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## BLACK BEAR HABITAT UTILIZATION AND HABITAT MODEL VALIDATION IN MICHIGAN

By

James Glenn Hirsch

A THESIS

Submitted to Michigan State University in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

Department of Fisheries and Wildlife

#### ABSTRACT

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# BLACK BEAR HABITAT UTILIZATION AND HABITAT MODEL VALIDATION IN MICHIGAN

By

James Glenn Hirsch

The habitat selection and movements of 33 radio-collared black bears (<u>Ursus americanus</u>) were monitored from March to December 1988, on Drummond Island, Michigan. An attempt was made to validate a Habitat Suitability Index (HSI) model designed for black bears. Habitat variables required by the HSI model were measured in appropriate vegetation types to determine HSI scores for each adult bear's home range. Adult male and female home range sizes were 75.64 km<sup>2</sup> and 48.14 km<sup>2</sup>, respectively. The movement of bears depended on the distribution and abundance of preferred foods. Significant correlations were not obtained when HSI scores were compared to home range sizes, cub litter sizes, cub weight gains, and mean daily movements. The HSI score for Drummond Island did not correspond well to average age of first reproduction and mean home range overlap. The black bear HSI model should be revised to better reflect black bear ecology.

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#### INTRODUCTION

The black bear (Ursus americanus) is an omnivore which usually occupies heavily forested regions interspersed with areas of early succession (Herrero 1979). Although primarily vegetarians, black bears will eat carrion and occasionally prey upon ungulate fawns (King 1967, Ballard et al. 1981, Ozoga and Verme 1982, Verspoor 1983, Mathews and Porter 1988, Larson et al. 1989). Early spring bear diets usually consist of grasses and forbs (Hatler 1972, Kelleyhouse 1980, Grenfell and Brody 1983, Rogers and Allen 1987, Rogers et al. 1988). These foods represent a source of protein, but do not result in weight gains (Landers et al. 1979, Beeman and Pelton 1980). As spring progresses, bears occupy upland areas to forage on upland forbs, ants, and the buds and catkins of aspen (<u>Populus</u> spp.) and balsam poplar (<u>P. balsamifera</u>) trees (Rogers and Allen 1987, Rogers et al. 1988).

Bears start to gain weight when their carbohydrate uptake increases in summer (Rogers 1976, 1987; Alt et al. 1980). The berries of Canada buffalceberry (<u>Shepherdia canadensis</u>), blueberries (<u>Vaccinium</u> spp.), serviceberry (<u>Amelanchier</u> spp.), wild strawberry (<u>Fragaria</u> spp.), wild sarsaparilla (<u>Aralia nudicaulis</u>), raspberries (<u>Rubus</u> spp.), and cherries (<u>Prunus</u> spp.) are preferred foods during summer (Rogers 1987, Rogers and Allen 1987, Noyce and Coy 1989). Such berries are most abundant in regenerating aspen stands and open upland vegetation

types in northcentral Minnesota (Noyce and Coy 1989). Roadsides and clear-cut areas were found to produce abundant soft mast in the central Adirondacks of New York (Warbuton 1982). Similarly, Lindzey and Meslow (1977) observed that soft mast producing species were 7-8 times more abundant in clear-cut areas than in older conifer and alder stands on Long Island, Washington. Grasses and forbs are still utilized during summer, but to a much lesser extant relative to spring (Hatler 1972, Zytaruk and Cartwright 1978, Grenfell and Brody 1983).

In fall, bears shift their diets from soft mast to hard mast. Mast from American beech (Fagus <u>grandifolia</u>), northern red oak (<u>Quercus</u> <u>rubra</u>) and other hard mast producing trees predominate fall diets (Piekielek and Burton 1975, Rogers 1976, Landers et al. 1979, Garshelis and Pelton 1981, Grenfell and Brody 1983, Rogers 1987, Rogers and Allen 1987). Such foods have a high fat content, allowing bears to build fat reserves necessary for winter dormancy. Soft mast crops still persisting in early fall, such as roundleaf dogwood (<u>Cornus rugosa</u>), highbush cranberry (<u>Viburnum trilobum</u>), and common winterberry holly (<u>Ilex laevigata</u>) are also utilized. However, these foods are not as energy rich as hard mast crops and are usually past their peak of availability (Rogers and Allen 1987).

Black bears are typically dormant from October-November to April-May in cool northern climates (Jonkel and Cowan 1971, Rogers 1977, 1987). In contrast, denning activity is usually brief or non-existent in southern regions (Landers et al. 1979). Bears tend to be quite variable in den selection and construction. For example, most bears at Fort McMurray, Alberta, were found to excavate dens within young aspen-

birch stands (Fuller and Keith 1980). By contrast, bears at Cold Lake, Alberta, usually excavated dens under rootmasses in mature stands of aspen-spruce and spruce (Tietje and Ruff 1980). Most den sites in the Catskill Mountains, New York, were in rock cavities in heavily forested areas averaging 1.6 km from the nearest road (O'Pezio 1980). Bears in Michigan's Upper Peninsula usually excavate dens under stumps or logs within conifer and mixed conifer-hardwood swamps (Erickson 1964a). Due to the low incidence of den re-use, the availability of den sites is never considered more limiting than the distribution and abundance of bear foods (Lindzey and Meslow 1976, Alt and Gruttadauria 1984, Rogers and Allen 1987).

Black bears commonly reach sexual maturity at 3-4 years; however, sexual maturity as late as 7 years has been reported (Kolenosky and Strathearn 1987). Both males and females mate promiscuously during the mid-June to mid-July breeding season (Kolenosky and Strathearn 1987, Rogers 1987). Adult females usually give birth to 1-3 cubs during winter dormancy. Bear cubs accompany their mother for approximately 18 months. Male bears do not participate in natal care; in fact, they will occasionally kill cubs (Rogers 1987). Overall, bears are solitary, congregating only around concentrated food sources such as garbage dumps.

Human encroachment on bear habitat is one of the major reasons for decreased bear numbers (Rogers 1987). Bears are secretive, avoiding human activity centers and dwellings unless a reliable food source (i.e. garbage dump, orchards) is available. Areas of high human activity frequently act as population sinks for bears (Rogers and Allen

1987). Timber harvesting activity also negatively impact bear populations by increasing hunting and poaching opportunities, as a result of road construction, and decreasing hard mast availability (Rogers and Allen 1987). However, logging can also positively affect bear habitat by providing increased soft mast production.

Historically, black bears were unprotected in Michigan until 1925, when declared a game animal by the state legislature (Stuewer 1957, Michigan Department of Natural Resources 1988). In 1939, however, the legislature removed statewide protection, but allowed the Natural Resources Commission to protect bears in counties that requested it. Prior to 1980, except for a brief period in the mid 1960's, bear hunters were only required to possess a deer license to harvest bears. Since 1980, a separate bear license has been required to hunt bear in Michigan. Michigan bear hunters numbered approximately 10,000 in 1985, and this number has subsequently increased (Michigan Department of Natural Resources 1988). The growing number of bear hunters has resulted in increased interest and concern over Michigan's black bear population (Smith 1985). In addition, there has been a persistent conflict between bear hunters that utilize baits and those that utilize dogs to harvest bears. In face of these issues and problems, increased knowledge of black bear population dynamics and habitat utilization is important to maintain optimal bear numbers and habitat.

The purpose of this study was to determine black bear home range sizes, home range overlap, movements, activity patterns, and habitat selection on Drummond Island, Michigan. Previous studies conducted on Michigan's black bear population have failed to intensively study these

aspects of black bear ecology (Erickson 1964b, Rogers et al. 1976, Manville 1982). Additionally, this study also involved validation of a recently developed Habitat Suitability Index (HSI) Model for black bears occupying the Upper Great Lakes Region (Rogers and Allen 1987). Since HSI models are objective and produce a numeric measure of habitat quality, they have the potential to be valuable wildlife management tools. However, the accuracy of most HSI models has not been tested. Validation of the black bear HSI model is necessary so that HSI scores are accepted by wildlife managers, judges, the public, and other factions involved or influencing land use decisions.

### **OBJECTIVES**

The main objectives of this study were to:

- 1) determine movements of bears on a daily and seasonal basis,
- 2) determine bear home range sizes and home range overlap,
- 3) determine seasonal habitat preferences and critical habitats for bears,
- 4) validate the accuracy of the black bear HSI model, and
- 5) make recommendations for habitat management for bears in Michigan.

