

PROCEDURES TO ENHANCE THE SUCCESS OF A BLACK BEAR REINTRODUCTION PROGRAM

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Abstract: Black bears (*Ursus americanus*) were extirpated from the Big South Fork area (BSFA) of Kentucky and Tennessee around the turn of this century. We developed a habitat suitability index (HSI) model to study the feasibility of a black bear reintroduction into this area. We applied the HSI model to the BSFA and identified high- and low-quality habitat components, their spatial distribution, and their projected change over time. Potential for human influences seems to be the weakest aspect of the BSFA as a successful reintroduction location. In conjunction with the habitat analysis, we developed a detailed release protocol, identifying factors that may further increase the probability of reintroduction success. Our approach could apply to other bear species and geographic areas because of the flexible structure of HSI models and acceptance of various types of data.

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Throughout the world, bear populations are affected by habitat loss and fragmentation, often resulting in population isolation, overexploitation, extermination, and increases in human-bear conflicts (Schoen 1990, Servheen 1990). Long-term survival of isolated populations may be substantially decreased through demographic and environmental stochasticities, natural catastrophes, or genetic effects (Shaffer 1987); reintroduction of bears into unoccupied range or augmentation of existing populations may be a valuable tool to counteract such negative effects (Griffith et al. 1989).

Although the black bear is the most numerous bear species in the world, its current distribution in the southeastern U.S. is fragmented (Fig. 1) because of habitat loss and overexploitation, comprising less than 10% of the historic range (Maehr 1984). Recently, however, bear habitat recovery has occurred in some regions due to land use changes and acquisition of lands by state and federal agencies. Such habitats often cannot be exploited by the species through natural colonization.

Black bears were successfully translocated into the Atchafalaya and Tensas River basins of Louisiana to augment populations (Taylor 1971). The reintroduction of black bears into the Interior Highlands of Arkansas was likely one of the most successful reintroductions of large carnivores in the world (Smith et al. 1990). About 250 bears from Minnesota and Manitoba, Canada were introduced in the 1960s to an area where bears had been extirpated; the current population as a result of these efforts is estimated at >2,500 bears (Smith et al. 1990). Other than the above, there has not been a concerted, systematic attempt at restoring a black bear population.

The BSFA of Kentucky and Tennessee is an area where land abandonment and subsequent purchase by government agencies has created potential habitat for bear reestablishment. Although black bear sightings occasionally are reported, no resident black bear population has been present in this area since the turn of the century. The closest resident population of black bears is approximately 150 km away. To reestablish a black bear population in this area, a reintroduction program would have to be initiated.

Reintroductions have received growing interest as indicated by the formation of the International Union for Conservation of Nature and Natural Resources (IUCN) Reintroduction Specialist Group in the late 1980s (Stuart 1991). Reintroduction is defined as the intentional release of individuals of a species into an area from which it has disappeared, with the goal of establishing a viable population (Stanley Price 1991). In reviewing the success of intentional releases of birds and mammals from 1973 to 1986, Griffith et al. (1989) found that success of translocations strongly depended on the habitat quality of the release area. Moreover, translocations of omnivorous species were found to be least successful (38%) compared with carnivores (48%) and herbivores (77%) (Griffith et al. 1989). The above findings, substantial projected costs for reintroduction, and the high profile of bears justify the use of habitat evaluation studies before reintroduction attempts. However, success of a reintroduction will not only depend on habitat quality but also on the release procedures, as was indicated by the analyses of Griffith et al. (1989) and Maguire and Servheen (1992). The objectives of this study were to

