To the Graduate Council:

I am submitting herewith a thesis written by James R. (Bob) Long entitled "Feasibility Assessment for the Reintroduction of North American Elk into Great Smoky Mountains National Park." I have examined the final copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Wildlife Science.

Michael R. Pelton, Major Professor

We have read this thesis and recommend its acceptance:

Accepted for the Council:

Associate Vice Chancellor and
Dean of The Graduate School

FEASIBILITY ASSESSMENT FOR THE REINTRODUCTION OF NORTH AMERICAN ELK INTO GREAT SMOKY MOUNTAINS NATIONAL PARK

A Thesis
Presented for the
Master of Science
Degree
The University of Tennessee, Knoxville

James R. (Bob) Long
August 1996

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"as a primary goal.....the biotic associations within each park should be maintained, or where necessary re-created, as nearly as possible in the condition that prevailed when the area was first visited by the white man.....a national park should represent a vignette of primitive America."

Leopold Committee Report, 1963

ACKNOWLEDGEMENTS

I would like to sincerely thank Dr. Michael R. Pelton for serving as my major professor and for his teachings and guidance, both in class and out.

Special thanks to Dr. David Buehler, Dr. Joe Clark, and Dr. John New for serving as members of my graduate committee, reviewing early drafts of the Habitat Suitability Index model, and keeping me updated on elk-related issues. I greatly appreciate Dr. Frank Van Manen for his assistance and advice during the development of the HSI.

Without the help and guidance of Dr. John Rennie and the late Dr. George Weaver, during the first months of my studies at The University of Tennessee (UT), I would not be here today.

To Ron White, Rocky Mountain Elk Foundation (RMEF) Field Director, thank you for your vision and support in bringing about this project. I appreciate the untiring work of Mike Hodge, David Shiflett, Lee Kribbs, Bill Nix, Tim Queen, Roger Queen, Joe Treadway and all other members of the East Tennessee and Great Smoky Mountains Chapters of the RMEF. Thanks to Carroll Schell, Kim Delozier, and Keith Langdon, of Great Smoky Mountains National Park, for their help and support throughout this project. I especially appreciate Sue Powell of the National Park Service for

generating the GIS maps and information so critical to this research.

I appreciate the hospitality and information received from Rawley Cogan, Mike Cartwright, and Tim Francis during my trips to Pennsylvania and Arkansas to study elk herds in their states.

Thanks to Chris Lucash, Barron Crawford, John Weller, Bill Stiver and Andrea Bixler for their friendship during my field work in the park. And last but not least, a special thanks to Rebecca Morrow and all the graduate students at UT for their help, support, and friendship during the entire study.

Funding was provided by the Rocky Mountain Elk Foundation, Great Smoky Mountains National Park, and the University of Tennessee.

ABSTRACT

An elk Habitat Suitability Index (HSI) model was developed to study the feasibility of reintroducing elk (Cervus elaphus) into Great Smoky Mountains National Park (GSMNP), TN and NC. The variables and indices identified in the model were the result of data gathered from: (1) a literature review, (2) field tours, (3) interagency discussions, and (4) on-site data collection and evaluation. The model was subdivided into forest area and open area, each having a separate set of variables. The model for forested area was based on evaluation of three variables associated with food and water, one to evaluate cover requirements, one related to topography, one related to interspersion of cover types, and three related to human influences. The model for open areas was based on evaluation of two variables for food and water, one related to cover, one associated with topography, and three related to human influences. Suitability index curves were assigned to each variable. Major limitations of the model were its simplification of natural systems, limited field data, and numerous assumptions. Application of the HSI in GSMNP, through field sampling and analysis, showed that the existing habitat was sufficient to warrant an experimental release of elk, to validate the findings of the HSI and phase I feasibility. Mean SI values for forested and open

areas were 0.81 (standard error 0.005; standard deviation 0.049) and 0.77 (standard error 0.008; standard deviation 0.035), respectively. The combined weighted mean for the entire park was 0.80. Based on habitat analysis and evaluation of mortality factors, recommendations for an experimental release are presented.

PREFACE

American elk (Cervus elaphus) have been extirpated from the GSMNP ecosystem for almost 200 years. Thus, careful evaluation of the feasibility of reintroducing this large herbivore is essential.