### STUDY AREA DESCRIPTION

This study was conducted on Drummond Island, Michigan, located at the northern end of Lake Huron, 1.6 km off the eastern tip of Michigan's Upper Peninsula (Fig. 1). The island, located within Chippewa County, is 337 km<sup>2</sup> in size and is occupied by 800 permanent and 3000 seasonal residents (Drummond Chamber of Commerce, pers. commun.). Drummond Island is accessible by ferry year round, and receives heavy recreational use. Sport fisherman take advantage of the good yellow perch (Perca flavescens), walleye (Stizostedion vitreum), and salmon (Oncorhynchus spp.) fisheries offered in the vicinity of Drummond Island. White-tailed deer (Odocoileus virginianus) and small game hunting are popular recreational activities during the fall. Bear hunting on Drummond Island was closed in 1982 because of concerns of overexploitation. However, a regulated permit hunt was established in September 1988. Logging and mining activities also occur on Drummond Island. Logging activities are generally concentrated at the eastern portion of the study area, while an open pit limestone mine exists at the western portion of the island. Slightly over 50% of the island is managed by the Michigan Department of Natural Resources (MDNR), Forest Management Division.

The climate of Drummond Island is considered maritime, but shifts to continental polar during the winter (Davis and Frey 1984). The mean





annual temperature is  $4.8^{\circ}$ C, with a monthly mean in July and January of  $18^{\circ}$ C and  $-10^{\circ}$ C, respectively (Hadeen 1988). Total annual precipitation averages 82 cm, with most falling as rain (Hadeen 1988). Snow is permanently on the ground from mid-November to mid-April (Davis and Frey 1984), resulting in a growing season that is slightly over 4 months long (Albert et al. 1986). Temperatures are moderated, and cloudiness and precipitation increased, because of Lake Huron. In early fall, the passage of cold air masses from the west over the warm waters of Lake Superior and Lake Huron results in frequent fog. Summer rains are associated with post-frontal northwest winds. Long term (1951-1980) mean monthly temperature and precipitation for 1988, are given in Figure 2 (Hadeen 1988).

Drummond Island consists of lower and middle Silurian Limestone and Dolomite bedrock, with the northern tip of the island containing upper Ordovician Limestone and Dolomite bedrock (Davis and Frey 1984). A thin layer of glacial till can be found over the majority of the island. Detour stony loam, Johnswood stony loam, and Carbondale muck are common soils within the study area (Veatch et al. 1927). The majority of organic soils (i.e. Carbondale muck) are concentrated in the central portion of the island due to the low elevation in that area. The Detour stony loam soil is fertile and has a high moisture content, but is excessively stony. The Johnswood stony loam is closely associated with the Detour stony loam, but is less stony. This soil is moderately fertile and fairly moist. The underlying drift in the Johnswood stony loam is not as clayey as the Detour stony loam; thus,



Figure 2. Mean monthly temperatures and total monthly precipitation at Chippewa County, Michigan, 1988.

it is better drained. Both soils tend to be too shallow for agricultural purposes.

Smooth terrain is predominate on the island, with frequent rolling ground moraines and an occasional large ridge. Elevations vary from 175 to 315 m. Vegetative coverage on Drummond Island consists of 42% aspen-birch, 28% conifer, 13% upland hardwoods, 5% openings, 4% wetlands, and 4% lowland hardwoods. In addition, 3% of the island is comprised of residential, industrial, and recreational areas. There are 2 farms on the island which, when combined, occupy < 1% of the total area.

The aspen-birch vegetation type consisted of quaking (P. tremuloides) and bigtooth aspen (P. grandidentata), with scattered paper birch (Betula papyrifera). However, some aspen-birch stands were exclusively paper birch. Common understory species within this vegetation type included red-osier (C. stolonifera) and roundleaf dogwood, Canada buffaloeberry, beaked hazel (Corylus rostrata), serviceberry, balsam fir (Abies balsamea), and northern white-cedar (Thuja occidentalis). Upland coniferous and lowland coniferous areas were both categorized as the coniferous vegetation type. Lowland coniferous areas (usually cedar swamps) were predominately northern white-cedar with scattered swamp honeysuckle (Ionicera oblongifolia) and speckled alder (Alnus rugosa) in the understory. Upland coniferous areas were predominately red pine (Pinus resinosa) with Canada buffalceberry, serviceberry, and common juniper (Juniperus communis) in the understory. The coniferous vegetation type however, was composed mostly of the lowland coniferous type. American beech and sugar maple

(Acer saccharum) were the dominate overstory species in the upland hardwood vegetation type, with red raspberry (Rubus strigosus), American beech, and sugar maple in the understory. Openings were typically dominated by wild strawberry and grasses, with common chokecherry (P. virginiana) occupying the periphery. However, some stands delineated as openings were actually regenerating aspen-birch stands. Shrub swamps, mudflats, and shallow marshes were all categorized as wetlands. Lowland hardwoods were predominately balsam poplar and ash (Fraxinus spp.) with a diverse understory that included black spruce (Picea mariana), red-osier dogwood, balsam poplar, ash, and speckled alder. METHODS

During summer, 1986, the MDNR, Wildlife Division trapped and eartagged 23 black bears on Drummond Island in an effort to study black bear populations (Visser 1987). Capture efforts continued again the following summer with some captured bears fitted with radio-collars. Additionally, 11 yearlings were fitted with radio-collars as a result of winter den checks. By spring 1988, 33 bears on Drummond Island were equipped with radio-collars, and subsequently monitored for this study.

### General Location Methods

Radio-collared bears were located from the ground at randomly selected times throughout their daily activity period (0500 to 2300 hours) from March to December 1988, using a portable TR-2 receiver with a hand-held 2 element yagi antenna (Telonics, Inc., Mesa, AZ). An attempt was made to locate bears at least once every 2 days but no more than once per day. The vegetation type for each location was identified by walking in on the bear or by moving around the animal a minimum of 3 sides. The overstory vegetation, described by the Michigan State Forest Operations Inventory system (Michigan State Forest Operations Inventory 1982), activity, and predominate shrub species were recorded for each location. Legal descriptions were used to a minimum of 16.2 ha (40 ac) to describe locations.

Bear activity was monitored from 2300 to 0500 hours during spring, summer, and fall (twice in spring, once in summer, and 4 times in fall) to determine if bears were active at all during the night. Activity for daytime and nighttime locations were determined by either direct observation or by the integrity of the radio signal. Bears whose radio signal varied in intensity were considered active, while bears whose radio signals were constant were considered inactive. This was a subjective measure of activity, since radio signals can be influenced by wind, vegetation, precipitation, topography, and observer skill (Burger 1988).

# Vegetation Sampling

Vegetation types were delineated on Drummond Island by a digitized vegetation coverage map developed by the Michigan Resource Inventory System (MIRIS), a program within the Land and Water Management Division of MDNR. This map was developed from the interpretation of color infrared aerial photos taken in 1978-79 (M. Scieszka, MDNR, pers. commun.).

Number and percent shrub cover of soft mast producing species were determined by the line intercept method (Canfield 1941, Hays et al. 1981) for aspen-birch, upland hardwood, and open vegetation types. Stratified random sampling was conducted, with stands for sampling selected from the MIRIS vegetation coverage map. Four 30 m long intercept lines were randomly located within each randomly selected stand. The number of soft mast producing species (including beaked hazel), that covered >1% of the line, and percent coverage of soft mast

producing species were tallied. Means of measured habitat variables were extrapolated to each vegetation type from the means of sampled stands. The required number (90% confidence interval that is  $\pm 20$ % of the mean) of replicate stands was determined by Stein's two-stage sample method (Steel and Torrie 1980). For other vegetation types (lowland hardwood, coniferous, and wetland vegetation types), ocular estimates of habitat variables were made, as the occurrence of soft mast producing species in these vegetation types was extremely low. The timing of soft mast production was noted for shrub species that were utilized by bears.

