

# COMPUTER-ASSISTED HABITAT MAPPING FOR BLACK BEAR MANAGEMENT IN SHENANDOAH NATIONAL PARK

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**Abstract:** The objective of black bear (*Ursus americanus*) management in Shenandoah National Park has been to minimize property damage and personal injury to Park visitors while maintaining the bear population as a part of the natural fauna. Past management attention has been directed at educating visitors; however, future efforts will incorporate more biologically oriented strategies, and will require new information on ecological matters such as bear habitat suitability, the location of areas of sensitive or critical habitat, and the impacts of proposed developments on bear habitat. A computer mapping system designed to assist in the bear management effort by meeting these types of information needs is described. Sample maps were prepared.

*Int. Conf. Bear Res. and Manage.* 5:302–306

The 483-km<sup>2</sup> Shenandoah National Park lies in a narrow and irregular strip along the crest of the Blue Ridge Mountains from Front Royal, Virginia, southwest to Waynesboro, Virginia. A parkway, the Skyline Drive, provides primary vehicular access and bisects the Park along the major mountain ridge.

Although the area was logged repeatedly prior to the establishment of Shenandoah National Park in 1934, almost all of the Park is now a closed-canopy forest. Soils are sandy and rocky, and upper slopes and ridges are dominated by xerophytic oaks (*Quercus* spp.) and pines (*Pinus* spp.). Coves, toeslopes, and more gradual midslopes contain a variety of mesophytic species typical of the northern Blue Ridge (Braun 1950:221–225).

Shenandoah provides habitat for a variety of wildlife species, including both small and larger mammals, notably white-tailed deer (*Odocoileus virginianus*) and black bear. Recent bear population estimates range from about 150 animals (Du Brock 1980) to approximately 300 (L.L. Hakel, unpubl. rep., Shenandoah Natl. Park, Luray, Va., 1977).

As in most national parks in the United States, a primary objective in the Shenandoah bear management plan was to minimize property damage and personal injury resulting from encounters with bears, while maintaining the bear population

at a level compatible with the habitat. To effect this end, a sociological strategy aimed at educating Park visitors was adopted. In 1975, a public relations campaign was launched in which visitors were warned of the physical hazards and legal consequences of feeding Park wildlife. Baptiste et al. (1979) found that this campaign was generally successful and that most visitors were aware of the bear problem and the dangers involved in feeding campground bears. Evidence for success of the program was also found in reductions in damage incidents from a high of 231 (\$14,672 in damages) in 1975 to a low of 54 (\$1,868) in 1979 (Shenandoah Natl. Park, unpubl. rep., Luray, Va., 1978; W.E. Phillips, Shenandoah Natl. Park, pers. commun.).

A biologically oriented strategy involving more direct management of the bear population was developed to complement the visitor-oriented effort. In an attempt to encourage bears to rely on natural foods, Park landfills were closed in 1975, and campground and picnic area garbage receptacles were made more secure against rummaging bears. Persistently obnoxious bears were trapped and relocated in remote areas both inside and outside the Park.

In 1972 the Virginia Commission of Game and Inland Fisheries, in conjunction with Shenandoah National Park, initiated research designed to estimate the bear population size and to gain insight into the bear population structure (Raybourne 1976). Basic biological information of this nature has begun to provide insight into bear ecology in Shenandoah. However, the development and effectiveness of a comprehensive, long-range bear

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plan for Shenandoah now depends on the availability of additional information on bear ecology in the Park. Questions concerning bear habitat suitability, the location of sensitive habitat, carrying capacities, saturation densities, movements, and the impacts of natural- and man-induced changes in bear habitat have yet to be addressed.

The purpose of this research was to develop a methodology for producing a few select types of information relevant to the management of bears in the Shenandoah National Park.

We gratefully acknowledge the Shenandoah National Park personnel who offered information and assistance during the progress of this study. Special thanks are due Park Biologist W.E. Phillips, Chief Park Ranger Larry Hakel, and Superintendent Robert Jacobsen for their cooperation.