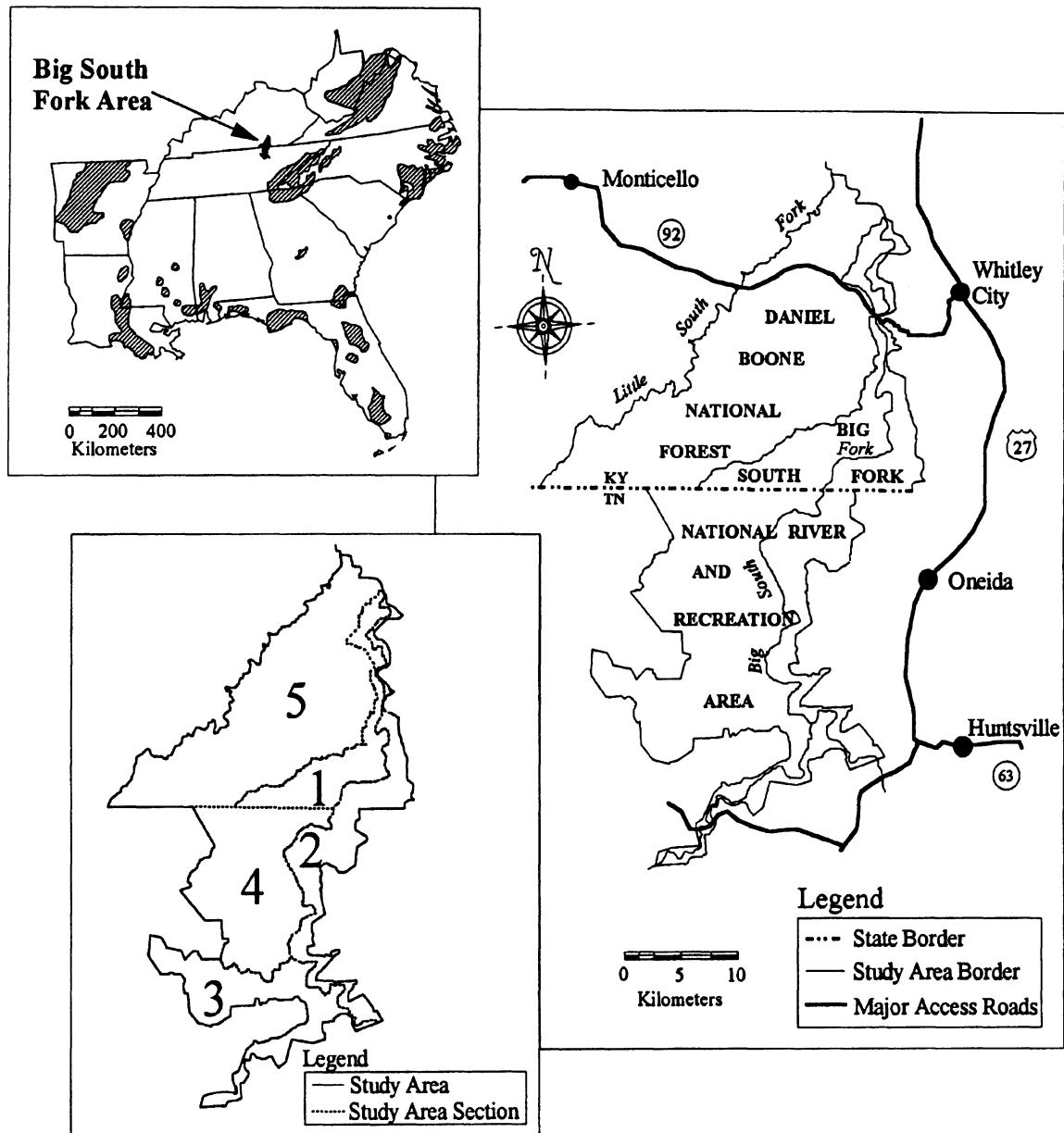


Fig. 1. The Big South Fork area (BSFA). Shaded areas represent current black bear distribution (Pelton 1982, Maehr 1984). Study area sections are numbered 1–5.

(1) evaluate the feasibility of a black bear reintroduction in the BSFA by determining relative quality of black bear habitat, and (2) develop a detailed release protocol.

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STUDY AREA

The Big South Fork basin of the Cumberland River was in the southeastern part of Kentucky and north-central Tennessee (Fig. 1). The study area encompassed part of Stearns Ranger District of Daniel Boone National Forest (DBNF), administered by the U. S. Dep. of Agric. For. Serv., and the Big South Fork National River and Recreation Area (BSFNRRRA), administered by the Natl. Park Serv. (NPS) (Fig. 1). The study area was about 780 km² and was divided into 5 sections to allow identification of low- and high-quality habitat within the study area (Fig. 1).

The climate of the BSFA was classified as humid mesothermal with little or no water deficiency (Thorntwaite 1948). Annual precipitation was approximately 127 cm (Natl. Oceanographic and Atmos. Adm. 1978). Mean temperatures ranged from -1 C to 10 C in January and from 19 C to 32 C in July; the mean number of frost-free days was 179 (Natl. Oceanographic and Atmos. Adm. 1978).

The study area largely was within the mid and northern Cumberland plateau regions of the Appalachian Plateau Physiographic Province (Thornbury 1965, Smalley 1986). The topography was characterized by long, narrow to moderately broad ridgetops and valleys with steep sideslopes (Smalley 1986). Average elevation of the plateau areas ranged from 490 m in the southern portion of the study area to 395 m in the northern portion. The river gorge reached 180 m in depth and was the most characteristic feature of the area.

The diversity of abiotic conditions in the BSFA was reflected by the relatively high plant and faunal diversity (Knowles et al. 1990). Bailey (1980) classified this area as the Appalachian oak and mixed-mesophytic forest sections in the eastern deciduous forest province of the lowland ecoregions. The forest vegetation in DBNF was managed for multiple use. NPS management policies only permitted removal of timber for development or maintenance of historic, public use, and administrative sites. Hunting seasons were in place for small and large game on the entire study area. The 1990 human population of all counties in the study area region was 87,946 or 13.2 people/km² (U.S. Bur. of the Census 1992).

METHODS

HSI Model

We developed an HSI model to estimate how the relative quality of habitat variables and components may affect the success of a black bear reintroduction. Our black

bear HSI model was based on a literature review, long-term research data, and experts' opinion. For a detailed documentation of the black bear HSI model and its verification level, see van Manen (1991).

The HSI is defined as a numerical index that represents the capacity of a given habitat to support a selected species and is based on the measurements of habitat variables that standardize habitat quality (U.S. Fish and Wildl. Serv. 1981). The HSI is determined through a combination of various suitability index (SI) values for identified habitat variables. An SI value represents a value of interest (the measured habitat condition of the variable) relative to a standard of comparison (the optimum habitat condition of the variable) (U.S. Fish and Wildl. Serv. 1981). By definition, the HSI and SI values provide a 0.0–1.0 index of habitat suitability for a particular habitat or habitat variable, respectively (Schamberger and O'Neil 1986). A direct linear relationship is assumed to exist between the HSI value and carrying capacity (U. S. Fish and Wildl. Serv. 1981).

Harris and Kangas (1988) argued that the definition of primary habitat be extended for "gamma species" (species that depend on a regional landscape for their existence) to include the requirement that an area has sufficient size or configuration to support a viable population. Because bears use habitat on a landscape scale (Schoen 1990), we chose landscape-scale variables associated with primary black bear habitat requirements. Besides the assumption of a linear relationship of HSI and carrying capacity, 3 more assumptions were necessary to implement the HSI model: (1) the SI curves of the variables represent actual species–habitat relationships, (2) where habitat variables or components are dependent, relationships can be described through mathematical equations, and (3) the entire model is used to evaluate an area.

Black bear habitat use in the southern Appalachian region is associated with relatively large and undisturbed oak–hickory (*Quercus* spp.–*Carya* spp.) and mixed-mesophytic forests with abundant hard and soft mast production (Pelton 1982). The HSI model included 8 habitat variables related to 3 habitat components: food, cover, and human impact (Fig. 2). We quantified habitat variables by use of the relationships between habitat measurements and SIs described in the HSI model (Fig. 3). Four variables were used to calculate indices of summer food availability (V1), fall food availability (V2), fall food productivity (V3), and fall food diversity (V4) (Fig. 3A–D). The cover component in the model was represented by 2 variables: protective cover (V5) and potential tree den sites (V6) (Fig. 3E–F). We determined that density readings of >60% (according to Nudds [1977]) adequately