Mean basal area of hard mast producing trees greater than 40 years old, and the number of hard mast producing tree species were determined by the Bitterlich method for the upland hardwood vegetation type. Each randomly selected stand was sampled with 20 randomly located samplepoints. Basal area was measured with a 10-factor tubular gauge, and the number of hard mast producing tree species was tallied at each sample-point. The mean dbh at which hard mast trees were greater than 40 years old was determined by comparing dbh with the number of annual growth rings found on increment bore cores. The required number (90% confidence interval that is  $\pm 20$ % of the mean) of replicate stands was determined by Stein's two-stage sample method (Steel and Torrie 1980).

#### Movements and Home Ranges

Bear locations were plotted on the MIRIS vegetation coverage map using ARC/INFO (Environmental Systems Research Institute, Redfield, CA), a geographic information system operated on a VAX 8650 (Digital

Equipment Corporation, Maynard, MA). Bears were categorized as adult males (n = 3), yearling males (n = 5), yearling females (n = 4), and adult females with (n = 4) and without cubs (n = 12). Bears  $\geq 3$  years of age were considered adults, since breeding was evident at this age. Adult females with cubs produced their litters in the winter of 1987-88, but these cub litter data were not used for validating the HSI model. Specific HSI model validation procedures are discussed in the HSI Model Validation section.

Distances moved between consecutive locations were calculated for all locations using a program created in ARC/INFO. Locations 3 days or more apart were deleted from analysis. Distances moved between consecutive locations that were 2 days apart, were not different from distances moved in 1 day. Thus, all movement data were expressed as kilometers moved between consecutive locations, without modifying the raw data.

Spring, breeding, and summer/fall time periods were separated for analysis purposes. The spring time-period occurred from den emergence to 12 June, breeding from 13 June to 13 July, and summer/fall from 14 July to denning. The start of the breeding time-period was delineated on the basis of increased sightings of unmarked bears, the occurrence of family breakup, and the location of adult males and females together. Frequent dump visits by adult males marked the end of the breeding time-period. Friedman's test (Siegel 1956) and the Friedmantype simultaneous rank test (Miller 1981) were used to compare mean daily movements among time periods for a given sex and age class. The Kruskal-Wallis analysis-of-variance test (Siegel 1956) and a modified

Kruskal-Wallis-type simultaneous rank test (Miller 1981) using mean ranks were used to compare mean daily movements among sex and ageclasses for a given time period. The selected alpha level was 0.10 for these and all other statistical tests.

The Microcomputer Program for the Analysis of Animal Locations (MCPAAL) (M. Stuwe and C. E. Blohowiak, Conserv. Res. Cent., Natl. Zool. Park, Smithsonian Inst., Front Royal, Va.) was used to determine annual home range sizes for radio-collared black bears. Annual home range sizes were calculated with minimum convex polygons (Mohr 1947) and 95% harmonic mean contours (Dixon and Chapman 1980) for adult males and females. The Mann-Whitney U test was utilized to test for significant differences between male and female home range sizes (Siegel 1956), while the Friedman's test (Siegel 1956) was used to compare home range sizes estimated by the harmonic mean method with those estimated by the minimum convex polygon method. Annual home ranges for adult male and female bears were also delineated with ARC/INFO using the minimum convex polygon method to determine home range overlap, habitat use, and HSI scores.

### Seasonal Habitat Use

The proportion of vegetation types in each seasonal home range was compared to the proportion of vegetation types on Drummond Island by the Chi-square goodness-of-fit test, with the null hypothesis that bears select vegetation types in proportion to their availability.

In addition, seasonal habitat use was studied within the annual home ranges of adult bears. Percent use of vegetation types were

determined seasonally for each bear that was successfully monitored throughout a specific season (i.e. spring, summer, and fall). Percent availability was determined from the vegetative composition of an adult bear's annual home range. Subsequently, significant differences between mean percent use and mean percent availability of specific vegetation types were determined by the Chi-square goodness-of-fit test.

Seasons were divided on the basis of plant phenology, with spring occurring from den emergence to 14 June, summer from 15 June to 5 September, and fall from 6 September to denning. The first soft mast crop to ripen (Canada buffaloeberry) and associated feeding sign defined the start of summer, while the initial appearance of beechnuts and associated feeding sign defined the start of fall.

### HSI Model Validation

Overall HSI scores were calculated for Drummond Island and for the annual home ranges of adult bears using procedures outlined by Rogers and Allen (1987). Percent area in forested wetlands, percent area in non-forested vegetation types, percent area in vegetation types that have hard mast producing trees, and percent area inside a zone of (human) influence were habitat variables measured using ARC/INFO (Fig. 3). The remaining habitat variables were measured in the field as discussed in the Vegetation Sampling section.

Overall HSI scores were determined by the following equation: HSI = ((SISP + (SISU x SIV6) + (SIFA x SIV7))/3) x SIHI where SISP = suitability index value for percent area in forested wetland vegetation types,



Relationship of habitat variables and life requisites in the black bear Habitat Suitability Index Model for the Upper GreatLakes Region (Rogers and Allen 1987). Figure 3.

SISU = suitability index for summer foods,
SIV6 = suitability index value for percent area in non-forested vegetation types,
SIFA = suitability index for fall foods,
SIV7 = suitability index value for percent area in hard mast producing vegetation types, and
SIHI = suitability index for percent area inside zones of human influence.

Percent area in lowland hardwood and lowland conifer (i.e. cedar swamps) vegetation types, as directed by the HSI model, were used to determine the spring suitability index (SISP). The suitability index for summer foods (SISU) was determined for aspen-birch, upland hardwood, open, coniferous, and wetland vegetation types using the following equation:

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

where

SIV2 = suitability index for percent shrub cover of soft mast producing species (includes hazel), and SIV3 = suitability index for number of soft mast

SIV3 = suitability index for number of soft mast $producing species present at <math>\geq 1$ % shrub cover.

The remaining vegetation types had a summer food suitability index of 0.0 because of a lack of soft mast production.

The suitability index for fall foods (SIFA) was determined for upland hardwoods using the following equation:

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

where SIV4 = suitability index for basal area of hard mast producing trees  $\geq$  40 years of age, and

# SIV5 = suitability index for number of hard mast producing species present with at least one mature tree per 0.4 ha.

The remaining vegetation types had a fall food suitability index of 0.0 because of a lack of hard mast production.

Percent area inside a zone of influence (SIHI) was calculated by 2 methods as described by Rogers and Allen (1987). The first method computed the area of a zone of influence around specific population "sinks" using the following equation:

$$z = -$$

Z = area of zone of influence

where

K = number of bears killed at the sink per year D = density of bears per 2.59 km<sup>2</sup> M = maximum sustainable annual mortality.

Population "sinks" are areas of high human use such as campgrounds, croplands, and residences (Rogers and Allen 1987). This method was applied to the town of Drummond because the number of bears killed per year at the town, the density of bears, and the maximum sustainable annual mortality were all known. Bear density and maximum sustainable annual mortality were obtained from a concurrent population study (Visser 1987).

The second method described by Rogers and Allen (1987) assigned fixed-sized circular areas around towns (102.07 km<sup>2</sup>), cropland (38.48 km<sup>2</sup>), and residences (3.80 km<sup>2</sup>). This method was applied to croplands and residences since the number of bears killed per year at such sites was unknown and/or less than 1.0 per year. All zones of influence were digitized using ARC/INFO and subsequently overlaid onto bear home ranges and the MIRIS vegetation coverage map. Percent area occupied by zones of influence was then determined.

Validation of the black bear HSI model was attempted by comparing HSI scores of annual home ranges with each of the following: 1)home range size, 2)1988-89 cub litter size (including 3 year old females that did not produce cubs), 3)cub weight gains (shortly after parturition to 1 year old), and 4)mean daily movements (km/day). Comparisons were done using Spearman rank correlation tests (Siegel 1956).

#### RESULTS

## Vegetation Sampling

Mean shrub cover of soft mast producing species, and mean number of soft mast producing species were determined for open, upland hardwood, and aspen-birch vegetation types with 20, 20, and 30 replicate stands, respectively (Table 1). The open vegetation type had the highest shrub cover and greatest variety of soft mast producing species (P < 0.10) consisting mostly of wild strawberry, serviceberry, and common chokecherry. Considerable variance in shrub cover was found in aspen-birch and upland hardwood vegetation types. Canada buffalceberry, roundleaf dogwood, and beaked hazel were predominately found within aspen-birch stands (Table 2). Upland hardwood stands however, typically contained only red raspberry (Table 2). Ocular estimates of percent shrub cover of soft mast producing species for coniferous, lowland hardwood, and wetland vegetation types were 1.5%, 1.5%, and 2.5%, respectively. Ocular estimates of the number of soft mast producing species for coniferous, lowland hardwood, and wetland vegetation types were 0.5, 0.5, and 1.0, respectively. The first and last shrubs to produce soft mast for bears on Drummond Island were Canada buffaloeberry and viburnums, respectively (Table 2).

