of the evaluation area. Figure 2 illustrates the assumed relationship between abundance of these cover types and a suitability index (SI) value for early spring foods. Greater than 50% availability of wetland, lowland, and riparian cover types would probably result in loss of upland resting sites and late spring foods. Lower availability is assumed to indicate less than optimum amounts of early spring food. Low availability may be particularly detrimental to yearlings, which commonly starve to death in early spring, and to lactating females, which have especially high metabolic demands in that season. Unusually high nuisance activity by bears occurred in northeastern Minnesota in 1985 when the primary early spring feeding habitats (lowlands and wetlands) were flooded due to near record rainfall. The complete absence of wetland cover types is not assumed to make habitat totally unsuitable but does reflect lower habitat quality. The suitability index for spring food (SISP) is expressed in Equation 1:

$$SISP = SIV1 \qquad (1)$$

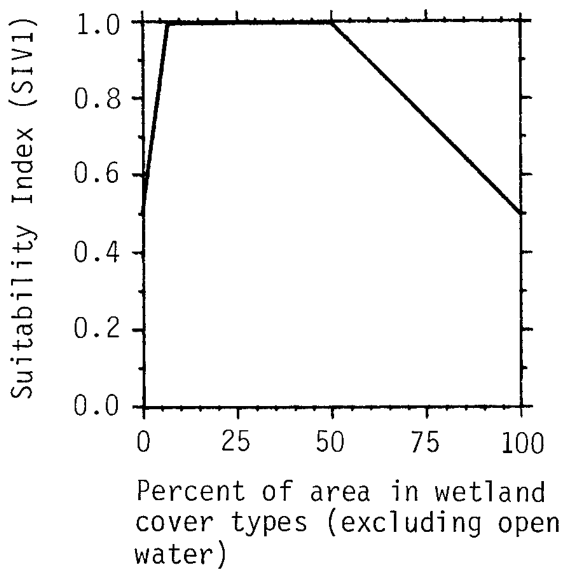

Figure 2. Relationships between the percentage of an evaluation area in wetland and SI values reflecting the availability of spring foods for black bears in the Upper Great Lakes Region.

Summer food component. The preferred summer diet is dominated by berries and fruits from the time they ripen in July until they disappear in late summer or early fall. In years of good production, hazelnuts are also a preferred food. Fruits and nuts make a major difference in the survival of cubs and the reproductive success of adult females throughout the northern United States (Jonkel and Cowan 1971; Rogers 1976, 1977, 1987; Elowe 1987). Some of the more important summer fruits in the Upper Great Lakes Region include wild sarsasparilla (*Aralia nudicaulis*), cherries (*Prunus* spp.), blueberries, raspberries, viburnums (*Viburnum* spp.), wild plums (*Prunus* spp.), hawthorn berries (*Crataegus* spp.), mountain-ash berries (*Sorbus* spp.), buffalo berries (*Shepherdia canadensis*), and apples. These foods vary in abundance from area to area and from year to year.

The majority of these foods are produced by shrub species associated with early to mid-successional seral stages, openings in forest canopies, and edges between forest and nonforest cover types (Arimond 1979). Exceptions are wild sarsaparilla, hazel, and black cherry, which tend to be associated with more mature forests. Many of the less shade tolerant species will grow in shade but produce little fruit there. Consequently, forest openings are important to fruit production for those species. Arimond (1979) found that production of pincherries (*P. pensylvanicus*), chokecherries (*P. virginianus*), blueberries, serviceberries, and raspberries was twice as high in stands with <800 trees/ha than in stands with >1,000 trees/ha.

For this model, the availability of summer food is assumed to be a function of the overall percent cover of species that produce fruits or nuts (primarily hazel) in summer and the number of these species present at >1% cover. Openings include clearcuts, roadsides, burns, wildlife openings, abandoned homesteads, abandoned farmsteads, powerlines, marsh edges, or any other secluded area with forest-nonforest edge. Small openings (15 to 30 m in diameter) within the forest also are conducive to the production of fruit, ants, and preferred forbs and may be preferred due to the proximity of forest cover. Such openings include insect damage areas, windfalls or the breakup of old growth forests, and edges of rock outcrops.

Although bears eat ants and some species of succulent vegetation in summer, fruit and nuts are the most important summer foods, as evidenced by poor growth, survival, and reproduction in summers when fruit and nut crops fail in northern forests (Rogers 1976, 1987; Elowe 1987). Therefore, for purposes of this model, cover types devoid of summer fruit and nut producing shrubs are assumed to have low potential for providing summer foods (Figure 3a). The availability of summer foods is assumed to increase with increasing density of the shrubs that produce them. Optimum availability of summer food is assumed to be reflected when fruit and nut producing species are present at densities ≥25% canopy cover (Figure 3a).

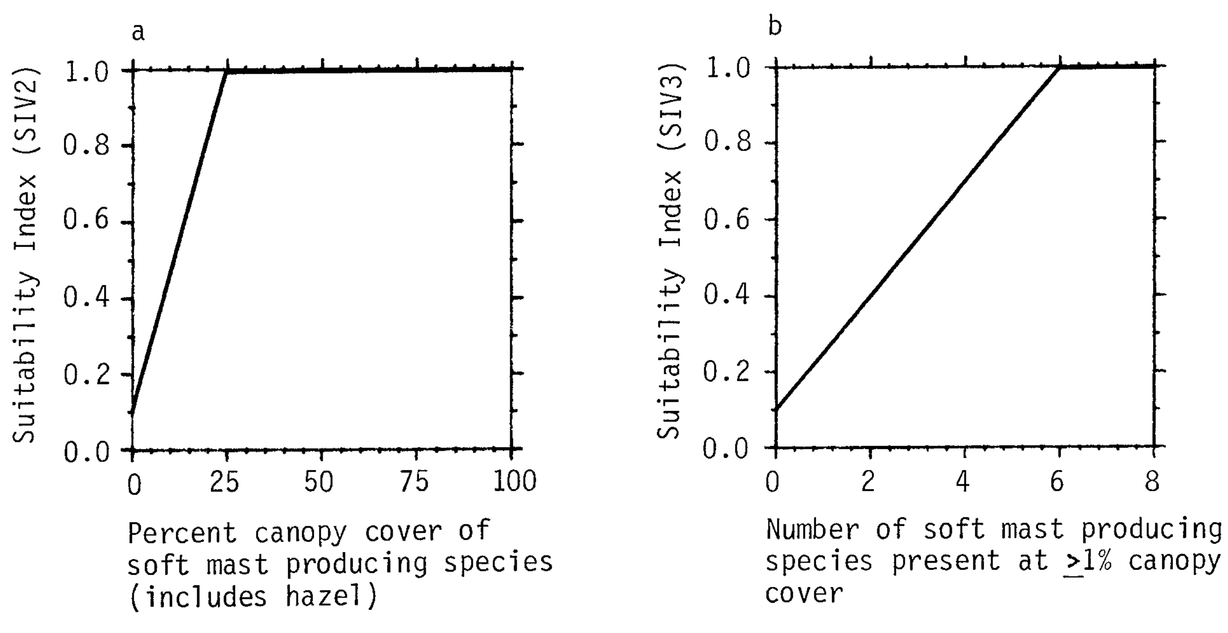

Figure 3. Relationships between variables used to evaluate the abundance and quality of summer fruit and nuts and suitability index values for black bear summer food in the Upper Great Lakes Region.