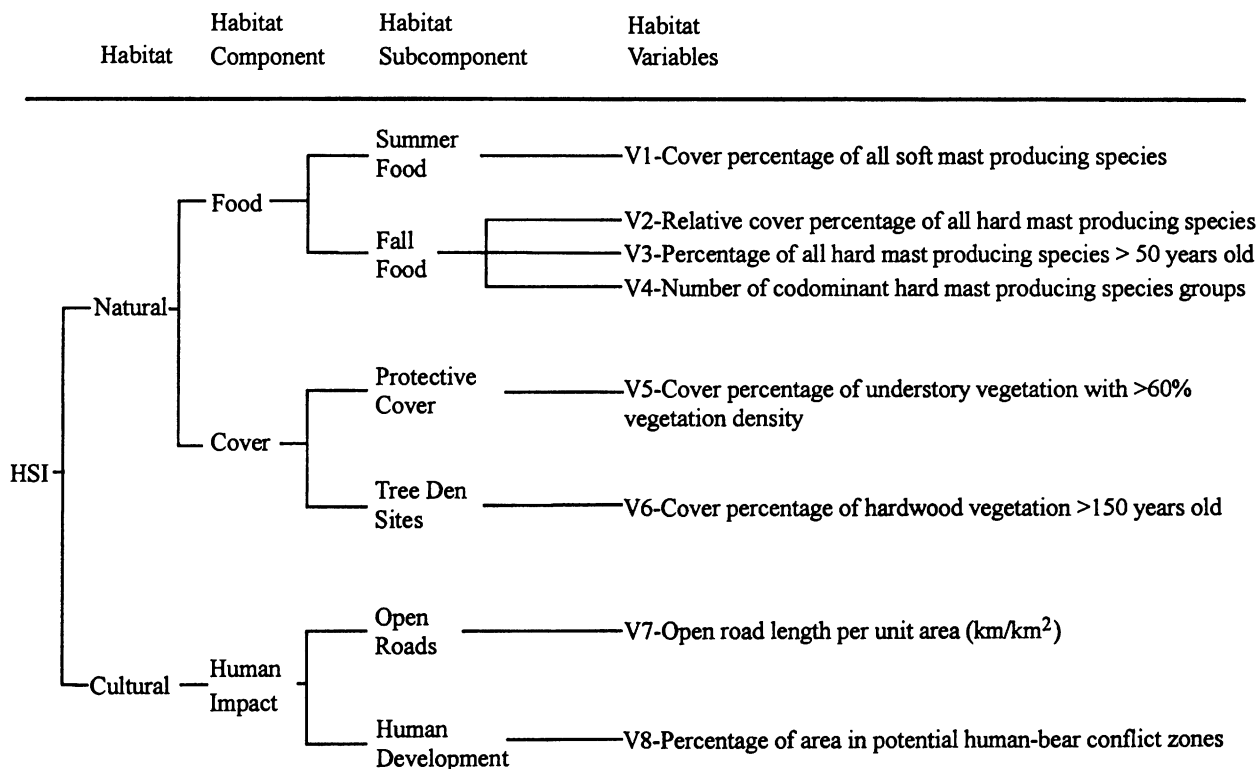


Fig. 2. Schematic diagram of the structure of the black bear Habitat Suitability Index model for the southern Appalachians.

represented protective cover by sampling high density understory vegetation known to be used by bears in Great Smoky Mountains National Park, Tennessee. Open road density (V7) and human development (V8) represented the human impact variables (Fig. 3G–H); these 2 variables were included in the model to evaluate the potential for illegal hunting, human disturbances, and human–bear conflicts. The size of potential human–bear conflict zones was determined based on average female home ranges in the southern Appalachians.

The SI values of the 8 variables and the component indices (CI) of the 3 habitat components were weighted according to importance and compensatory relationships among the variables or components were used to calculate an overall HSI value:

$$CI_{FOOD} = (SI_{V1} \cdot (SI_{V2} + SI_{V3} + SI_{V4})^2)^{1/3} \quad (1)$$

$$\text{If } SI_{V5} \leq SI_{V6}, CI_{COVER} = \frac{(SI_{V5} + SI_{V6})}{2} \text{ else } CI_{COVER} = SI_{V5} \quad (2)$$

$$CI_{HUMAN \text{ IMPACT}} = \frac{(SI_{V7} + SI_{V8})}{2} \quad (3)$$

$$HSI = \frac{(2 \cdot CI_{FOOD} + CI_{COVER} + CI_{HUMAN \text{ IMPACT}})}{4} \quad (4)$$

Model Application

All variables related to vegetation structure and composition were measured in the study area in 1990. We collected vegetation data from 101 random field plots. We located each plot from U.S. Geol. Surv. 1:24,000 topographic maps. At each location, 4 quarters were established according to the point-centered quarter method of Mueller-Dombois and Ellenberg (1974). In each quarter of the sample sites, we estimated coverage of soft mast producing species with the relevé method of Braun-Blanquet (1932). We determined relative cover and age of hard mast producing species by measuring diameter at breast height (DBH) of the sample trees and collecting increment bore samples (Avery 1975). We considered 3 hard mast producing species groups to determine fall food diversity: white oak group, red oak group, and a group with hickory, American beech (*Fagus grandifolia*), and black walnut (*Juglans nigra*). We estimated vegetation density by determining the percentage of vegetation that covered a vegetation profile board (2-m height) at 15-m reading distance (Nudds 1977, Griffith and Youtie 1988). We estimated availability of potential den trees (DBH > 84 cm; Johnson 1978) and other potential den sites within a 50-m radius of each sample point. Open road density