Mean basal area of hard mast producing trees greater than 40 years of age was determined from 17 replicate stands of upland hardwoods

Table 1. Mean (S.E.) percent shrub cover of soft mast producing species, mean (S.E.) number of soft mast producing species, and mean (S.E.) basal area of hard mast producing trees > 40 years of age for vegetation types on Drummond Island, Michigan, 1988.

VEGETATION TYPE	% SHRUB COVER	NUMBER OF SPECIES	BASAL AREA (m <sup>2</sup> /0.4 ha)
open	15.2 <sup>A</sup> (1.8)	2.6 <sup>A(</sup> 0.2)	0.0
aspen-birch	11.0 <sup>B</sup> (1.9)	1.3 <sup>B</sup> (0.2)	0.0
upland hardwood	6.7 <sup>B</sup> (2.0)	0.6 <sup>B</sup> (0.1)	2.1(0.2)

ABValues with different letters within a column are significantly different (P < 0.10) by the Kruskal-Wallis analysis-of-variance test (Siegel 1956) and the Kruskal-Wallis-type simultaneous rank test (Miller 1981).

SPECIES	TIME AVAILABLE	VEGETATION TYPE LOCATION
Canada buffaloeberry ( <u>Shepherdia</u> <u>canadensis</u> )	Mid-JuneEarly July	Aspen-birch
Serviceberry ( <u>Amelanchier</u> spp.)	Mid-JuneLate July	Aspen-birch, Open
Wild strawberry ( <u>Fragaria</u> spp.)	Mid-JuneEarly July	Open
Red-osier dogwood ( <u>Cornus</u> <u>stolonifera</u> )	Mid-JulyEarly Aug	Aspen-birch
Red raspberry ( <u>Rubus strigosus)</u>	Mid-JulyMid-Aug	Upland hardwood
Common chokecherry ( <u>Prunus virginiana</u> )	Early AugMid-Aug	Open
Roundleaf dogwood ( <u>Cornus rugosa</u> )	Mid-AugEarly Sep	Aspen-birch
Beaked hazel ( <u>Corylus cornuta)</u>	Mid-AugEarly Sep	Aspen-birch
Viburnums ( <u>Viburnum</u> spp.)	Early SepEarly Oct	Aspen-birch

Table 2. Timing of soft mast production and vegetation type location for major shrub species used by black bears on Drummond Island, Michigan, 1988.

(Table 1). American beech was the only hard mast tree species commonly encountered on the study area.

#### Movements and Home Ranges

One thousand-eight-hundred-forty-six bear radio-locations were obtained, 451 (24%) of which involved direct observations. The number of locations per bear ranged from 1 to 85 with a mean of 56 locations. Seasonal trends in mean daily movements were not observed for any sex and age-class (Table 3). However, significant differences were observed among sex and age-classes for spring and breeding time periods (P < 0.10) (Table 3). During spring, adult females with cubs moved significantly less per day than other sex and age-classes (P < 0.10)(Table 3). Adult males, during the breeding season, moved the most per day relative to all other sex and age-classes (Table 3); however, this figure was only significantly different from male and female yearlings (P < 0.10).

Mean annual home range size for adult males and females (Table 4) were not significantly different. Annual home ranges calculated by the harmonic mean method were significantly smaller than annual home ranges determined by the minimum convex polygon method (P < 0.10) (Table 4). Mean percent overlap among adult males, mean percent overlap between adult males and adult females, and mean percent overlap among adult females were 60.25% (SE = 22.02), 86.77% (SE = 1.12), and 76.92% (SE = 6.26), respectively. Mean percent bears that were active, between 2300 and 0500 hours, during spring, summer, and fall were 9% (SE = 9), 20% (no SE), and 27% (SE = 18), respectively. These data do not include
Table 3. Mean (S.E.) daily movements (km/day) of adult male, adult female without cub, adult female with cub, yearling male, and yearling female black bears during spring, breeding, and summer/fall on Drummond Island, Michigan, 1988.

	SPRING	BREEDING	SUMMER/FALL
AD MALE	1.92 <sup>A</sup> (0.28)	3.52 <sup>A</sup> (0.17)	1.22 <sup>A</sup> (0.33)
AD FEMALE	1.89 <sup>A</sup> (0.25)	2.17 <sup>AB</sup> (0.37)	2.55 <sup>A</sup> (0.26)
AD FEMALE W/CUB	0.85 <sup>B</sup> (0.24)	1.79 <sup>AB</sup> (0.27)	1.65 <sup>A</sup> (0.42)
YR MALE	-	1.38 <sup>B</sup> (0.26)	1.83 <sup>A</sup> (0.30)
YR FEMALE	-	1.29 <sup>B</sup> (0.19)	1.52 <sup>A</sup> (0.39)

ABvalues with different letters within a column are significantly different (P < 0.10) by the Kruskal-Wallis analysis-of-variance test (Siegel 1956) and a modified Kruskal-Wallis-type simultaneous rank test (Miller 1981) using mean ranks.

Table 4. Annual home range sizes (km<sup>2</sup>) of adult black bears calculated by the minimum convex polygon method (MCP), and harmonic mean method (HMM) using 95% contours, on Drummond Island, Michigan, 1988.

A	ADULT MALES		ADULT FEMALES		
BEAR#	MCP	HMM	BEAR#	MCP	HMM
190	72.22	68.00	670	64.91	48.07
510	87.00	84.48	630	20.31	17.61
620	67.71	41.76	090	16.56	15.80
			490	12.65	11.89
			210	66.89	45.27
			480	130.00	91.33
			770	14.59	10.60
			140	15.55	15.94
			050	38.70	21.97
			040	90.05	82.29
			470	78.69	67.21
			250	28.80	24.20
MEAN	75.64	64.75	MEAN	48.14	37.68
SE	5.83	12.44	SE	10.91	8.30

bears that utilized the garbage dump. Individuals that used the garbage dump were typically nocturnal.

# Seasonal Habitat Use

The proportion of vegetation types within seasonal home ranges were the same as those found over the study area for all adult bears. However, use of vegetation types within annual home ranges differed from availability for all seasons (P < 0.10) (Table 5). The number of adult bears that were successfully monitored for spring, summer, and fall habitat use were 19, 18, and 16 bears, respectively (Table 5). Yearling bears were not used for this analysis, and some adults were not successfully monitored throughout all 3 seasons due to radio-collar loss, legal and illegal harvest, and natural mortality. This reduced the number of usable radio-locations from 1846 to 1137. Aspen-birch, coniferous, and upland hardwood vegetation types were heavily utilized during spring, with the use of upland hardwoods exceeding availability (Table 5). During summer, aspen-birch and upland hardwood vegetation types were heavily utilized with the use of aspen-birch exceeding availability (Table 5). Mean percent use of wetland and coniferous vegetation types during fall, were 13% and 36%, respectively, with the use of both exceeding availability (Table 5).

# HSI Model Validation

The HSI score for Drummond Island and the mean HSI score for the annual home ranges of adult bears were not significantly different (Table 6). In addition, major suitability index values for the annual

SPRING SUMMER FALL  $A_{N1} = 520$  $A_{N1} = 466$  $A_{N1} = 151$  $B_{N2} = 19$  $B_{N2} = 18$  $B_{N2} = 16$ X&USE X&AVAIL, 0.15\*\* 1.91 VEGETATION TYPE X&USE 0.19\*\* X&AVAIL. XXUSE XXAVAIL. developed areas 2.10 1.50 0.00 1.93\*\* 4.46\*\* garbage dump 0.02 0.03 1.04 0.03 croplands 0.04 0.00 0.04 0.00 0.00 0.04 1.82\*\* 5.77 3.61 5.10 4.01 5.26 open 23.77\*\* 40.62 58.72\*\* 40.49 aspen-birch 44.09 42.97 17.20\* upland hardwood 14.20 14.41 14.46 20.08 15.11 14.22\*\* 28.69 35.70\* coniferous 28.69 27.51 27.68 0.80\*\* 1.50\*\* 4.37 lowland hardwood 4.09 4.54 4.55 13.05\*\* 2.54\* 1.72\*\* 4.43 wetland 3.95 4.53

 $x^2 = 499.78^{**}$ 

 $x^2 = 47.95^{**}$ 

Table 5. Mean percent use and mean percent availability of vegetation types by season for adult black bears on Drummond Island, Michigan, 1988.