Reliability of summer food supplies is assumed to increase with species diversity (Figure 3b). Flowering and fruiting dates differ slightly, reducing the chances that all species would be similarly affected by drought or frost. Thus, as the number of food producing species increases, the likelihood of all crops failing decreases. For purposes of this model, the presence of ≥6 species of summer fruit or nut producing species is assumed to indicate maximum potential for summer food availability (Figure 3b). Sites with lower numbers of species are assumed to be less dependable and are assigned lower suitability values.

Productivity of individual food producing plants depends partly on sunlight for many species. Thus, forest openings enhance fruit production. It is important, however, that these openings be small for maximum use by bears, especially mothers with cubs (Jonkel and Cowan 1971; McCollum 1973; Hugie 1982). Where there are no openings, only the shade tolerant species will show high productivity.

The relationships presented in Figure 3 are combined in Equation 2 to determine the suitability index for summer food (SISU).

$$SISU = (SIV2 \times SIV3)^{1/2} \qquad (2)$$

Equation 2 is based on the following assumptions. Percent canopy cover of soft mast producing species and the number of soft mast producing species present are assumed to have equal weight in the definition of the abundance and quality of summer food for black bears. High quality summer food resources will exist where nonforested cover types or early stages of forest succession support ≥25% canopy cover of soft mast producing species. The index value for summer food will be greater in areas where ≥6 species of soft mast or nut (i.e., hazel) producing species are present. Areas with less diversity in soft mast producing species are assumed to reflect lower habitat quality as a result of a greater possibility of crop failures where few species are present.

Fall food component. The major fall food of black bears in the Upper Great Lakes Region is northern red oak acorns. Beech (*Fagus grandifolia*), found in the eastern half of the region, is a second source of fall mast. Other hard mast species are of lesser importance in fall because they are scarce in this region. Hickory is a more southern species barely present in the Upper Great Lakes Region. Bur oak (*Q. macrocarpa*) is widely scattered, primarily on calcareous sites (Fowells 1965). Hazel ripens in August and early September, and few nuts remain after September 21. Some berries may still be available after September 21, especially mountain-ash, hawthorn, dogwood (*Cornus* spp.), and viburnum, but these are not as energy rich as acorns or nuts and are generally past their peak of availability. Feral apples are important where they occur. Additional species of oak are important in the northern lower peninsula of Michigan. For purposes of this model, oak and beech are assumed to be the species of major importance. The availability of hard mast in fall is assumed to be a function of the basal area of mature mast producing trees (≥40 years old) (Figure 4a) and the number of hard mast species represented by at least one mature tree/0.4 ha, on the average (Figure 4b).

The age of maturity varies between mast producing species. Northern red oak begins to fruit at age 25, but does not produce acorns abundantly until age 50 (Fowells 1965). Some acorns are produced each year, with good crops every 2 to 5 years (Fowells 1965; Elias 1980). Bur oak begins producing acorns at age 35, good crops at 2- to 3-year intervals, and optimum production at 75 to 150 years old (Fowells 1965). Some production continues through age 400, which is older than has been reported for any other American oak. Beech begins nut production at about 40 to 60 years and continues production until more than 300 years old (Fowells 1965; D.W. Blodgett, Vermont Department of Fish and Wildlife, Pittsford; pers. comm.). However, production of abundant, sound nuts is sporadic. During a 10-year study in Michigan, nut production failed or was poor in 6 years, was intermediate 3 years, and was abundant 1 year (Gysel 1971). In an 11-year study in New Hampshire, nut production failed or was poor in 5 years, was intermediate 5 years, and good 1 year (R.E. Graber, Northeast Forest Experiment Station, Durham, New Hampshire; pers. comm.). The false notion that large crops occur every 2 to 4 years is due to inclusion of incomplete nuts that will not provide food for wildlife (Gysel 1971).