**METHODS**

The product of this research was MAP4B, a computer mapping system designed to manipulate spatial habitat data and to display results in map format. The MAP4B system was composed of 3 major functional parts: (1) a habitat assessment component consisting of a series of programs for reading in and manipulating raw habitat data, (2) a display program for producing line printer maps, and (3) a series of special-purpose auxiliary programs for changing or manipulating map data.

The habitat assessment procedure utilized 4 key habitat criteria: (1) proximity to potential poaching sources, (2) distance to potential unnatural food sources such as campgrounds and picnic areas, (3) distance from human disturbance, and (4) a black bear forest type preference index developed by Beeman (1975:94) that integrated forage and cover availability. A relative importance value indicating the importance of a criterion to habitat suitability was assigned to each of these criteria. These values ranged from 0 (not important) to 9 (extremely important). Similarly, 10 categories were established to accommodate varying amounts or relative intensity (e.g., distance to a picnic area) of each criterion. Integer values were assigned to categories in a linear manner along an interval scale on which the upper end corresponded to the ideal situation (Table 1). Selection of habitat criteria and assignment of rela-

Table 1. Importance values and intensity levels for 4 criteria used to evaluate black bear habitat in Shenandoah National Park, Virginia.

Habitat criterion	Relative intensity value	Relative importance value
1. Proximity to potential poaching source		3
a) outside Park	0	
b) within 1.6 km of peripheral access to Park	2	
c) over 1.6 km from peripheral access to Park	9	
2. Distance to campground or picnic area		9
a) over 1.6 km	0	
b) within 1.6 km	1	
3. Distance from regularly travelled road or development		8
a) within 1.6 km	0	
b) over 1.6 km	9	
4. Forest type preference index <sup>a</sup>		9
a) closed oak type	9	
b) open oak type	3.4	
c) cove hardwood type	3.7	

<sup>a</sup> Decimal values for relative intensity were obtained by standardizing Beeman's (1975:94) preference to a scale of 0-9.

tive importance and intensity values to respective criteria were based on literature, opinions of various black bear researchers, and opinions of Park personnel familiar with the distribution, movements, and relative density of bears within the Park. Although these values were assigned subjectively, they represented the best available information specific to bear ecology in Shenandoah.

A linear additive model was used in the assessment algorithm. For any given location (cell), a qualitative measure of habitat suitability was calculated using the formula:

$$V_j = \sum_{i=1}^n b_i x_{ij} \tag{1}$$

where

- $V_j$  = the habitat value of the  $j$ th location (cell),
- $b_i$  = the relative importance value of the  $i$ th habitat criterion,
- $x_{ij}$  = relative intensity value of the  $i$ th habitat criterion,
- $i = 1, 2, \dots, n,$
- $j = 1, 2, \dots, m,$
- $m$  = number of locations,
- $n$  = number of habitat criteria.

Standard 1:24,000 scale United States Geological Survey topographic maps were used as base maps, and all map data were registered to base