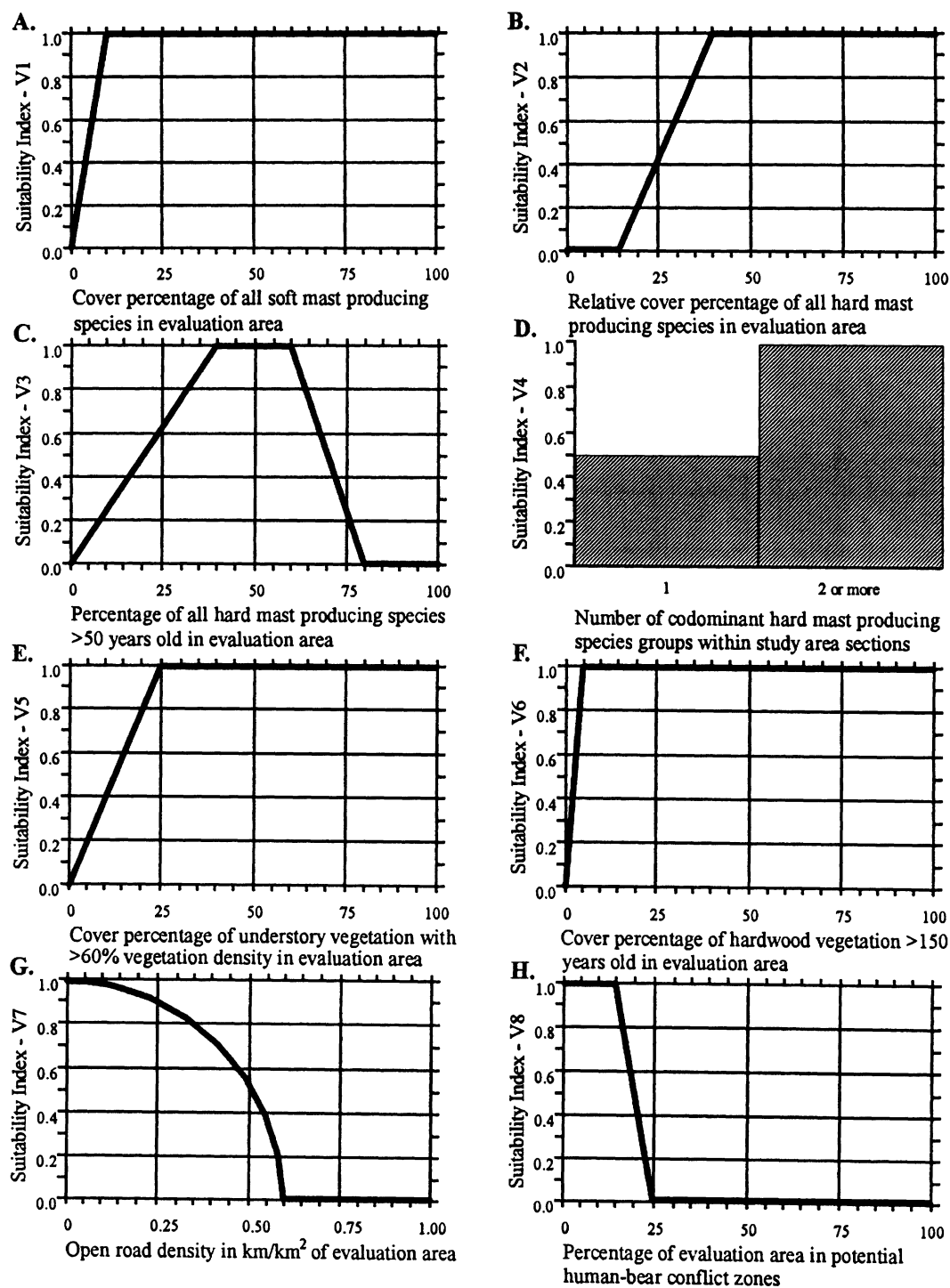


Fig. 3. Suitability indices (SI) for 8 habitat variables used in the black bear Habitat Suitability Index model. (A) Summer food availability. (B) Fall food availability. (C) Fall food productivity. (D) Fall food diversity. (E) Protective cover availability. (F) Tree den site availability. (G) Open road density. (H) Human development.

was measured from U. S. Geol. Surv. 1:24,000 topographic maps. We also included unmapped roads that

we identified in the field. Potential human–bear conflict zones were identified from field observations and a visi-

tor impact study (Turner and Hammitt 1983). We used continuous inventory of stand condition (CISC) data (U.S. Dep. of Agric. For. Serv. 1988) for DBNF to confirm and supplement the field measurements.

All measurements and corresponding SI and CI values were calculated for the entire study area and each of the study area sections. We assessed differences in habitat suitability among study area sections based on euclidean distances (Morrison 1990) among weighted suitability indices of the food, cover, and human impact components. The euclidean distances were used to construct a dendrogram. All statistical analyses were performed using Statistical Analysis System software (SAS Inst., Inc. 1990).

Release Procedures

We identified and evaluated factors related to 4 sources of variation that could influence short-term reintroduction success: (1) survival, (2) reproduction, (3) post-release movements, and (4) human–bear conflicts. We applied a logistic regression model based on Griffith et al. (1989) to find how habitat quality, number of release animals, and length of program may influence probability of reintroduction success. We used this general model to represent late-breeding, native game mammals that are released within the core of historic range. This was not an attempt to extrapolate the analysis of Griffith et al. (1989) to the species level or beyond the general conditions of their data. We identified the best release areas based on the HSI outcome. Other factors related to release procedures were determined based on previous field research and literature.

RESULTS

Habitat Evaluation

For each variable, measurements are reported for the entire study area and ranges and standard deviations are based on study area sections. Three major soft mast producing genera (*Vaccinium*, *Gaylussacia*, and *Rubus*) provided 7.3% coverage (range = 2.5–12.5%, $n = 5$, $SD = 3.55$), resulting in an SI for summer food of 0.73 (Table 1). Mean cover percent of soft mast producers was significantly higher on the plateau areas ($\bar{x} = 9.60$, $n = 188$, $SD = 16.54$) compared with the gorge ($\bar{x} = 5.19$, $n = 216$, $SD = 15.81$) ($Z = 9.59$, $P < 0.0001$). Fall food producers were represented by the genera *Quercus*, *Carya*, *Fagus*, and *Juglans* and comprised 56.1% relative cover (range = 46.1–54.3%, $n = 5$, $SD = 8.79$). The absolute

frequency of hard mast producing species was 79.2%, resulting in an SI value for hard mast availability of 1.0 (Table 1). Mean relative coverage of hard mast producing species was not different for the plateau ($\bar{x} = 3.56$, $n = 8$, $SD = 3.73$) compared with the gorge ($\bar{x} = 2.51$, $n = 11$, $SD = 2.93$; $Z = 0.54$, $P = 0.59$). Based on a linear regression equation and 95% confidence intervals ($AGE = 24.35 + 1.21 \times DBH$; $r^2 = 0.40$, $n = 83$, $P = 0.0001$) derived from the vegetation samples, we determined that at least 29.4% of the hard mast producing trees were older than the minimum productive age of 50 years. The associated SI value for fall food productivity for the study area was 0.74 (Table 1). Codominance of hard mast producing species groups occurred in 3 of the 5 study area sections, resulting in an SI value for fall food diversity of 0.80 (Table 1).

Protective cover was available at 16.7% of the sample points (range = 10.7–24.0%, $n = 5$, $SD = 5.49$) resulting in an SI of 0.66 for this variable (Table 1). Vegetation density readings were significantly higher in the gorge ($\bar{x} = 45.77$, $n = 214$, $SD = 28.53$) compared with the plateau areas ($\bar{x} = 36.14$, $n = 188$, $SD = 25.37$; $Z = -3.43$, $P = 0.0007$). The field surveys did not result in the identification of any potential den trees. The CISC data indicated the existence of one 19.8-ha old-growth Eastern hemlock (*Tsuga canadensis*)–hardwood stand in DBNF. The lack of potential tree dens resulted in an SI of 0.0 for this variable. Potential rock dens were found at 26.7% of the sample locations.