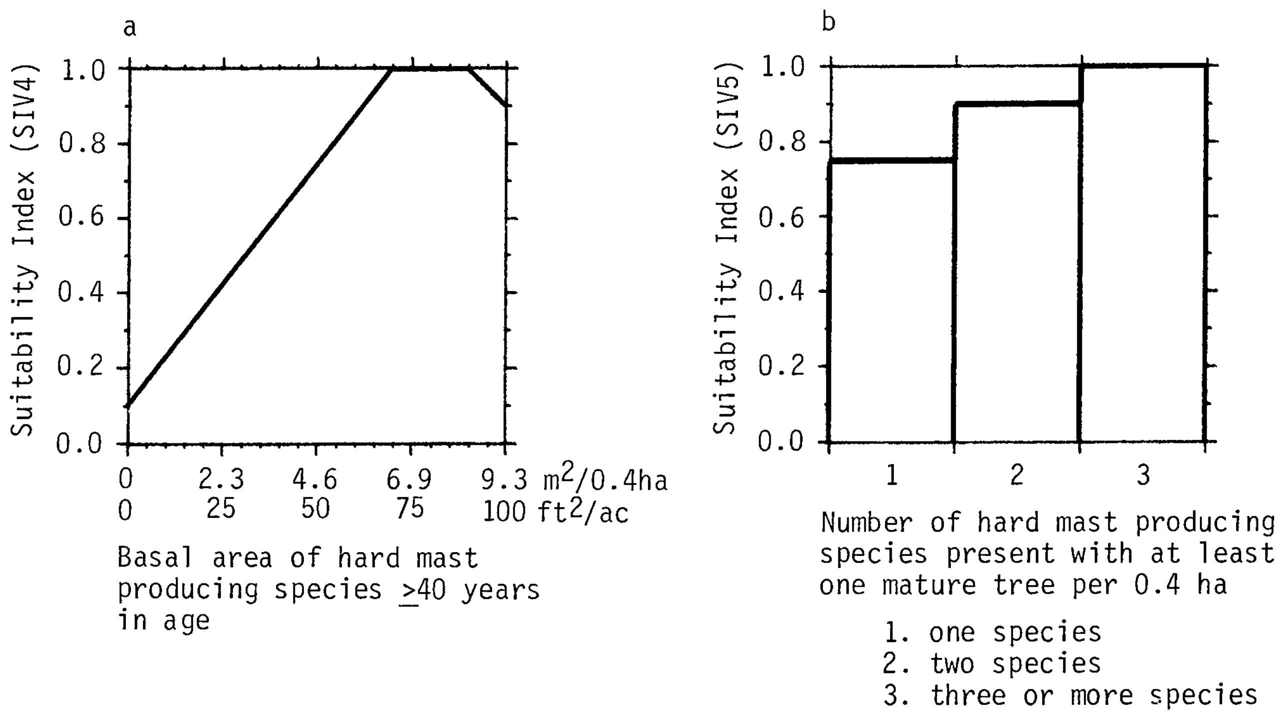

Figure 4. Relationships between habitat variables used to evaluate the availability of hard mast and suitability indices for the availability of fall food for black bears in the Upper Great Lakes Region.

Northern red oak is the primary producer of hard mast in fall in the Upper Great Lakes Region. A northern red oak tree of 25 cm dbh may produce 1.8 kg of fresh acorns per year, a 36 cm dbh tree may produce 2.6 kg, a 41 cm dbh tree may produce 4.5 kg, and a 51 cm tree may produce 7.2 kg (Shaw 1970). Production may be optimal at 51 cm to 56 cm dbh and decline with increasing size, according to a study in the southern portion of the species' range (Downs and McQuilkin 1944). A fully stocked mature stand would be expected to include, 6.5 to 8.4 m^2/0.4 ha basal area of mature trees, 1.4 m^2 basal area of pole-sized trees, and 0.5 m^2 of smaller trees. At 0.1 m^2 basal area/36 cm dbh tree, a 0.4 ha stand with 6.5 m^2 basal area would contain 64 trees. At 2.6 kg of acorns per tree, such a stand would produce 165 kg of acorns per 0.4 ha (Shaw 1970).

Mature oak stands of that density are uncommon enough to be the target of bear migrations, as was noted in Tennessee (Garshelis and Pelton 1981) and Minnesota (Rogers 1987). The chances of bears finding a given stand, however, decrease with distance from the usual home range. For example, in northeastern Minnesota, where oak stands are rare, a mother led her cubs to an oak stand 34 km outside her territory. The cubs returned to the stand as adults, but other radio-collared bears living an equal distance from the stand did not find it and showed slower growth and poorer reproductive success (Rogers 1987).

The amount of hard mast that can be used by a black bear in competition with other wildlife, including other bears, has not been well established. Shaw (1970) stated that wildlife other than bears will use as much as 38.5 kg of acorns per 0.4 ha. Rogers and Wilker (unpubl.) observed the consumption of 3 kg of hazelnuts (3,073 grams, 2,605 nuts) by a wild, free-ranging, 2-yr-old black bear in 24 hours.

The presence of large conifers for refuge may enhance the value of mast feeding areas, despite the presence of other trees. Droppings from bears feeding on acorns in an oak stand in fall in Minnesota were clustered around a large (>50 cm dbh) white pine, and over 90% of the droppings from bears feeding on black cherries in a maple-beech-cherry stand in Michigan were within 3 m of scattered, large (>40 cm dbh) hemlock trees (Rogers, unpubl.). Water may also enhance use of hard mast because hard mast contains little water, and bears drink several times a day while feeding on it (Rogers and Wilker, unpubl.).

Mature stands composed of three or more species of hard mast producing trees are assumed to provide optimum availability of fall food. Figure 4a is based on the assumption that the availability of hard mast will increase as basal area of mature trees (>40 years old) increases to fully stocked (6.5 to 8.4 m^2/0.4 ha) basal area. Large dominant and codominant trees with exposed, sunlit crowns are expected to produce more mast than do overtopped suppressed trees (Spurr and Barnes 1980). Therefore, stands with basal area >8.4 m^2/ha are assumed to be of slightly less value due to overcrowding of the trees, leading to lower mast production. Trees >40 years old are assumed to be of sufficient size to produce significant amounts of mast for efficient feeding by black bears. It is recognized that production will vary with site conditions (e.g., microclimate, soils, moisture, nutrients), and that some younger trees may produce significant amounts of mast and some older trees may produce little mast. Users may wish to substitute dbh or crown size as a surrogate for the age constraint used in this model. Based on local knowledge and experience, these parameters may be more easily obtained measures of tree maturity and mast production.

Because time of flowering varies by species, adverse weather is less likely to result in total crop failure in stands composed of several species than in monotypic stands (Nixon et al. 1975; Spurr and Barnes 1980). Therefore, forest stands composed of several hard mast producing species are assumed to have greater potential than monotypic stands for providing dependable fall foods for black bears (Figure 4b). Stands composed of only one species are assumed to have only three-quarters the value of forest stands composed of three or more species of hard mast producing trees.

The relationships presented in Figure 4 have been combined in Equation 3 to determine the suitability index for fall food (SIFA).

$$SIFA = (SIV4 \times SIV5)^{1/2} \tag{3}$$

Equation 3 is based on the following assumptions. The SI value determined for basal area of hard mast bearing species >40 years old (SIV4) is assumed to be compensatory with the SI value for the number of hard mast producing species (SIV5). Optimum conditions in terms of hard mast availability are assumed to occur when a fully stocked stand is composed of at least three species of hard mast bearing trees. A low value for one variable will be offset by a higher value for the other variable. For example, a stand with 3.2 m^2/0.4 ha basal area of hard mast bearing species will receive a higher SI value if three or more mast species are present than if there are only one or two species.

Interspersion and Composition Component

Ideally, a measure of cover type interspersion of food and cover resources could be used to evaluate the quality of black bear habitat. Presumably, greater interspersion of cover types providing required resources would reflect habitat of higher suitability than would an equally sized area with low interspersion. A specific measure of interspersion is not included in this model, however, based on the following rationale: (1) correlations between a cover type interspersion in relation to habitat quality and black bear response (e.g., improved physiological condition, higher reproductive rates) are undetermined; and (2) black bears are highly mobile and are capable of making long movements in relatively short periods of time. For example, in Minnesota sows with cubs traveling to known sources of food had average movements of 12.1 km/day, whereas, sows without cubs had average movements of 23.2 km/day (Rogers 1987). A 4-year-old male traveling to a familiar feeding area moved at a rate of 7.0 km/hr. Additionally, black bears appear to be capable of learning the locations of food-rich areas that are well outside their home range. Knowledge of these sites may be passed on from generation to generation and movements to them may be extensive. The sites are normally used for a relatively short period of time before the bears return to their normal home range. Therefore, due to the potentially large area used and the mobility of the species, evaluation of cover type interspersion may have little merit in the evaluation of habitat quality for the species.