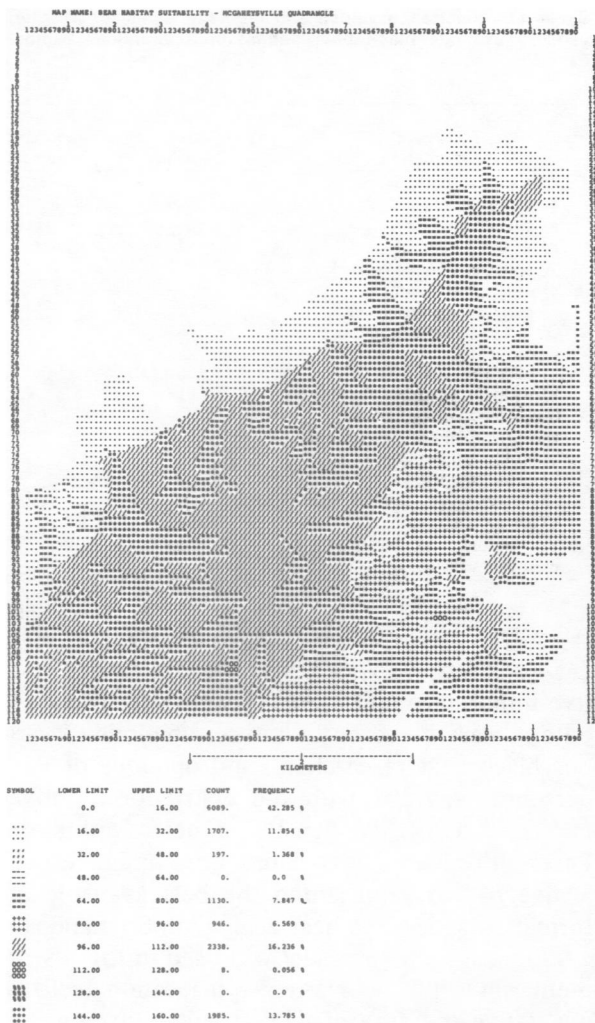


Fig. 1. Computer-generated map showing bear habitat suitability. Darker symbols indicate increased suitability.

maps prior to encoding. Some criterion maps were coded manually by overlaying a transparent grid pattern and recording a value for each grid cell element. The value of an element in this grid was the relative magnitude of the intensity of that criterion in that cell. Data were stored within the program as a 120 by 120 matrix of integer values, with each element (cell) representing an area of approximately 1.05 ha.

Other criterion maps were coded semi-automatically using an electronic digitizer. A Numonics 237 Graphics Calculator/digitizer (Numonics Corp., Lansdale, Pennsylvania) and a Tektronix 4051 minicomputer (Tektronix Corp., Beaverton, Oregon) were used for this purpose.

Modifications of 2 packaged programs (Federation of Rocky Mountain States 1977) were used to convert recorded polygon data into proper format and to produce punched cards.

The display feature of MAP4B was used to produce individual criteria maps. When these maps had been checked for coding errors, a final map of bear habitat suitability was produced with MAP4B using standard matrix addition to sum the weighted criteria maps (matrices). That is, each criterion map was weighted by a scalar ( $b_i$ ) and summed on a cell-by-cell basis to produce a matrix of sum values,  $[V]$ . The resulting cell values in the composite map were stratified linearly, and quantitative differences in habitat suitability were displayed as 1 of 10 contrasting symbols.

Products were a series of computer line-printer maps measuring 30.5 cm by 38.1 cm. Row and column numbers were provided along the margins to serve as numerical reference points. A scale and a legend showing frequency counts and value ranges by symbol were supplied with each map.

Special-purpose programs were developed to extend the utility of the basic MAP4B mapping system. One such program was capable of producing interspersed maps based on the number of different vegetation types present within a given radial distance of each cell in the map grid. Another auxiliary program was used to generate maps delineating zones or distances from fixed locations. In addition, programs for changing map display symbols and determining slope and aspect from elevation data were developed.

In order to have the capability to estimate habitat conditions in the future, a separate computer program was developed to predict percentage vegetative species composition and age distribution of all tree species in stands as a result of topographic features, managerial actions, and natural vegetative succession. This program used a Markov chain (Phillips et al. 1976:232–242) approach to forecast tree size-class distributions, and a Boolean approach to determine tree species likely to regenerate successfully on a site based on the biotic conditions present. Although it is amenable to cellular data bases, the prediction program is in need of further testing to become an operational part of the MAP4B system. Pending validation, results from the prediction

program may be used to predict future bear habitat suitability based on projected vegetative characteristics.

### RESULTS AND DISCUSSION

A goal of this research was to provide information pertinent for black bear management in Shenandoah National Park. To this end, a series of thematic maps was prepared for the McGaheysville Quadrangle, a 8857.6-ha test area in the southern portion of Shenandoah. Maps displaying habitat criteria used in the assessment procedure, and the location of Park facilities such as trails, campgrounds, and picnic areas, were produced along with a composite map of bear habitat suitability (see Fig. 1). The darker symbols, representing increasing habitat suitability, indicated that the most suitable habitat lies toward the Park interior in a somewhat dispersed fashion. Although contrasting symbols were normally assigned along equally-sized intervals using the greatest cumulative sum value within a map as the upper limit, this feature was altered in order to enhance visual contrast in Fig. 1. This procedure was found particularly useful in isolating areas having superior or inferior potential as bear habitat.