\*Significantly different from availability (P < 0.10).

 $x^2 = 112.73^{**}$ 

\*\*Significantly different from availability (P < 0.05).

AN1 = Total number of locations.

 $B_{N2}$  = Sample size of adult bears.

Table 6. Suitability index value for percent area in wetland vegetation types (SISP), suitability index for summer foods (SISU), suitability index value for percent area in non-forested vegetation types (SIV6), suitability index value for fall foods (SIFA), suitability index value for percent area in hard mast producing vegetation types (SIV7), suitability index value for percent area in zones of human influence (SIHI), and habitat suitability index score (HSI) for all of Drummond Island and for the annual home ranges of adult black bears on Drummond Island, Michigan, 1988.

Decert	OTOD	OTOI	07776	OTEN	0777	сли	UCT
Bear	SISP		5100	<u>SIFA</u>	517	SIRI	
210	1.0	0.29	0.40	0.18	0.98	0.29	0.13
670	1.0	0.27	0.32	0.14	0.63	0.48	0.19
630	1.0	0.29	0.31	0.18	0.90	0.86	0.36
090	1.0	0.27	0.25	0.10	0.55	0.80	0.30
490	1.0	0.26	0.21	0.14	0.70	0.95	0.36
510	1.0	0.26	0.29	0.13	0.63	0.55	0.21
480	1.0	0.30	0.54	0.02	0.18	1.0	0.39
250	1.0	0.28	0.48	0.04	0.27	1.0	0.38
470	1.0	0.31	0.66	0.05	0.31	0.99	0.40
040	1.0	0.30	0.42	0.07	0.39	1.0	0.38
050	1.0	0.28	0.42	0.04	0.22	1.0	0.38
140	1.0	0.28	0.25	0.15	0.78	0.67	0.27
190	1.0	0.30	0.57	0.06	0.38	0.58	0.23
620	1.0	0.29	0.60	0.02	0.19	0.69	0.27
770	1.0	0.25	0.21	0.003	0.13	0.50	0.18
MEAN	1.0	0.28	0.40	0.09	0.48	0.76	0.30
S.E.	0.0	0.01	0.04	0.02	0.07	0.06	0.02
Drummond Island	1.0	0.28	0.38	0.08	0.40	0.70	0.27

home ranges of adult bears were not significantly different from the values obtained for Drummond Island (Table 6). The fall food suitability index (SIFA) for Drummond Island was the lowest value relative to other suitability indices, while the spring food suitability index (SISP) was the highest (Table 6). In addition, bear home ranges that had high SIHI values tended to have higher HSI scores.

Spearman rank correlation coefficients were not significant for comparisons between HSI score of annual home ranges with each of the following: 1) annual home range size ( $r_s = 0.26$ ), 2) cub litter size ( $r_s = 0.14$ ), 3) cub weight gain ( $r_s = 0.0$ ), and 4) mean daily movements ( $r_s = -0.09$ ) (Fig. 4-7).



Figure 4. Spearmans rank correlation analysis of annual home range size and overall HSI score (n = 15) for adult black bears on Drummond Island, Michigan, 1988.



Figure 5. Spearmans rank correlation analysis of cub litter size and overall HSI score (n = 7) for adult female black bears on Drummond Island, Michigan, 1988.



Figure 6. Spearmans rank correlation analysis of cub weight gains and overall HSI scores (n = 6) of adult female black bears on Drummond Island, Michigan, 1988.



Figure 7. Spearmans rank correlation analysis of mean daily movements and overall HSI scores (n = 15) for adult black bears on Drummond Island, Michigan, 1988.

### DISCUSSION

### Movements and Home Ranges

Seasonal variation in mean daily movements were not observed for any sex and age-class. However, there was a tendency for adult males to have high daily movements during the breeding season. The small number of adult males monitored in this study might have contributed to the nonsignificant test result. Alt et al. (1976) found that adult male daily movements were greatest during the breeding season, but this was also observed for solitary females. Rogers (1987) found that adult females increased their daily movements when in estrus, Movement data from Drummond Island could not evaluate this because adult females are in estrus for only 2 to 3 days, while our daily movement data were combined over a 1 month period. Other researchers, however, believe that adult females should move less per day relative to males and occupy areas just large enough to assure adequate nutrition (Amstrup and Beecham 1976, Pelton and Burghardt 1976).

Sex and age-specific mean daily movements differed among Drummond Island bears during spring and breeding time periods. Adult females with cubs exhibited the smallest mean daily movements during spring relative to adult females without cubs, and adult males. This is probably the case due to the limited mobility of cubs during spring. Cubs have been found to suppress the movements of the mother for at

least 4 months after den emergence (Lindzey and Meslow 1977, Alt et al. 1982). Adult males had high mean daily movements during the breeding time period. This is an attempt by males to maximize their encounters with receptive females and thus enhance their reproductive success (Rogers 1987).

Adult male home ranges tended to be larger than adult female home ranges, similar to what has been found in numerous studies elsewhere (Erickson and Petrides 1964, Jonkel and Cowan 1971, Poelker and Hartwell 1973, Alt et al. 1976, Amstrup and Beecham 1976, Lindzey and Meslow 1977, Rogers 1977, Reynolds and Beecham 1980, Garshelis and Pelton 1981, Kohn 1982, Young and Ruff 1982, Rogers 1987). The mean annual home range size for adult males  $(75.64 \text{ km}^2)$  was similar to that reported from Wisconsin (71.5 km<sup>2</sup>) (Kohn 1982), but higher than what was found in the Upper Peninsula of Michigan (51.7 km<sup>2</sup>) (Erickson and Petrides 1964). In addition, the mean annual home range size for adult females (48.14  $\text{km}^2$ ) was much higher than that found in Wisconsin (13.7 km<sup>2</sup>) (Kohn 1982) and that reported from the Upper Peninsula of Michigan (26 km<sup>2</sup>) (Erickson and Petrides 1964). These differences may be attributed to the severe summer drought that occurred during the study period, which reduced the summer berry supply. Pelchat and Ruff (1986) found black bears in Alberta to have larger home range sizes during years of food scarcity. However, differences can also be attributed to the different methods used by the other studies to delineate home range.

Home range sizes estimated by the harmonic mean method were consistently smaller than those estimated by the minimum convex polygon method. A potential problem with both methods is that they assume an animal uses all areas within their home range boundary (Arthur et al. 1989). However, on Drummond Island, a home range delineated by a minimum convex polygon usually included more area used for travel and more water than one delineated by a harmonic mean. <u>Burt's (1943)</u> definition of home range excludes migration routes as part of a home range. Thus, the harmonic mean method probably represents a better estimate of home range size, but the minimum convex polygon method is useful for comparative purposes.

Extensive home range overlap was observed between sexes and ageclasses, and among sex and age-classes. Home range overlap estimates were conservative estimates since all bears within the study area were not radio-collared. Extensive home range overlap was also found for black bears in New York, Idaho, Washington, Tennessee, Ontario, and North Carolina (Sauer et al. 1969, Amstrup and Beecham 1976, Lindzey and Meslow 1977, Reynolds and Beecham 1980, Garshelis and Pelton 1981, Kolenosky and Strathearn 1987, Powell 1987). However, some studies have reported territorality in adult females (Jonkel and Cowan 1971, Fuller and Keith 1980, Young and Ruff 1982, Rogers 1987). Where home range overlap occurred, among bears of the same sex and age, temporal separation and agonistic encounters were, in some cases, observed. Mutual avoidance by temporal separation was also reported by Lindzey and Meslow (1977) and Garshelis and Pelton (1981). Additionally, the amount of home range overlap observed could be a function of habitat quality. Garshelis and Pelton (1981) and Rogers (1987) both suggested that food abundance may influence the degree of home range overlap

among bears. Powell (1987) observed extensive home range overlap in adult female black bears in North Carolina, and concluded that increased habitat productivity results in decreased territorial behavior. However, Reynolds and Beecham (1980) suggested that the patchy and unpredictable distribution of food resources in a area results in increased home range size. Subsequently, the cost of defending the home range from other bears increases to a point were defenses break down and home range overlap ensues.