This model, however, is based on the assumption that overall cover type composition is important in the evaluation of black bear habitat quality. To ensure optimum growth and reproductive success, year-round black bear habitat must provide suitable and abundant food resources during spring, summer, and fall. This model assumes that, for optimal habitat conditions, 7% to 50% of an evaluation area must be in wetland cover types to provide spring food (Figure 5a), 25% to 50% of an area must be in cover types that produce summer food (Figure 5b), and ≥35% of an area must be in cover types that produce fall foods (Figure 5c).

Summer foods are typically produced in greatest abundance in early stages of forest succession (e.g., burned areas, clearcuts, and thinned forest stands). Important soft mast species, however, are produced in forested cover types as well. Maximum availability of summer foods is assumed to occur where nonforested (e.g., <25% tree canopy cover) cover types ≤250 m from forest cover types compose 25% to 50% of the evaluation area (Figure 5b). Figure 5b is assumed to provide an indirect measure of forest-nonforest cover type interspersion as well as availability of summer foods. The availability of summer foods is assumed to decrease in evaluation areas where nonforested cover types >250 m from forest cover types account for >50% of the total evaluation area. Where nonforested cover types account for >50% of the area, forest cover is assumed to be excessively reduced, resulting in an inadequate amount of cover and precluding black bear access to foods present. Evaluation areas with ≥75% nonforested cover types are assumed to be indicative of unsuitable black bear habitat as a result of insufficient escape and security cover.

Fall foods, chiefly hard mast, are produced primarily within forest cover types. It is assumed that the absence of hard mast producing species will reflect low value but not totally unsuitable black bear habitat in the Upper Great Lakes region (Figure 5c). Maximum availability of fall foods is assumed to be present when ≥35% of the evaluation area is in cover types that have ≥1% canopy cover of hard mast producing species.

The variables used to evaluate cover type composition are used in Equation 5 (p. 35) to determine an HSI value for black bear habitat in the Upper Great Lakes Region.

Special Consideration Component: Human-Bear Incompatibility

Human use and habitation have the potential to directly influence the suitability of an area as year-round black bear habitat. Garbage, campers' food, and agricultural crops that lead to bears being killed are detriments to bear habitat. Such sites are especially deleterious in years of scarce natural food when bears forage farther and more boldly than usual. Areas of human use and habitation tend to act as sinks that deplete bears from surrounding areas because people kill them at unsustainable rates. Even at low population

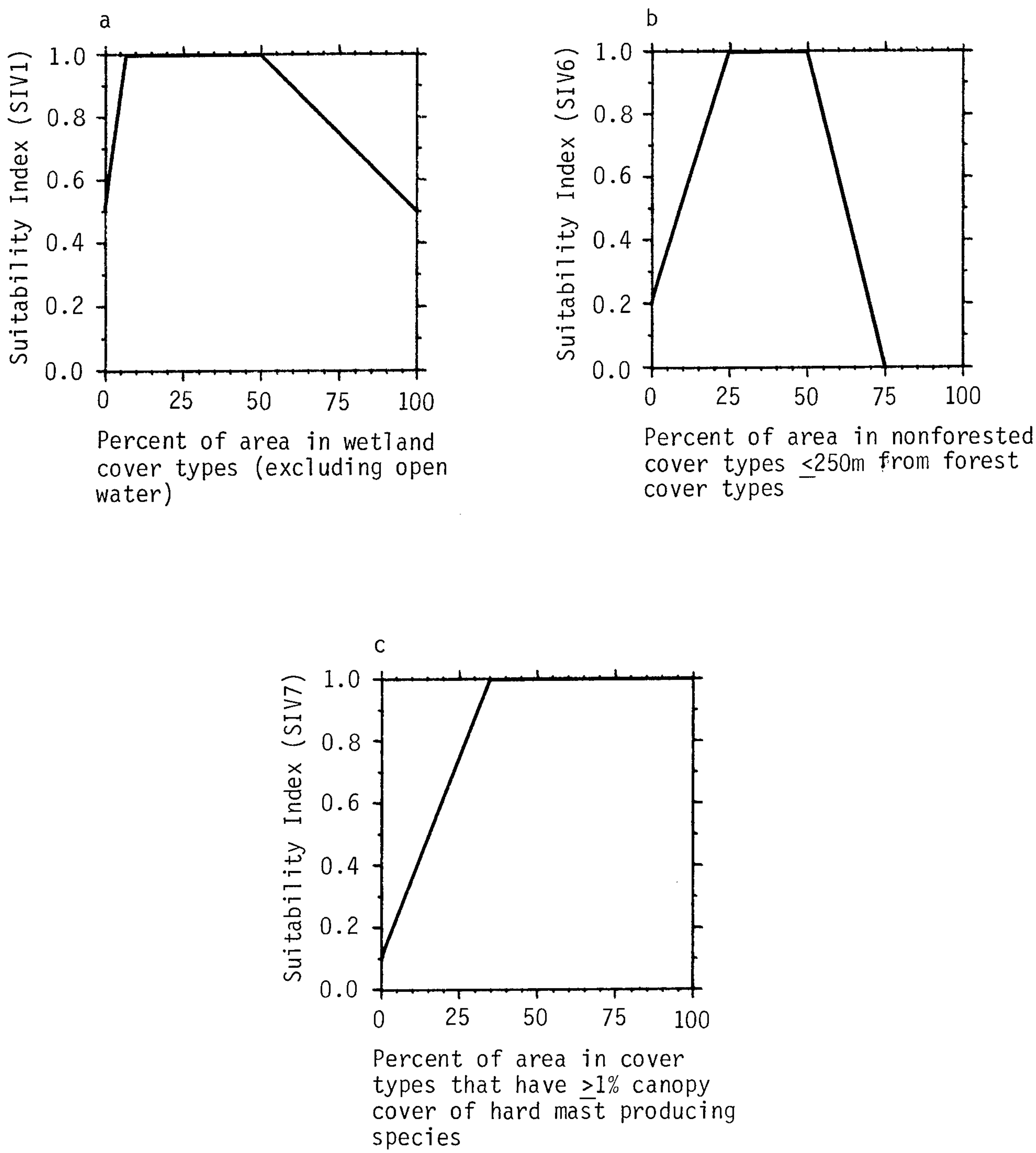

Figure 5. Relationships between cover type composition and habitat quality for black bears in the Upper Great Lakes Region.

densities, bears will continue to be attracted to human related food in times of natural food shortage, and black bear reproductive rates show little density dependence, being dependent primarily on the widely fluctuating levels of natural food crops.