Density of open roads was 1.17 km/km² for the entire study area (range = 0.55–1.75, $n = 5$, $SD = 0.44$), which resulted in an SI of 0.0 (Table 1). The 912.5 km of open roads in the area were mostly gravel and dirt roads; only 125.9 km of these roads were improved. We identified 7 potential human–bear conflict zones; these zones included locally popular recreation areas, developed visitor facilities, developed campgrounds, and concentrations of residences. Five of these areas were within the river gorge. The potential conflict zones comprised 172 km² or 22.1% of the study area (range = 14.8–29.4%, $n = 5$, $SD = 5.57$), resulting in an SI of 0.29 (Table 1).

The CI values for the food, cover, and human impact components were 0.81, 0.66, and 0.15, respectively, resulting in an overall HSI of 0.61 (Table 2). The euclidean distances among the study area sections based on CI values for the 3 habitat components showed that study area sections 1 and 4 were most similar, followed by sections 2 and 3, whereas section 5, the National Forest area, was the least similar to any of the other sections (Fig. 4).

Table 1. Suitability indices (SI) of black bear habitat variables for the Big South Fork study area in southeastern Kentucky and north central Tennessee, 1990.

Study area section	Suitability indices ^a							
	V1	V2	V3	V4	V5	V6	V7	V8
1	0.75	1.00	b	1.00	0.80	0.00	0.00	0.00
2	0.78	1.00	b	0.50	0.43	0.00	0.00	0.00
3	0.69	1.00	b	0.50	0.59	0.00	0.38	0.02
4	1.00	1.00	b	1.00	0.96	0.00	0.00	0.00
5	0.25	1.00	b	1.00	0.50	0.00	0.00	1.00
Overall	0.73 ^c	1.00 ^c	0.74 ^c	0.80 ^d	0.66 ^c	0.00 ^c	0.00 ^c	0.29 ^c

^a Key to variables:

- V1 = Cover percentage of all soft mast producing species
- V2 = Relative cover percentage of all hard mast producing species
- V3 = Percentage of all hard mast producing species >50 years old
- V4 = Number of codominant hard mast producing species groups
- V5 = Cover percentage of understory vegetation with >60% vegetation density
- V6 = Cover percentage of hardwood vegetation >150 years old
- V7 = Open road length per unit area (km/km²)
- V8 = Percentage of area in potential human-bear conflict zones

^b Not calculated due to small sample sizes.

^c Calculated separately from study area sections.

^d Average of all study area sections.

DISCUSSION

Habitat Evaluation

The results of the HSI evaluation indicate the adequacy of food and, to a lesser extent, protective cover. The limiting factors within the food component were summer food availability and fall food productivity. If the SI for summer food on DBNF increased from 0.73 to 0.81, the aver-

Table 2. Component indices (CI) and overall black bear habitat suitability index (HSI) for the Big South Fork study area in southeastern Kentucky and north central Tennessee, 1990.

Study area section	Component index			HSI ^d
	Food ^a	Cover ^b	Human impact ^c	
1	0.86	0.80	0.00	0.63
2	0.76	0.43	0.00	0.49
3	0.72	0.59	0.20	0.56
4	0.94	0.96	0.00	0.71
5	0.59	0.50	0.50	0.55
Overall ^e	0.81	0.66	0.15	0.61

^a See equation 1.

^b See equation 2.

^c See equation 3.

^d See equation 4.

^e Calculated separately from study area sections.

age for the BSFNRRRA, the HSI would increase by 1.6%. Projection of future hard mast productivity indicated that, due to natural maturation of the forest, at least 48.8% of all hard mast producing species would reach the optimal production age within approximately 10 years; this would result in a 3.3% increase in HSI to 0.63. Because black bears use secure winter dens other than tree dens, we used tree den availability only as a positively contributing variable, and the low SI values did not affect the overall HSI. In the long term, forest maturation will result in increased availability of tree dens, which may increase the HSI by 6.6% to 0.65.

The potential influence of human activities was high relative to the other habitat variables. If the negative effect of human-related activities were eliminated, the HSI outcome would increase by 34.4% to 0.82. Therefore, to increase the quality of habitat in the short term, it seems most effective to manage the potentially negative effects of human activities rather than the natural habitat components. Reintroductions of large carnivores often will require public support, as was suggested by early red wolf (*Canis rufus*) reintroduction attempts (Phillips and Parker 1988) and grizzly bear (*Ursus arctos*) augmentations (Maguire and Servheen 1992). Integration of public education and information programs into bear reintroduction projects provides a way to identify and resolve potential conflicts before release. However, such programs may

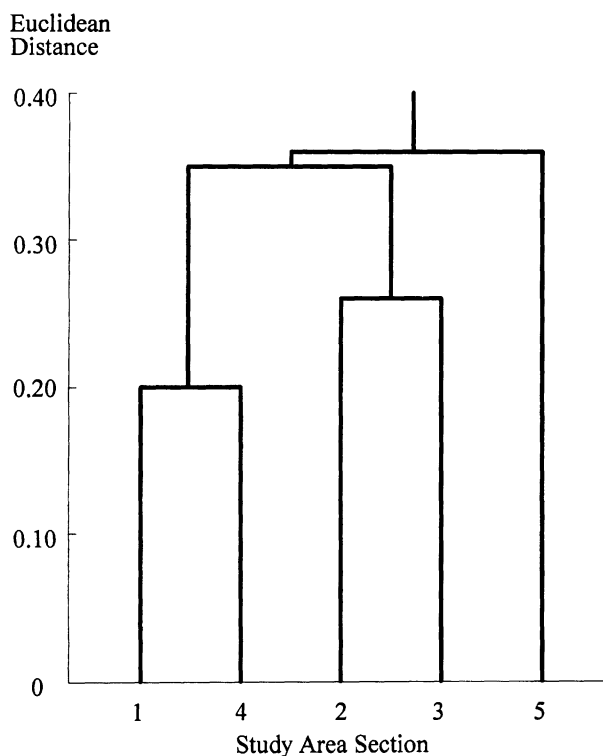


Fig. 4. Dendrogram of Big South Fork study area sections in southeastern Kentucky and north central Tennessee based on euclidean distances among weighted component indices of the habitat components food, cover, and human impact of the black bear HSI model, 1990.

need to be complemented with a reduction of road density in certain areas and proper garbage management at human activity sites.