## Seasonal Habitat Use

Habitat selection was not evident when the proportion of vegetation types within seasonal home ranges (spring, summer, and fall) were compared with the proportion of vegetation types within the study area. This is due to the relatively uniform distribution of vegetation types throughout the study area, and the large amount of area bears can traverse.

Habitat use, within annual home ranges, reflected the distribution and abundance of preferred bear foods. Coniferous, aspenbirch, and upland hardwood vegetation types were heavily utilized during spring. However, the use of coniferous and aspen-birch vegetation types did not exceed availability, unlike the use of upland hardwoods. Bears in early spring forage on grasses and forbs (Hatler 1972, Kelleyhouse 1980, Grenfell and Brody 1983, Rogers and Allen 1987, Rogers et al. 1988). These foods, on Drummond Island, were typically found within cedar swamps. As spring progresses, bears forage on upland forbs, ants, and the buds and catkins of poplar trees (Rogers

1987, Rogers and Allen 1987, Rogers et al. 1988). These foods were usually within mature upland hardwood stands and mature aspen-birch stands. Forbs frequently occurring in bear scat collected in the Upper Peninsula of Michigan were jack-in-the-pulpit (<u>Arisaema triphyllum</u>), sweet cicely (<u>Osmorhiza spp.</u>), and wild calla (<u>Calla palustris</u>) (Rogers 1989). Developed areas, lowland hardwood, and wetland vegetation types did not contain preferred bear foods. Thus, percent use of these vegetation types was significantly less than availability.

Use of the garbage dump exceeded availability; however, mean percent use was only 2%, because garbage dump visits by radio-collared bears were limited to 3 adult males. These visits were usually at night when only a limited number of locations were obtained (up to 2300 hours). Typically adult males utilized the dump for only several days at a time before leaving the vicinity.

Bears heavily utilized upland hardwood and aspen-birch vegetation types during summer to forage on summer berries. However, it was only the use of aspen-birch that exceeded availability. Regenerating aspenbirch stands and thinned upland hardwood stands on Drummond Island had more soft mast production relative to older, un-thinned stands. Summer berries were found in most aspen stands in northcentral Minnesota, but soft mast was most abundant in regenerating aspen stands and open upland vegetation types (Noyce and Coy 1989). Lindzey and Meslow (1977) found bears to select clear-cuts, that were between 6 and 11 years old, for their abundant summer berry supply.

Most studies have found preferred vegetation types in summer to have an abundant berry supply (Lindzey and Meslow 1977, Fuller and

Keith 1980, Grenfell and Brody 1986, Pelchat and Ruff 1986, Young and Beecham 1986, Unsworth et al. 1989). Mean percent shrub cover and mean number of soft mast producing species were highest in the open vegetation type. However, mean percent use of the open vegetation type was only 4% which did not exceed availability. This lack of correspondence between soft mast abundance and bear habitat selection may be partially attributed to inaccuracies in the MIRIS vegetation coverage map. Ten of 20 sampled stands, delineated as the open vegetation type by the MIRIS vegetation coverage map, were actually young (< 10 years old) regenerating aspen-birch stands. Mean percent shrub cover of soft mast producing species and mean number of soft mast producing species were usually higher in regenerating aspen-birch stands than in the typical open vegetation type. Regenerating aspenbirch stands usually contained Canada buffaloeberry and serviceberry, with lesser amounts of beaked hazel and viburnums. The open vegetation type, on the other hand, contained wild strawberry, with common chokecherry and serviceberry in the periphery. Thus, for the open vegetation type, mean percent shrub cover and mean number of soft mast producing species were inflated by the misclassification of regenerating aspen-birch stands.

Garbage dump use during summer exceeded availability, but use, as in spring, was limited to adult males. Adult males intensely utilized the garbage dump immediately following the breeding season. This resulted in limited movement patterns by adult males. Eighty-four percent of adult male locations were within 2 km of the garbage dump from 14 July to 12 September. The garbage dump was used rarely after

12 September. Developed areas, coniferous, lowland hardwood, and wetland vegetation types did not contain an abundant berry supply; thus, their use was less than availability.

Use of coniferous and wetland vegetation types exceeded availability during fall. Black bears on Drummond Island appeared to utilize cedar swamps and wetlands in late fall to forage on the roots and tubers of lowland forbs, and the berries of common winterberry holly. In addition, bears foraged on beechnuts which typically occurred within mature upland hardwood stands. Hard mast is usually considered a preferred food item for bears in fall (Piekielek and Burton 1975, Rogers 1976, Landers et al. 1979, Garshelis and Pelton 1981, Grenfell and Brody 1983, Rogers 1987, Rogers and Allen 1987). However, mean percent use of upland hardwoods did not exceed availability. Fall foods were not found within open and aspen-birch vegetation types; thus, these vegetation types were used less than availability.

### HSI Model Validation

The overall HSI score for Drummond Island was 0.27 which inferred poor quality habitat for black bears. The low suitability index value for fall foods (SIFA) suggested that the quantity and quality of fall foods limits black bear habitat quality on Drummond Island. Conversely, the optimal (1.0) suitability index value for percent area in forested wetland vegetation types suggested that the quantity and quality of spring foods is least limiting to black bear habitat quality. However, this suitability index value should be viewed with

caution since bear use of lowland hardwoods during spring was significantly less than availability. Percent area in lowland hardwoods was one criteria used to determine the spring suitability index. In addition, the spring suitability index does not take into consideration spring use of upland hardwoods. The quantity and quality of summer foods, vegetation type composition, and human influences also limit black bear habitat quality, but to a lesser degree relative to the quantity and quality of fall foods.

It appears, for Drummond Island, that the spring food suitability index and the human intolerance suitability index strongly influenced HSI scores among adult bears. The spring food suitability index was 1.0 for all bears. When this value was entered into the overall HSI equation, the average of spring, summer, and fall food life requisites was approximately 0.33 (1.0/3). This was subsequently multiplied by the human intolerance suitability index which resulted in an average HSI score of 0.30 with little variation. This pattern is from the method by which summer and fall food life requisite scores are obtained. Summer and fall food life requisite scores are determined by multiplying 2 suitability index values together (SISU and SIV6 for summer, SIFA and SIV7 for fall), none of which were very high. Thus, summer and fall food life requisites were insignificant relative to the spring food suitability index. Since the spring food suitability index was constant (1.0) among adult bears, but a poor reflection of spring food availability, the human intolerance suitability index caused the most variability among HSI scores. Thus, the present HSI model is insensitive to changes in summer and fall food life requisite scores on

Drummond Island.

Black bear density is not a good indicator of habitat quality. The bear density on Drummond Island was estimated at 26 bears/100  $\text{km}^2$ (including cubs) (L. G. Visser, MDNR, pers. commun.), which is higher than most reported densities in the Upper Great Lakes Region. Kohn (1982) reported the same bear density in Wisconsin (26 bears/100  $\text{km}^2$ ). Rogers (1987) reported a density of 22 bears/100 km<sup>2</sup> in northeastern Minnesota. Erickson and Petrides (1964) observed a bear density of 11 bears/100 km<sup>2</sup> in Michigan's Upper Peninsula. However, all of these reported densities came from populations subjected to human-caused mortality, and the level of mortality varied among these studies. In addition, maximum black bear densities are not known for the Upper Great Lakes Region and for other parts of the country as well. Hellgren and Vaughan (1989) reported a bear density of 55-66 bears/100 km<sup>2</sup> in the Great Dismal Swamp, but even at this high density humancaused mortality appeared to limit the population. It is therefore impractical to assess habitat quality by black bear abundance alone. The level of human-caused mortality is difficult to quantify, but has a strong influence on population density.

Average home range overlap among adult females is a potential indicator of habitat quality. Powell (1987) concluded that increased habitat quality results in increased home range overlap among adult female black bears. Extensive home range overlap was observed among adult females, which suggested that Drummond Island had high quality bear habitat. Conversely, Rogers (1977, 1987) found territorality among adult females in poor quality habitat. However, human influences

on bear densities are likely to affect social interactions. Thus, home range overlap may be an indicator of habitat quality on Drummond Island but other factors can also have an influence on home range overlap.