In order to compute a zone of influence around the sinks we assume the following:

1. The zone of influence is a circular area centered on the sink.

2. The sustainable mortality rate of the entire zone is equal to the mortality rate at the sink.

Thus, in order to compute the area of the zone of influence we must know the maximum sustainable mortality rate, the density of bears the habitat can support on a sustained basis, and the number of bears killed per year at the "sink". The size of the zone is calculated using the following equation:

$$Z = \frac{K}{DM}$$

where Z = area of zone of influence

K = number of bears killed at the sink per year

D = density of bears per mi^2

M = maximum sustainable annual mortality

For example, if the sustainable yearly mortality rate is 15% per year, supportable bear density is 1 bear/3 mi^2 (including cubs), and the estimated unregulated kill at a sink is 20 bears/year, the zone of influence would be calculated as follows:

Zone of influence around a sink when 20 bears/year are killed $= \dfrac{20 \text{ bears}}{0.33 \text{ bear/mi}^2 \times 0.15} = 404 \text{ mi}^2$

Where the required data on maximum sustainable mortality rate, density of bears the habitat can support, or kill rate at the sink are not available, zones of influence for individual sites are defined by the following radii: 5.7 km (3.6 mi) around towns; 3.5 km [2.2 mi (the approximate diameter of a female territory, Rogers 1987)] around cropland; and 1.1 km (0.7 mi) around residences. The total area inside all zones of influence is calculated (total area is not always the simple sum of each individual zone as portions of zones may overlap) and a suitability index assigned to the percent of evaluation area inside zones of influence using the relationship in Figure 6.

The suitability index for human intolerance (SIHI) is expressed in Equation 4:

$$SIHI = SIV8 \tag{4}$$

Equation 4 is based on the following assumptions. As human use and habitation increases, black bear habitat quality is assumed to be degraded as a result of greater potential for human-bear interaction, depredation, and bear mortality. Minimum habitat quality is assumed to exist where an entire evaluation area is a zone, or zones, of influence. In such instances, the evaluation area is assumed to have long-term ability to support bears only if there are remote areas elsewhere to continuously supply new individuals. Habitat conditions in zones of influence are considered when calculating bear habitat suitability for the evaluation area and the model will show habitat improvements in these areas having a beneficial effect on habitat. Where no portion of an evaluation area is within a zone of influence, it is assumed that there are no direct detrimental human effects, and habitat suitability is determined solely by measurement of spring, summer, and fall foods.

It is recommended that inventory and analysis of seasonal food quality be completed within an evaluation area without regard to the location of zones of influence. Elimination of these areas in the evaluation of spring, summer, and fall food quality could fail to include important seasonal food producing sites resulting in an underestimation of the habitat value of the evaluation area. The zone of influence thus serves as a modifier of habitat quality.

The size of zones of influence for a given level of unregulated, human caused deaths will vary regionally. Where better habitat enables bears to reproduce faster or in smaller territories, smaller zones of influence will suffice. Bear mortality around areas of human use and habitation will vary with local and individual attitudes about bears. Public education can increase understanding of bears and reduce unnecessary killing. For example, in Pennsylvania, it is common for people to feed, observe, and admire potential nuisance bears rather than shoot them (G. Alt, pers. comm.). Feeding can prevent bears from seeking food in less desirable places and can prevent some nuisance activity. Although feeding of bears is not recommended, considerable understanding and tolerance of bears has developed in Pennsylvania, permitting a high population of bears and people to coexist. There have been no serious injuries from bears in Pennsylvania this century (Alt, pers. comm.).

Where bears are killed around human habitation areas, replacement bears tend to be dispersing subadult males, females from adjacent areas, and temporary inhabitants foraging outside their usual ranges (Rogers 1987). Bears that live adjacent to human habitation have the greatest chance of being shot, although some of the 90 bears reported shot on the outskirts of Duluth, Minnesota, during 1985 came from at least 107 km away (Rogers 1987).

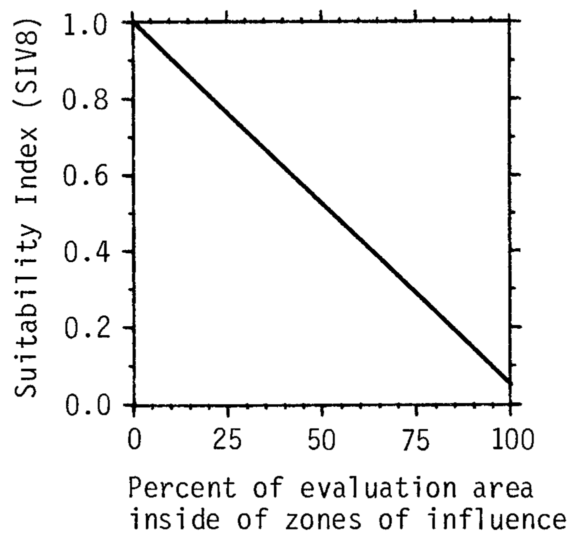

Figure 6. Suitability index for percent of evaluation area inside zones of influence (areas around sites of human use and habitation) for black bears in the Upper Great Lakes Region.

<u>HSI determination.</u> HSI (Equation 5) value for black bear habitat is a function of three major components: (1) quantity and quality of spring, summer, and fall foods (SIV1 to SIV5); (2) cover type composition within the evaluation area (SIV1, SIV6, and SIV7); and (3) the influence of human use and habitation on black bear habitat quality (SIV8).

$$HSI = \frac{SISP + (SISU \times SIV6) + (SIFA \times SIV7)}{3} \times SIHI \qquad (5)$$

where SISP = suitability index value for percent of area in wetland cover types (SIV1)

SISU = suitability index for summer food (Equation 2)

SIV6 = suitability index value for percent of area in nonforested cover types ≤250 m from forested cover types

SIFA = suitability index for fall food (Equation 3)

SIV7 = suitability index value for percent of area in cover types that have ≥1% canopy cover of hard mast producing species

SIHI = suitability index for human intolerance (Equation 4)

The availability of spring food as well as wetland cover type composition is a function of SIV1, percent of area in wetlands. Suitability index values for summer (Equation 2) and fall (Equation 3) foods are directly modified by their cover type composition values. The average of these products provides an overall suitability index value for food. Human intolerance (Equation 4) directly modifies the overall food suitability index, yielding the HSI.