Study area sections 1 and 4 seems to provide the best black bear habitat because of high availability and productivity of food sources along with sufficient protective cover. The availability of protective cover was relatively low for sections 2 and 5. The potential for human impact seems to be the weakest aspect of sections 1–4. The quality of all 3 habitat components of section 5 was relatively low. The quality of the summer food component on DBNF may be improved through minor changes in forest management; soft mast availability may be enhanced by prescribed burning (Harlow and Van Lear 1989). Although the potential for human impact in sections 1 and 4 was relatively high, these sections provided the highest quality natural habitat. The central position and remoteness of these sections indicate the importance of this portion of the study area to establish a core population from which dispersal could take place. The river gorges are relatively inaccessible to people and provide the best protective

cover for bears. It seems important to maintain and enhance the remote character of these areas to provide potential travel and dispersal corridors for bears.

As all habitat models, HSI models are simplifications of the systems they depict (Schamberger and O'Neil 1986). A good model preserves most system dynamics (Maynard Smith 1974) in the simplest way possible. HSI models have been criticized because of unreasonable assumptions and oversimplification of species–habitat relationships. However, the effectiveness of models depends on the intended use of the results (Laymon and Barrett 1986). The simple structure of our HSI model was intended to objectively and systematically assess the feasibility of a black bear reintroduction into the BSFA; we were able to determine the relative quality of habitat variables and components, their spatial distribution, and the effects of projected habitat changes over time.

Another criticism with regard to habitat modeling in general is that many models are never validated (Stormer and Johnson 1986). We submit that our HSI model has not been validated. The ultimate measure of habitat suitability may be the ability of an area to sustain viable populations (Lancia et al. 1986). Obviously, this is difficult because many factors not directly related to habitat (e.g., predation, competition, weather) may influence animal populations (Schamberger and O'Neil 1986). In case of extinct or remnant populations, little or no habitat use data can be acquired, thus limiting habitat evaluations to relatively general models based on the best information available from other populations with similar habitat conditions.

Due to the flexible structure of HSI models and acceptance of different types of input data, our approach applies to other bear species and different geographic regions. On a regional scale, the HSI model may be useful to identify which areas need most protection, where populations can be augmented or reintroduced most effectively, and how population linkages may be established. Although our model was not designed for use with GIS data, the rapid growth of this technology has greatly facilitated regional habitat modeling. Two important factors in developing GIS-based HSI models are: (1) compatibility of resolution of information used in the model and in the GIS, and (2) the feasibility of generalizing habitat requirements so that GIS-based variables can adequately represent the life requisites of the species (Donovan et al. 1987). Bears are ideal candidates for habitat analysis with GIS due to their broad habitat requirements and the appropriateness of landscape scales to bear ecology (Clark and van Manen 1993).

Release Procedures

Based on the logistic regression equation of Griffith et al. (1989), various combinations of habitat quality, program length, and the total number of release animals indicated that the effect of increased program length on reintroduction success was strongest when relatively few animals are released, and vice versa; the effectiveness of releasing many animals over a longer time may be limited (Fig. 5). We suggest that a minimum of 40 bears released over 6–7 years is logistically feasible and provides a reasonable probability of reintroduction success.

A viable demographic structure in a reintroduced population depends partly on the sex and age structure of the release animals. Using existing data and experts' opinion to evaluate different sex and age groups for grizzly bear augmentation, Maguire and Servheen (1992) found that 4-year-old females provided the best trade-off among reproductive contribution, probability of retention, and probability of conflict. Translocated bears may be motivated to return to their original home ranges because of familiarity with that area or social relationships (Beeman and Pelton 1976). In a study of transplanted non-nuisance brown bears, Miller and Ballard (1982) found that nonreturning bears of both sexes were younger than returning bears. Thus, the motivation to return may increase

with age. Mace and Haroldson (1984) suggested that subadult female grizzly bears may not have invested as much as adult bears in establishing and maintaining home ranges, presumably reducing the need to return to their areas of origin. These studies seem to indicate that reintroduction success may be enhanced by releasing young adult bears (i.e., approximately 4–6 years) because they are less likely to exhibit extensive post-release movements, thereby reducing the probability of conflict. Because of greater female reproductive contribution to a bear population, a 2:1 sex-ratio of females to males may further increase the probability of reintroduction success.

The area of origin of the release animals should closely resemble habitat of the release area, especially when adult animals are used (Servheen et al. 1987), and should be within the same subspecies range. Stiver and Pelton (1997) found that captive or nuisance black bears may not provide a viable option for reintroduction or augmentation. Indeed, Griffith et al. (1989) found that wild-caught animals from high-density and increasing populations had the highest probability of translocation success; they found no association between success and immediate or delayed release. However, the success of red wolf reintroductions in the southeastern U.S. has been partly contributed to the use of an approximately 6-month acclimation period where captive-bred wolves were gradually fed a natural diet (Phillips and Parker 1988). After unacclimated releases in Arkansas, some male bears were sighted and killed up to 435 km away from release sites, although many bears, mostly females, remained close (Smith et al. 1990). An on-site acclimation period may enhance reintroduction success by reducing post-release movements. When wild bears are used, however, the risk of human habituation will increase with time. A maximum acclimation period of 4 weeks may be appropriate during which human presence should be minimized. To further enhance the probability of reintroduction success, bears should be released during summer when food sources usually are abundant and predictable. Due to high annual variation of hard mast abundance in the southern Appalachians and associated shifts in black bear home ranges (Garshelis and Pelton 1981), release in fall may not be a feasible option. Alternatively, the winter denning period may be used as an acclimation period by placing bears in natural or artificial dens; after den emergence bears are sedentary and will likely stay within the vicinity of the release site, particularly females with cubs.