Mean age of first reproduction is also a potential indicator of habitat quality. The average age of first reproduction for bears on Drummond Island was 4.5 years (L. G. Visser, MDNR, pers. commun.). By contrast, the average age of first reproduction for bears in northeastern Minnesota and east-central Ontario were 6.3 and 6.0 years, respectively (Rogers 1987, Kolenosky 1989). These areas are generally considered poor black bear habitat. On the other hand, most bears in Pennsylvania first reproduced between 3 and 4 years of age (Alt 1989). Thus, average age of first reproduction indicated that Drummond Island was not poor quality black bear habitat.

Cub litter size was not a good indicator of black bear habitat quality on Drummond Island. Mean cub litter size for bears on Drummond Island was 2.19 (SE = 0.16) (L. G. Visser, MDNR, pers. commun.), which was similar to that found in Michigan's Upper Peninsula (2.15), Minnesota (2.46), and Wisconsin (2.4) (Erickson and Nellor 1964, Rogers 1976, Kohn 1982). However, habitat quality apparently differed among these studies.

The mean HSI score for annual home ranges was not significantly different from the overall HSI score for Drummond Island. This is to be expected since the vegetative composition within seasonal home ranges was similar to that found over the whole study area (Table 6). This is also due to the structure of the present HSI model. Spring food and human intolerance life requisites strongly influenced HSI

scores instead of all 4 life requisites (spring foods, summer foods, fall foods, and human intolerance life requisites).

No significant correlations were obtained when HSI scores of annual home ranges were compared with cub weight gain, cub litter size, home range size, and mean daily movements. Rogers (1976) found that a scarcity of summer and fall foods resulted in retarded cub weight gains and low cub production. It was assumed that overall habitat quality influenced these parameters. When comparing HSI score with cub litter size and HSI score with cub weight gain, a valid HSI model should yield positive correlations. However, significant correlations were not obtained in this study, but sample sizes were very small. Additional data are needed to test the HSI model in this manner.

Young and Ruff (1982) suggested that the home range sizes of adult female bears could be a means of comparing habitat quality among populations. Similarly, Sanderson (1966) suggested that there is probably an inverse relationship between home range size and habitat quality. This has not been demonstrated for black bear home ranges, but has been illustrated with the territory sizes of song sparrows (<u>Melospiza melodia</u>) (Ricklefs 1979). Therefore, it was expected that a valid HSI model would show a negative correlation between HSI score and annual home range size. However, this was not observed for this study.

Correlation analysis was also conducted on mean daily movements (km/day). Amstrup and Beecham (1976) found an inverse relationship between food abundance and mean daily movements for bears in Idaho. Thus, it was expected that a negative correlation would exist between HSI score and mean daily movements. However, a significant correlation

was not observed.

In addition, problems were encountered when using the MIRIS vegetation coverage map for obtaining habitat variables required by the HSI model. The classification scheme used for the MIRIS vegetation coverage map failed to recognize age classes and stocking densities of forested stands, which is necessary to reduce variances of measured habitat variables and more accurately explain black bear habitat use. A potential solution to this problem is to incorporate stand age and stocking density to the MIRIS classification scheme.

An additional modification, to increase accuracy, is the use of an ecological land classification scheme. An ecological land classification scheme takes into consideration the effects of soils and site factors on the vegetative composition of an area. For example, the understory species composition of 2 aspen-birch stands of identical age and stocking density will often be different. However, these differences can often be attributed to soils and site factors.

Finally, inaccuracies were found in delineating and classifying certain vegetation types. For example, 10 of 20 open stands sampled from the MIRIS vegetation coverage map were actually young ( $\leq$  10 years old) regenerating aspen-birch stands. This caused minor errors in HSI score determination, since only 5% of the study area was delineated as the open vegetation type. Thus, even with a 50% error rate in delineating this vegetation type, only 2.5% of the total area would be affected. A vegetation coverage map with greater detail and accuracy should be utilized for future research to reduce variances of measured habitat variables and reduce error in HSI score determination.

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The black bear HSI model should be altered in an attempt to improve its accuracy. Percent area in forested wetland vegetation types is a poor determinant of the spring food life requisite score. Bears in spring use a wide variety of vegetation types to forage on a diversity of foods. Bears in early spring forage on grasses and forbs (Hatler 1972, Kelleyhouse 1980, Grenfell and Brody 1983, Rogers 1987, Rogers and Allen 1987, Rogers et al. 1988). As spring progresses, bears occupy upland areas to feed on upland forbs, ants, and the buds and catkins of poplars (Rogers and Allen 1987, Rogers et al. 1988). In addition, spring use of lowland hardwoods (a forested wetland vegetation type) by bears was less than availability (Table 5). Spring habitat quality should not be measured solely by percent area in forested wetland vegetation types. Habitat variables that actually measure spring food abundance should be incorporated into the model, and the sensitivity of the model to these foods refined.

The relationship between basal area and hard mast abundance (SIV4 in HSI model) should also be altered. The minimum optimal basal area ( in the present black bear HSI model appears to be too high for upland hardwood stands in the Upper Great Lakes Region. Rogers and Allen (1987) based their assumed optimal basal area on upland hardwood stands in Pennsylvania. Species composition and basal areas of upland hardwood stands in Pennsylvania are different from those of the Upper Great Lakes Region. Additional research is needed to determine the proper relationship between basal area and hard mast abundance. In addition, the fall food life requisite score has little impact on the overall HSI score because the fall food life requisite score is

obtained by multiplying 2 suitability indices together (SIFA and SIV7). The present HSI model also fails to take into consideration other fall food items. Black bears on Drummond Island selected cedar swamps and non-forested wetland vegetation types during fall to forage on the tubers and roots of lowland forbs. A methodology should be developed that accurately measures the abundance of these lowland foods, or that incorporates these vegetation types into the model.

The present HSI model suggests that optimal bear habitat is composed of 25 to 50% non-forested vegetation types (SIV6 in present HSI model). This is a poor assumption since not all non-forested vegetation types produce an abundance of summer berries (i.e. herbaceous rangelands). In an earlier draft of the HSI model, it was assumed that optimal bear habitat was composed of 50% summer food producing vegetation types (Rogers et al. 1986). This included nonforested as well as forested vegetation types. This probably represents a better measure of SIV6 than what is presently used in the HSI model. The model should be altered so that it is assumed that ideal black bear habitat contain at least 50% summer food-producing vegetation types (Fig. 8). Summer food producing vegetation types are those that have > 10% soft mast shrub cover. The 10% shrub cover criteria was selected because this produced a suitability index score for soft mast abundance (SIV2 in HSI model) of 0.50. The altered suitability index increased the value of SIV6 for Drummond Island from 0.38 to 0.97, and subsequently increased the overall HSI score from 0.27 to 0.30.

Measurement and calculation of the human intolerance life



Figure 8. Proposed relationship between summer vegetation type composition suitability index score and percent area in summer food-producing vegetation types. Dotted line shows non-forested vegetation type relationship given by present black bear HSI model (Rogers and Allen 1987). requisite score should also be altered. Variables utilized in the present HSI model to determine the human intolerance life requisite score are typically difficult to obtain by most wildlife managers. Bear density, number of illegally killed bears, and maximum sustainable annual mortality are usually unknown in most management situations. An alternative method outlined by the HSI model assigns fixed sized circular areas around towns, croplands, and residences, which are easily delineated, but fail to take into consideration regional differences in human attitudes towards bears. In addition, the data suggest that the fixed sized area method represents a worst case scenario. The human intolerance zone around the town of Drummond, as calculated by bear density and mortality rates (14.58 km<sup>2</sup>), was much smaller than its appropriate fixed sized area method can drastically reduce an overall HSI score for an area.