Equation 5 is based on the following assumptions. Spring, summer, and fall food components are assumed to have equal value in the determination of year-round habitat quality. The absence of a major seasonal food source will result in a low HSI value but not totally unsuitable conditions. Cover type composition directly modifies seasonal food availability, based on the overall distribution of major cover types that provide each of the required seasonal foods. Evaluation areas that contain less than assumed optimum cover type composition (Figure 5) will receive an HSI of <1.0 regardless of the amount and quality of the food resources that are present. Human intolerance may result in a less than optimum HSI value regardless of the amount and quality of food resources present. Evaluation areas where human habitation or agriculture is present at greater than acceptable densities (Figure 6) will result in a minimum HSI value regardless of the amount, quality, and distribution of food resources.

Application of the Model

This model is based on the assumption that the entire model will be used to evaluate a relatively large area (i.e., approximate area of a female territory, 10 km^2). However, alternatives are available for users who do not wish to evaluate such a large area or all three seasonal food life requisites. Any of the life requisite components (e.g., spring, summer, or fall food and human intolerance) can be used individually for habitat analysis. For example, the summer food component can be used to evaluate and compare one or more management areas (e.g., compartments) in relation to the abundance and quality of summer food (SIV2 and SIV3) and recommended cover type composition (SIV6). Individual model variables may be used as guidelines for management prescriptions on a smaller scale (e.g., individual sites or stands). In areas where seasonal food suitability and quantity are perceived to be adequate the human intolerance component alone provides a means to evaluate the impact of human use or habitation on black bear habitat suitability.

When the entire model is applied to a tract as large as 10 km^2, it can be assumed that the evaluation area will be composed of several forested and nonforested cover types. Forested cover types may be further broken down into specific forest types or stands. The complexity in application of this model will increase in direct relation to the number of individual cover types evaluated. Additionally, application of the model is further complicated by the fact that forested cover types may provide summer as well as fall foods. Therefore, some forested cover types, if not all, may require evaluation of the quantity and quality of more than one seasonal food resource.

The following steps are provided as guidance for application of the model to a large area (e.g., 10 km^2) or other evaluation area composed of numerous cover types.

1. Stratify the evaluation area into cover types.

2. Determine the area of each cover type and the total area of the evaluation area.

3. Determine the area of wetland cover types. Calculate the percentage of the evaluation area in wetland cover types and enter this value into SIV1 to calculate a spring food index (SISP, Equation 1). This index value also will be used in Equation 5 for calculation of the HSI.

4. Calculate summer food (SISU, Equation 2) and fall (SIFA, Equation 3) food values in appropriate cover types.

   Since large evaluation areas, or major cover types (e.g., deciduous forest) will be composed of several cover types it will be necessary to determine average SISU and SIFA values weighted by area. The following steps are recommended for determination of weighted summer and fall food indices.

   a. Stratify the major cover type (e.g., deciduous forest) into component cover types (e.g., aspen, mixed hardwood, mixed conifer/hardwood). Determine the total area of deciduous forest and the area of each component cover types.

   b. Calculate the SISU and/or SIFA for each component cover type as appropriate.

   c. Multiply the index derived in step b for each component cover type by its area. Sum these values (separately for SISU and SIFA if both are calculated) and divide this value by the total area of all component cover types evaluated to obtain a weighted food value.

      The steps outlined above are expressed by the following equation:

$$\text{SISU or SIFA (weighted by area)} = \frac{\sum_{i=1}^{n} \text{SI value}_i\, A_i}{\sum_{i=1}^{n} A_i}$$

where n = number of cover types evaluated

SI value = suitability index for SISU or SIFA

A_i = area of individual cover type

5. Enter the spring food index (SISP), weighted summer food index (SISU), and weighted fall food index (SIFA) values calculated in step 4 into Equation 5.

6. Determine the total area of nonforested cover types ≤250 m from forested cover types in the evaluation area (SIV6) and the total area of cover types that have >1% canopy cover of hard mast producing species (SIV7). Divide the area of nonforested cover types ≤250 m from forested cover types and the area in hard mast producing cover types each by the area of the evaluation area. Enter the resulting percentage values into SIV6 and SIV7 respectively to obtain index values. Enter these values into Equation 5.

7. Calculate the human intolerance index (SIV8, Equation 4) and enter the value into Equation 5).

8. Calculation of Equation 5 yields the final (weighted by area) HSI value.

Summary of model variables. Eight variables are used in this model to evaluate food availability, cover type composition, human intolerance, and their assumed influence on black bear habitat quality in the Upper Great Lakes Region. The relationships between habitat variables, life requisite values, and the HSI are summarized in Figure 7. Variable definitions and suggested measurement techniques are provided in Figure 8.