Feasibility studies will not be able to predict exactly where and when unusual events may occur (e.g., crop damage, human–bear interactions). Post-release moni-

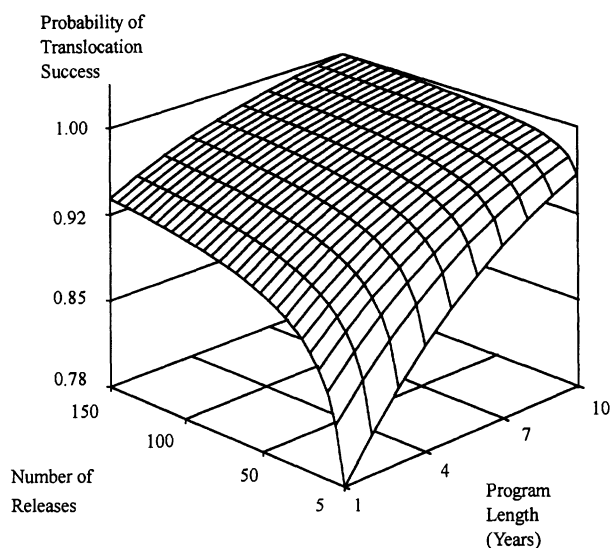


Fig. 5. Relationship between number of animals released and program length on the probability of success of translocation. Based on logistic regression equation of Griffith et al. (1989). Remaining settings of the model were kept constant and were based on late breeding, native game mammals released in good habitat within the core of historic range.

toring will be important to assess or prevent such events and to provide data to measure reintroduction success (Stanley Price 1991). Reintroduced populations are relatively easy to study due to initial small size and known sex and age structure; intensive monitoring may provide a unique opportunity to test the performance of population estimators and indices.

In summary, we propose the following release procedures for a reintroduction to establish a black bear population within the BSFA: (1) a minimum of 40 bears should be released of which approximately 2/3 should be 4- to 6-year-old females and the remainder males of similar age, (2) release animals should be obtained from stable or increasing high-density bear populations in the southern Appalachian region, (3) release animals should not have a known history of human habituation, (4) an acclimation period of ≤ 4 weeks may be desirable, (5) the prime release sites should be within study area section 4 and the southern portion of section 1 where habitat quality was greatest, (6) releases should be spread out equally over a period of approximately 6–7 years, (7) capture of animals should occur in mid summer to allow release in late summer, (8) released bears should be intensively monitored using standard radio-telemetry procedures and all monitoring should be thoroughly documented, so that (9) success can be evaluated based on previously established criteria.

CONCLUSIONS

The HSI model provided an objective and systematic approach to evaluate black bear habitat in the BSFA. The potentially negative effect of human activities seems to be the weakest aspect of the BSFA with regard to reestablishment of a black bear population. The effects of human activities on bears are difficult to predict because they partly depend on management actions related to a reintroduction attempt and public attitudes towards bears. Even if an area has suitable bear habitat, many different factors will influence the success of a reintroduction attempt. The development of detailed release procedures should enhance the probability of reintroduction success.

Reintroduction attempts should be planned as experiments (May 1991), and they should be used to better quantify the factors that influence reintroduction success. With regard to the BSFA, an experimental release of a small number of bears would help to evaluate the effects of human activities when no management actions are taken; such experiment can also be used to test the effectiveness of different release procedures.

The techniques and concepts used in study could apply to other bear species and different geographic regions.

Although our purpose was to study the biological aspects of reestablishing a black bear population, we point out that social, economic, and political aspects also will be important factors for successful reintroduction of large carnivores.

LITERATURE CITED

- AVERY, T.E. 1975. Natural resources measurements. McGraw-Hill, New York, N.Y. Second ed. 339pp.
- BAILEY, R.G. 1980. Description of the ecoregions of the United States. U.S. Dep. Agric., Misc. Publ. No. 1391. 77pp.
- BEEMAN, L.E., AND M.R. PELTON. 1976. Homing of black bears in the Great Smoky Mountains National Park. *Int. Conf. Bear Res. and Manage.* 3:87–95.
- BRAUN-BLANQUET, J. 1932. Plant sociology: the study of plant communities. McGraw-Hill, New York, N.Y. 439pp.
- CLARK, J.D., AND F.T. VAN MANEN. 1993. Geographic information systems and black bear habitat analyses. *East. Workshop Black Bear Res. and Manage.* 11:137–153.
- DONOVAN, M.L., D.L. RABE, AND E.O. OLSON, JR. 1987. Use of geographic information systems to develop habitat suitability models. *Wildl. Soc. Bull.* 15:574–579.
- GARSHELIS, D.L., AND M.R. PELTON. 1981. Movements of black bears in the Great Smoky Mountains National Park. *J. Wildl. Manage.* 45:912–925.
- GRIFFITH, B, J.M. SCOTT, J.W. CARPENTER, AND C. REED. 1989. Translocation as a species conservation tool: status and strategy. *Science* 245:477–480.
- , AND B.A. YOUTIE. 1988. Two devices for estimating foliage density and deer hiding cover. *Wildl. Soc. Bull.* 16:206–210.
- HARLOW, R.F., AND D.H. VAN LEAR. 1989. Effects of prescribed burning on mast production in the Southeast. Pages 54–65 in C.E. McGhee, ed. *Proc. South. Appalachian Mast Manage. Workshop.* Univ. Tenn., Knoxville.
- HARRIS, L.D., AND P. KANGAS. 1988. Reconsideration of the habitat concept. *Trans. North Am. Wildl. Natur. Resour. Conf.* 53:137–143.
- JOHNSON, K.G. 1978. Den ecology of black bears in the Great Smoky Mountains National Park. M.S. Thesis, Univ. Tenn., Knoxville. 107pp.
- KNOWLES, B.J., J.N. CAMPBELL, AND R.R. HANNAN. 1990. Cooperative inventory of endangered, threatened, sensitive, and rare species, Daniel Boone National Forest, Stearns Ranger District. U.S. For. Serv., The Nature Conservancy, Kentucky State Nature Preserve Comm., Kentucky Dep. of Fish and Wildl. Res. Winchester, K.Y. 169pp.
- LANCIA, R.A., D.A. ADAMS, AND E.M. LUNK. 1986. Temporal and spatial aspects of species-habitat models. Pages 65–69 in J. Verner, M.L. Morrison, and C.J. Ralph, eds. *Wildlife 2000: modeling habitat relationships of terrestrial vertebrates.* Univ. Wisconsin Press, Madison.
- LAYMON, S.A., AND R.H. BARRETT. 1986. Developing and testing habitat-capability models: pitfalls and recommendations.