Primary road and dwelling density are more appropriate measures of black bear human intolerance. Road density is easily measured and has been used to measure habitat effectiveness for Rocky Mountain elk (<u>Cervus elaphus nelsoni</u>) (Lyon et al. 1985). Dwelling density is also easily measured, but care should be taken to tally only those dwellings that are occupied year-round. Most black bear nuisance complaints on Drummond Island came from permanent residents, which suggested that seasonal residents were more tolerant of bears than permanent residents. Thus, seasonal dwellings are not likely to negatively impact bear populations. Suitability index curves for road and dwelling density were modified from Rogers et al. (1986), and these

suitability curves can be easily modified to take into account regional differences in human attitudes towards bears (Fig. 9-10). The human intolerance life requisite score should be calculated by determining the mean of the 2 suitability indices. The primary road density and dwelling density on Drummond Island was 0.66 km/2.59 km<sup>2</sup> and 2.1 dwellings/2.59 km<sup>2</sup>, respectively. The altered HSI model increased the human intolerance life requisite score for Drummond Island from 0.70 to 0.82.

The overall HSI equation should be altered to better reflect black bear ecology. A proposed HSI equation is:

 $HSI = (SISP + 2((SISU + SIV6/2) + (SIFA + SIV7/2))/5) \times SIHI$ 

where SISP = suitability index for spring food abundance,

- SISU = suitability index for summer food abundance,
- SIV6 = suitability index for percent composition of summer foodproducing vegetation types,
- SIFA = suitability index for fall food abundance,
- SIV7 = suitability index for percent composition of fall food producing vegetation types, and

SIHI = suitability index for human intolerance.

The proposed HSI equation gives more weight to summer and fall food life requisite scores. Summer and fall foods strongly influence cub growth, cub production, and subadult survival (Rogers 1976). Spring foods, on the other hand, are high in protein but do not result in weight gains necessary for winter dormancy and reproductive success (Jonkel and Cowan 1971, Landers et al. 1979, Kohn 1982).

The proposed HSI equation assumes that food abundance and percent composition of food producing vegetation types have equal weight when



Figure 9. Proposed relationship between human intolerance suitability index score and primary road density for black bears in the Upper Great Lakes Region (modified from Rogers et al. 1986).



Figure 10. Proposed relationship between human intolerance suitability index score and permanent dwelling density for black bears in the Upper Great Lakes Region (modified from Rogers et al 1986).

calculating summer and fall food life requisite scores. Thus SISU and SIV6 are averaged to determine the summer food life requisite, and likewise SIFA and SIV7 are averaged to determine the fall food life requisite score. The present HSI model multiplies both SISU and SIV6 together, and SIFA and SIV7 together, which serve as reduction functions, rather than modifying functions (i.e.  $(0.2 \times 0.2) < (0.2 + 0.2)/2$ ).

These modifications increased the HSI score for Drummond Island from 0.27 to 0.36. Average age of first reproduction, mean cub litter size, and mean home range overlap among adult females indicated that Drummond Island should have an HSI score of approximately 0.60. Based on the findings of this study, the HSI model needs some added modifications. Additional research on parameters of the model will help clarify necessary modifications.

### CONCLUSIONS

1. Significant seasonal trends in mean daily movements were not found for bears on Drummond Island. However, there was a tendency for adult males to have high daily movements during the breeding season. The small number of adult males monitored in this study probably contributed to the nonsignificant test result.

2. Sex and age-specific mean daily movements differed among bears during spring and breeding time periods. Adult females with cubs moved significantly less per day relative to other sex and age classes during spring. Adult males had high daily movements during the breeding season, but this result was only significantly different from male and female yearlings.

3. Adult male home ranges tended to be larger than adult female home ranges, but small sample size appeared to keep differences from being statistically significant.

4. Home range sizes estimated by the harmonic mean method were significantly smaller than those estimated by the minimum convex polygon method. The harmonic mean method probably represented a better estimate of home range size but the minimum convex polygon method is useful for comparative purposes.

5. Extensive home range overlap was observed between sexes and ageclasses, and among sex and age-classes.

6. Habitat selection reflected the distribution and abundance of preferred bear foods.

7. During spring, aspen-birch, coniferous, and upland hardwood vegetation types were heavily utilized, with the use of upland hardwoods exceeding availability. The garbage dump was also preferred, primarily by adult males.

8. Aspen-birch and upland hardwood vegetation types were heavily utilized during summer, with the use of aspen-birch exceeding availability. The garbage dump was also preferred but the majority of use was limited to adult males.

9. During fall, bears utilized upland hardwood, wetland, and coniferous vegetation types, with the use of wetland and coniferous vegetation types exceeding availability.

10. Percent use was less than availability for most vegetation types that lacked preferred bear foods.

11. No significant correlations were obtained for comparison of HSI scores with each of the following: a)home range size, b)cub litter size, c)cub weight gain, and d)mean daily movements. In addition, the HSI score for Drummond Island did not correspond well to average age of first reproduction and mean home range overlap among adult females.

#### MANAGEMENT RECOMMENDATIONS

Habitat management practices should enhance the production of preferred bear foods. Cedar swamps, mature upland hardwood stands, and aspen-birch stands should be maintained to supply bears with spring foods. Cedar swamps provide bears with grasses and forbs which are preferred early spring foods. As spring progresses, bears feed on ants, forbs, and the buds and catkins of poplar trees (Rogers and Allen 1987, Rogers et al. 1988), which typically occur within mature aspen-birch and upland hardwood vegetation types.

Cuttings should be conducted on aspen-birch and upland hardwood vegetation types to enhance soft mast production. Regenerating aspenbirch stands and thinned upland hardwood stands on Drummond Island had more soft mast production than older, un-thinned stands. Lindzey and Meslow (1977) found bears to select clear-cuts, that were between 6 and 11 years old, to forage on summer berries. Noyce and Coy (1989) found soft mast to be most abundant in regenerating aspen stands and open upland vegetation types. Selective cutting of non-mast producing woody plants should be practiced on permanent openings to enhance or maintain soft mast production. Permanent openings contained wild strawberry, with serviceberry and common chokecherry found at the periphery.

Mature upland hardwood stands should be maintained to provide

bears with beechnuts, a preferred fall food. Since upland hardwoods, on Drummond Island, are dominated by American beech and sugar maple, light selection cuts favoring American beech can be utilized for timber regeneration. However, the saw log basal area should not be less than  $4.6 \text{ m}^2/0.4$  ha (Tubbs 1977). Mature cedar swamps and non-forested wetlands should be preserved to supply bears, during late fall, with roots and tubers from mesic plants.

Ideal black bear habitat should be composed of 15% spring foodproducing vegetation types, 50% summer food-producing vegetation types, and 35% hard mast producing vegetation types (Rogers et al. 1986). Cedar swamps, aspen-birch stands, openings, non-forested wetlands, and upland hardwoods produced a variety of preferred bear foods. Cedar swamps supplied bears with early spring grasses and forbs. In addition, during late fall, starchy roots and tubers were supplied by both cedar swamps and non-forested wetlands. Aspen-birch stands not only provided aspen leaves and catkins as late spring foods, but also produced an abundant berry supply during summer, especially in regenerating stands. Permanent openings, especially at the periphery, supplied additional summer berries. Upland hardwoods provided bear foods year-round. During late spring, upland hardwoods supplied bears with insects and forbs. Raspberries and other soft mast producers were available in upland hardwoods in summer, usually where logging activity occurred. Finally, during early fall, beechnuts were produced within mature stands.

Human encroachment on bear habitat is one of the major reasons for decreased bear numbers (Rogers 1987). Bears are secretive, and

generally avoid human activity centers and dwellings unless a reliable food source is available. Bears that utilize artificial food sources (i.e. garbage) are more likely to succumb to human-caused mortality (Rogers 1987, Rogers and Allen 1987). Thus, human development should be restricted where possible. In addition, roads constructed as a result of logging activity should be closed to minimize human disturbances and poaching opportunities.

The black bear HSI model should be revised and re-evaluated in terms of how the model corresponds to spring and fall black bear habitat preferences. The present HSI model evaluates spring food abundance through percent area in forested wetland vegetation types. However, mean percent use of lowland hardwoods (a forested wetland vegetation type) by bears was significantly less than availability. In addition, fall food abundance is evaluated in the present HSI model by quantifying hard mast production. However, bears during fall, preferred non-forested wetlands and cedar swamps to forage on starchy roots and tubers. The present HSI model failed to address roots and tubers as fall foods. The model should also be revised in terms of its quantification. The HSI score for Drummond Island (0.27) was very low, and did not correspond well to average age of first reproduction and mean home range overlap among adult females. Based on the findings of this study, the HSI model needs modifications to more accurately reflect black bear habitat quality.
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