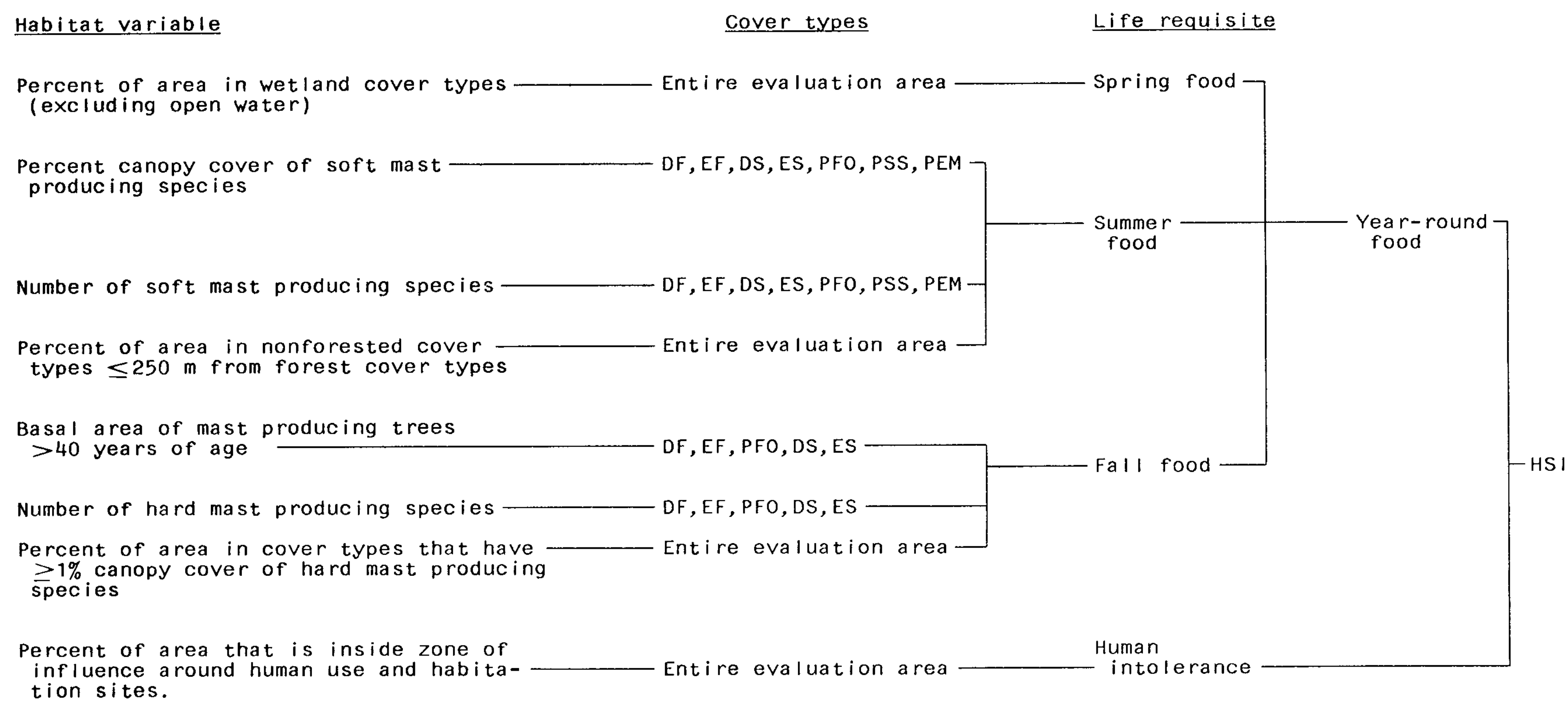

Figure 7. Relationships of habitat variables, cover types, and life requisites in the black bear model for the Upper Great Lakes region. See Figure 8 for specific definition of variables and additional guidance in measurement of habitat variables.

Variable (definition)	Cover types	Suggested technique
Percent of area in wetland cover types [the area of wetland cover types divided by the total area of the evaluation area. Open water (e.g., lakes, large rivers) should be excluded from the determination of wetland area]. Wetland definitions in this model follow Cowardin et al. (1979). Users should include riparian areas and other low-land sites that may not typically be called wetlands in the evaluation of this value. Note: The value derived for this variable is used as a surrogate measure of the availability of spring food (Figure 2) and as a measure of habitat composition (Figure 5a).	Entire evaluation area	Remote sensing
Percent canopy cover of soft mast producing species [the percent of the ground that is shaded by a vertical projection of the canopies of vegetation that produce soft mast (e.g., serviceberry, blueberry). May include trees, shrubs, as well as herbaceous vegetation, i.e., wild sarsasparilla. Hazel should be included in this calculation since it is a food available in summer.]	DF,EF,DTS,ETS,ES,DS, DSS,ESS,PFO,PEM	Transect, line intercept, quadrat

Figure 8. Definitions of variables and suggested measurement techniques.

Variable (definition)	Cover types	Suggested technique
Number of soft mast producing species (the number of individual species of plants present at ≥1% canopy cover per cover type that produce soft mast. Hazel should be included in this calculation since it is a food available in summer).	DF,EF,DTS,ETS,ES, DS,DSS,ESS,PFO,PEM	Transect, line intercept, quadrat
Percent of area in nonforested cover types ≤250 m from forest cover types [the area of nonforested cover types (<25% canopy cover of trees) ≤250 m from forest cover types divided by total area of evaluation area].	Entire evaluation area	Remote sensing
Basal area of mast producing trees >40 years in age [the area of exposed stems of mature (>40 yr) mast producing trees if cut horizontally at 1.4 m (4.5 ft) in height. Expressed in m^2/ha or ft^2/ac].	DF,EF,DTS,ETS,ES, DS,PFO	Bitterlich method, transect, line intercept, quadrat
Number of hard mast producing species [the number of individual species of plants present with at least 1 mature tree/ 0.4 ha (1 ac) that produce hard mast (e.g., oak, hickory)].	DF,EF,DTS,ETS,ES, DS,PFO	Transect, line intercept, quadrat
Percent of area in cover types that have ≥1% canopy cover of hard mast producing species (the area of cover types that have ≥1% canopy cover of hard mast producing species divided by total area of evaluation area).	Entire evaluation area	Remote sensing

Figure 8. (Continued)

Variable (definition)	Cover types	Suggested technique
Percent of area that is inside zone of human influence around human use and habitation sites [the percent of the total evaluation area that is inside zones of negative human influence around campgrounds, residences, resorts, attractive agricultural crops (e.g., corn, oats, orchards), and towns. Suggested radii of zones of influence are 5.7 km (3.6 mi) around towns; 1.1 km (0.7 mi) around residences, resorts, and 3.5 km (2.2 mi) around attractive cropland. The size of these areas may vary regionally based on human acceptance of black bears, habitat quality, and bear density. Remote campgrounds, accessible only by backpackers or canoe (e.g., those in the Boundary Waters Canoe Area) are not recommended to have a negative influence zone assigned due to their primitive nature and the attitudes typical of the users].	Entire evaluation area	Remote sensing

Figure 8. (Concluded)

Model assumptions. The black bear HSI model for the Upper Great Lakes Region has been formulated based on the following major assumptions.

1. Excluding human influence, the availability and distribution of spring, summer, and fall foods are the most influential characteristics that define the quality of black bear habitat.

2. The availability of water and den sites is less limiting in the definition of black bear habitat quality than is the availability and distribution of food.

3. Spring, summer, and fall foods are assumed to have equal value in the definition of year-round food quality.

4. Optimum food conditions can occur only if all three seasonal food resources are available.

5. Human intolerance has a direct effect on the quality of black bear habitat.

6. Cover type composition is assumed to indirectly reflect the availability of food resources and cover type interspersion.

7. Escape and security cover are assumed to be indirectly addressed by the evaluation of cover type composition. It is assumed that if wetlands, shrub-dominated, and forested cover types are all present within the evaluation area at assumed optimum composition (Figure 5), that sufficient escape and security cover also will be provided.

8. Year-round food availability and quality, as reflected by SI values, are assumed to be correlated with the physiological status and reproductive success of black bears.

Research needs. Additional information is needed to refine the model and make it more specific to ecologically different areas within the Upper Great Lakes Region. Information is particularly needed on the food habits of bears in different portions of the region in order to identify the habitats that supply those foods in the different seasons. Information is needed to identify the forest management practices that produce favorable bear habitat, including the most favorable sizes and shapes of clearcuts, the proper interspersion of cover types, and the most beneficial scheduling of cutting, regeneration operations, and timber stand improvements. This information could be directly incorporated into the integrated resource management processes in the various State and National forests of the region.