- Pages 87–91 in J. Verner, M.L. Morrison, and C.J. Ralph, eds. *Wildlife 2000: modeling habitat relationships of terrestrial vertebrates*. Univ. Wisconsin Press, Madison.
- MACE, R., AND M. HAROLDSON. 1984. Scope of work and proposed study design: grizzly bear population augmentation. Rep. to U.S. Dep. Inter., Fish and Wildl. Serv., Grizzly Bear Recovery Coord. Missoula, Mont. 32pp.
- MAEHR, D.S. 1984. Distribution of black bears in eastern North America. *East. Workshop Black Bear Res. and Manage.* 7:74.
- MAGUIRE, L.A., AND C. SERVHEEN. 1992. Integrating biological and sociological concerns in endangered species management: augmentation of grizzly bear populations. *Cons. Biol.* 6:426–434.
- MAY, R.M. 1991. The role of ecological theory in planning re-introduction of endangered species. *Symp. Zool. Soc. London* 62:145–163.
- MAYNARD SMITH, J. 1974. *Models in ecology*. Cambridge Univ. Press, Cambridge, U.K. 146pp.
- MILLER, S.D., AND W.B. BALLARD. 1982. Homing of transplanted Alaskan brown bears. *J. Wildl. Manage.* 46:869–876.
- MORRISON, D.F. 1990. *Multivariate statistical methods*. McGraw-Hill Publ. Co., New York, N.Y. 495pp.
- MUELLER-DOMBOIS, D., AND H. ELLENBERG. 1974. *Aims and methods of vegetation ecology*. John Wiley and Sons, Inc., New York, N.Y. 547pp.
- NATIONAL OCEANOGRAPHIC AND ATMOSPHERIC ADMINISTRATION. 1978. *Climates of the States*. Gale Research Co., Detroit, Mich. 1185pp.
- NUDDS, T.D. 1977. Quantifying the vegetative structure of wildlife cover. *Wildl. Soc. Bull.* 5:113–117.
- PELTON, M.R. 1982. Black bear. Pages 504–514 in J.A. Chapman and G.A. Feldhamer, eds. *Wild mammals of North America; biology management, and economics*. John Hopkins Univ. Press, Baltimore, Md.
- PHILLIPS, M.K., AND W.T. PARKER. 1988. Red wolf recovery: a progress report. *Cons. Biol.* 2:139–141.
- SAS INSTITUTE, INC. 1990. *SAS/STAT user's guide, Version 6, Fourth ed., Vol. 1 and 2*. SAS Inst., Inc., Cary, N.C. 1686pp.
- SCHAMBERGER, M.L., AND L.J. O'NEIL. 1986. Concepts and constraints of habitat-model testing. Pages 5–10 in J. Verner, M.L. Morrison, and C.J. Ralph, eds. *Wildlife 2000: modeling habitat relationships of terrestrial vertebrates*. Univ. Wisconsin Press, Madison.
- SCHOEN, J.W. 1990. Bear habitat management: a review and future perspective. *Int. Conf. Bear Res. and Manage.* 8:143–154.
- SERVHEEN, C. 1990. The status and conservation of the bears of the world. *Int. Conf. Bear Res. and Manage. Monogr. Ser. No. 2*. 32pp.
- , W. KASWORM, AND A. CHRISTENSEN. 1987. Approaches to augmenting grizzly bear populations in the Cabinet Mountains of Montana. *Int. Conf. Bear Res. and Manage.* 7:363–368.
- SHAFFER, M.L. 1987. Minimum viable populations: coping with uncertainty. Pages 69–86 in M.E. Soulé, ed. *Viable populations for conservation*. Cambridge Univ. Press, Cambridge, U.K.
- SMALLEY, G.W. 1986. Classification and evaluation of forest sites in the Northern Cumberland Plateau. U.S. Dep. Agric. For. Serv. Gen. Tech. Rep. SO-60. 74pp.
- SMITH, K.G., J.D. CLARK, AND P.S. GIPSON. 1990. History of black bears in Arkansas: over-exploitation, near elimination, and successful reintroduction. *East. Workshop Black Bear Res. and Manage.* 10:5–14.
- STANLEY PRICE, M.R. 1991. A review of mammal re-introductions, and the role of the Re-introduction Specialist Group of IUCN/SSC. *Symp. Zool. Soc. London* 62:9–25.
- STIVER, W.H., M.R. PELTON, AND C.D. SCOTT. 1997. Potential use of pen-reared black bears for augmentations or reintroductions. *Int. Conf. Bear Res. and Manage.* 9(2):145–150.
- STORMER, F.A., AND D.H. JOHNSON. 1986. Introduction: biometric approaches to modeling. Pages 159–160 in J. Verner, M.L. Morrison, and C.J. Ralph, eds. *Wildlife 2000: modeling habitat relationships of terrestrial vertebrates*. Univ. Wisconsin Press, Madison.
- STUART, S.N. 1991. Re-introductions: to what extent are they needed? *Symp. Zool. Soc. Lond.* 62:27–37.
- TAYLOR, D.F. 1971. A radio-telemetry study of the black bear (*Euarctos americanus*) with notes on its history and present status in Louisiana. M.S. Thesis, Louisiana State Univ., Baton Rouge. 87pp.
- THORNBURY, W.D. 1965. *Regional geomorphology of the United States*. John Wiley and Sons, New York, N.Y. 617pp.
- THORNTHWAITTE, C.W. 1948. An approach toward a rational classification of climate. *Geogr. Rev.* 38:55–94.
- TURNER, D.A., AND W.E. HAMMITT. 1983. Visitor use and impact sites: the Big South Fork. Phase I: Observational study. Southeast Reg. Natl. Park Serv., Atlanta, Ga. 43pp.
- U.S. BUREAU OF THE CENSUS. 1992. 1990 census of population and housing, southern states. Summary Tape File 1A. U.S. Dep. Commerce. Washington, D.C. (Computer files).
- U.S. DEPARTMENT OF AGRICULTURE FOREST SERVICE. 1988. Continuous inventory of stand condition summary. U.S. For. Serv., Stearns Ranger Dist., Whitley City, Ky.
- U.S. FISH AND WILDLIFE SERVICE. 1981. Standards for the development of habitat suitability index models. 103 ESM. U.S. Dep. Inter. Fish and Wildl. Serv., Div. Ecol. Serv., Washington, D.C. 162 pp.
- VAN MANEN, F.T. 1991. A feasibility study for the potential reintroduction of black bears into the Big South Fork area of Kentucky and Tennessee. *Tenn. Wildl. Res. Agency Tech. Rep. No. 91–3*. 158pp.