Areas of specific managerial interest were delineated also with the MAP4B system. To demonstrate this application, a map was prepared of potential mating areas, i.e., sites with a high degree of remoteness from human disturbance and an abundance of cover. Examination of Fig. 2 will reveal an area having high potential suitability as a mating habitat just left of the map center. Several other suitable areas were delineated near the lower right corner of the map. It is noteworthy that the Skyline Drive courses through this latter area, and that virtually all of the better mating habitat within this map was found to be within 2 km of the highway. Information of this type could be useful in planning developments (e.g., hiking trails and campgrounds) that could result in undue disturbance of bears by visitors.

### CONCLUSIONS

Although MAP4B has been implemented in the Shenandoah Park only on an experimental basis, the system appeared to be an effective method for displaying spatial information and iso-

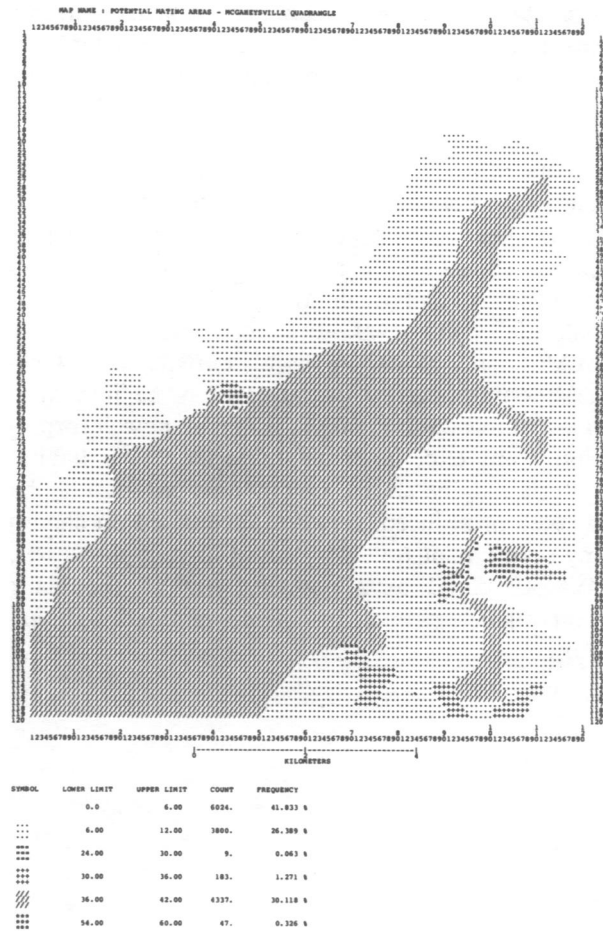


Fig. 2. Computer-generated map of potential bear breeding areas. Darker symbols indicate increased suitability.

lating areas that may require special managerial attention. The black bear habitat assessment procedure for Shenandoah was appropriate specifically to Shenandoah National Park, and may be neither appropriate nor valid in other localities or locations. However, the system is deliberately general and may be used in other localities, provided appropriate input data are available.

The MAP4B system was designed to assess habitat potential and not predict or estimate actual numbers of bears. The MAP4B system was not developed or designed to produce definitive information; it was designed to convert habitat data into reasonable estimates of habitat potential based on predetermined and prespecified criteria. In assessing bear habitat in Shenandoah Park, realistic criteria, based on the best information

available, were used. However, much additional research on black bear ecology in Shenandoah and elsewhere will be needed to validate totally the criteria used in assessing bear habitat in Shenandoah.

The primary utility of the MAP4B system is the capability to allow the user to articulate and define bear habitat potential based on known or suspected ecological relationships, and to derive quantitative and qualitative estimates of habitat potential. However, the long-term utility of MAP4B lies in its use as a heuristic habitat assessment model. This model may be improved over time pending the addition of new information from experience or research. New habitat criteria may be added, or previous criteria may be deleted or reduced in importance based on changing opinions of the user. Used in such a manner, MAP4B could be a powerful tool in the black bear management effort in Shenandoah National Park.

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