Habitat use is expected to differ not only between ecologically different areas but also between years of high food production and years of scarcity. The foods bears use in years when fruits and nuts are scarce are not well known over much of the Upper Great Lakes Region. Ants may be an important food in such years, but little is known regarding bear preferences for the different ant species, the ecology of preferred species, or the forest management practices that produce those species.

Little is known about the amount of food that bears eat in years of abundance versus years of scarcity or about the amount of food that managers must maintain for bears. How much is enough? Excess food will not increase black bear survival, growth, and reproductive success. Identifying critical foods and habitats in which improvements will make a difference to bears will enable managers to maximize the benefits of habitat improvement budgets. This research need relates to the model component on forest composition. The recommended guidelines of 7% to 50% wetland, 25% to 50% nonforested upland, and ≥35% hard mast producing cover types are in particular need of validation and refinement for the ecologically different areas of the Upper Great Lakes Region. As diet information in the different areas becomes known, forest composition recommendations can be refined.

There is also a need for information on the effects of human use and habitation on black bear populations. The model component on human intolerance of bears provides a method for quantifying the amount of remote habitat that is needed to counter the effects of unregulated killing by people in less remote areas. Further information on bear mortality around campgrounds, farms, resorts, towns, and isolated residences will enable better predictions of how bears will be affected by urban sprawl, lakeside home developments, human population expansion, and increasing recreational use of the forest. This information will help refine estimates of the amount of land needed for a minimum viable population. There is a further need for information on bear repellents to enable people to deter nuisance bears without killing them.

The model is intended to aid managers in assessing the effects of forest management alternatives on bear habitat in the Upper Great Lakes Region. Balancing the needs of bears with those of other wildlife or man is left for the forest managers.

Finally, it should be reiterated that the model is hypothetical in many respects. The model is the best effort of experienced wildlife biologists and knowledgeable reviewers familiar with black bears and their habitat in the Upper Great Lakes Region. However, the limits of that knowledge are evident in the number of assumptions that are made. All assumptions need field testing to obtain empirical data. The model identifies some of the kinds of information needed for enlightened management of black bear habitat and provides a structure for incorporating that information as it is obtained.

SOURCES OF OTHER MODELS

McLaughlin et al. (1987) developed a model for evaluation of year-round black bear habitat that is applicable to conifer-deciduous forests in Maine, New Hampshire, Vermont, and Massachusetts. The model is based on 14 variables that are used to evaluate spring, summer, and fall food resources and 2 variables to evaluate cover quality.

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A review and synthesis of existing information were used to develop a Habitat Suitability Index (HSI) model for the black bear (Ursus americanus). The model consolidates habitat use information into a framework appropriate for field application, and is scaled to produce an index between 0.0 (unsuitable habitat) and 1.0 (optimum habitat). HSI models are designed to be used with Habitat Evaluation Procedures previously developed by U.S. Fish and Wildlife Service.

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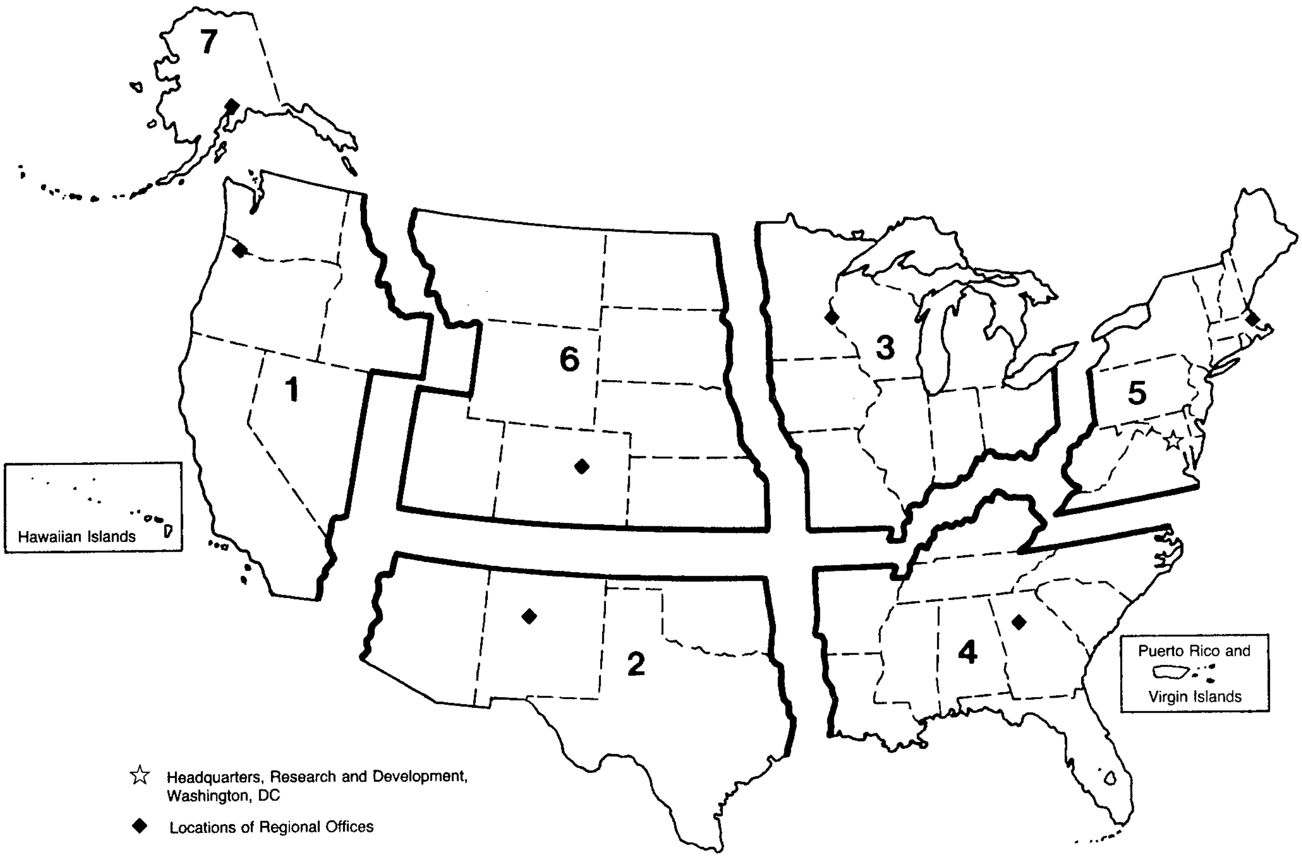

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