Chapter I provides the introduction, justification for the current project, and includes a discussion of past eastern reintroduction attempts. A discussion of this project will indicate monies should not be allocated unless the probability for success is high.

Chapter II discusses the Great Smoky Mountains National Park study area. It is important to understand the past uses and abuses of the park in relation to current forest conditions.

Chapter III presents a look at the literature pertinent to the development of the HSI for Southeastern United States. Because there are no existing elk in the study area, a literature review was the main means available for acquiring data to construct the model.

Chapter IV discusses the elk Habitat Suitability Index (HSI) model developed for the Southeast. The model provides an important tool to structure the quantification of elk habitat quality and quantity. The HSI is not intended to describe specific ecological processes within an ecosystem and should not be used as such. The overall purpose of the

model is to measure the quality and quantity of specified habitat parameters known or assumed to be critical to maintain a viable elk population. This model has not been verified with field data from elk populations in southeastern United States and may provide erroneous results. Chapter IV includes the application of the HSI model in Great Smoky Mountains National Park. Application of this model in regions outside GSMNP is not adviseable without further field testing.

Chapter V presents the results which are a structured approach to the evaluation of elk habitat; this enables the identification of strengths, weaknesses, and spacial relationships within the study area.

Chapter VI lists recommendations presented to increase the probability for success of an experimental release.

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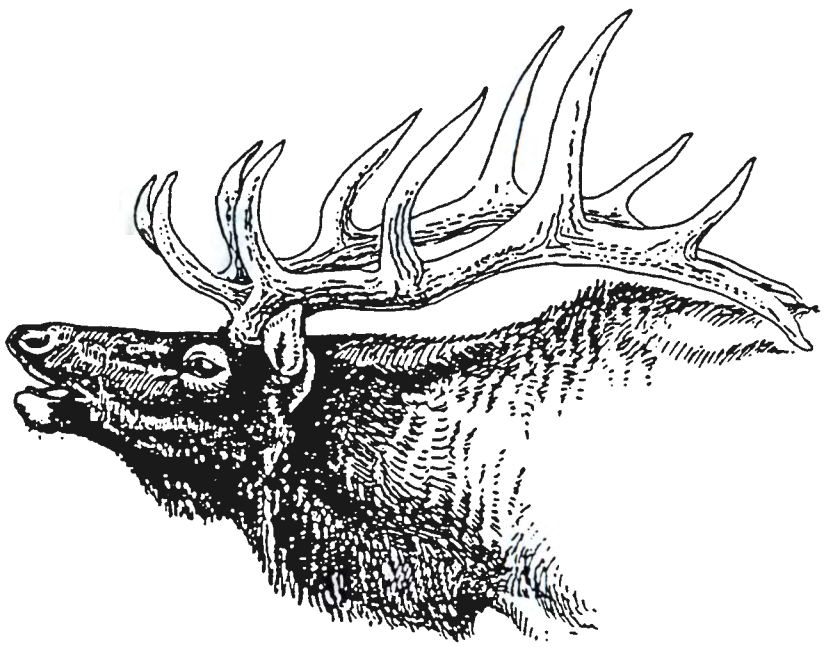
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CHAPTER I

INTRODUCTION

When Europeans first arrived in North America, an estimated 10,000,000 elk of six subspecies ranged from coast to coast and from Canada to Mexico (Geist 1991 and Raskevitz 1984) (Figure 1). By 1922, only an estimated 90,000 elk were left; two subspecies were extinct, three were near extinction, and one had been extirpated from most of its original range (Raskevitz 1984). Since 1900, conservation efforts have increased elk populations to an estimated 886,500 (Figure 2) (Rocky Mountain Elk Foundation 1996, Personal comm.).

Until the early to mid-1800's American elk roamed through the southern Appalachian mountains, but they have since been extirpated. In 1896, Rhoads stated: "At the beginning of the present century (1800's), this noble animal was probably a visitant to every county in the state (Tennessee), abounding in the high passes and coves of the southern Alleghenies, frequenting the licks near the present site of Nashville, and roaming through the glades and canebrakes of the Mississippi bottoms". Ganier (1928) reported that the last one in eastern Tennessee was shot in 1849 (Linzey and Linzey 1971). Rhoads (1896) also stated

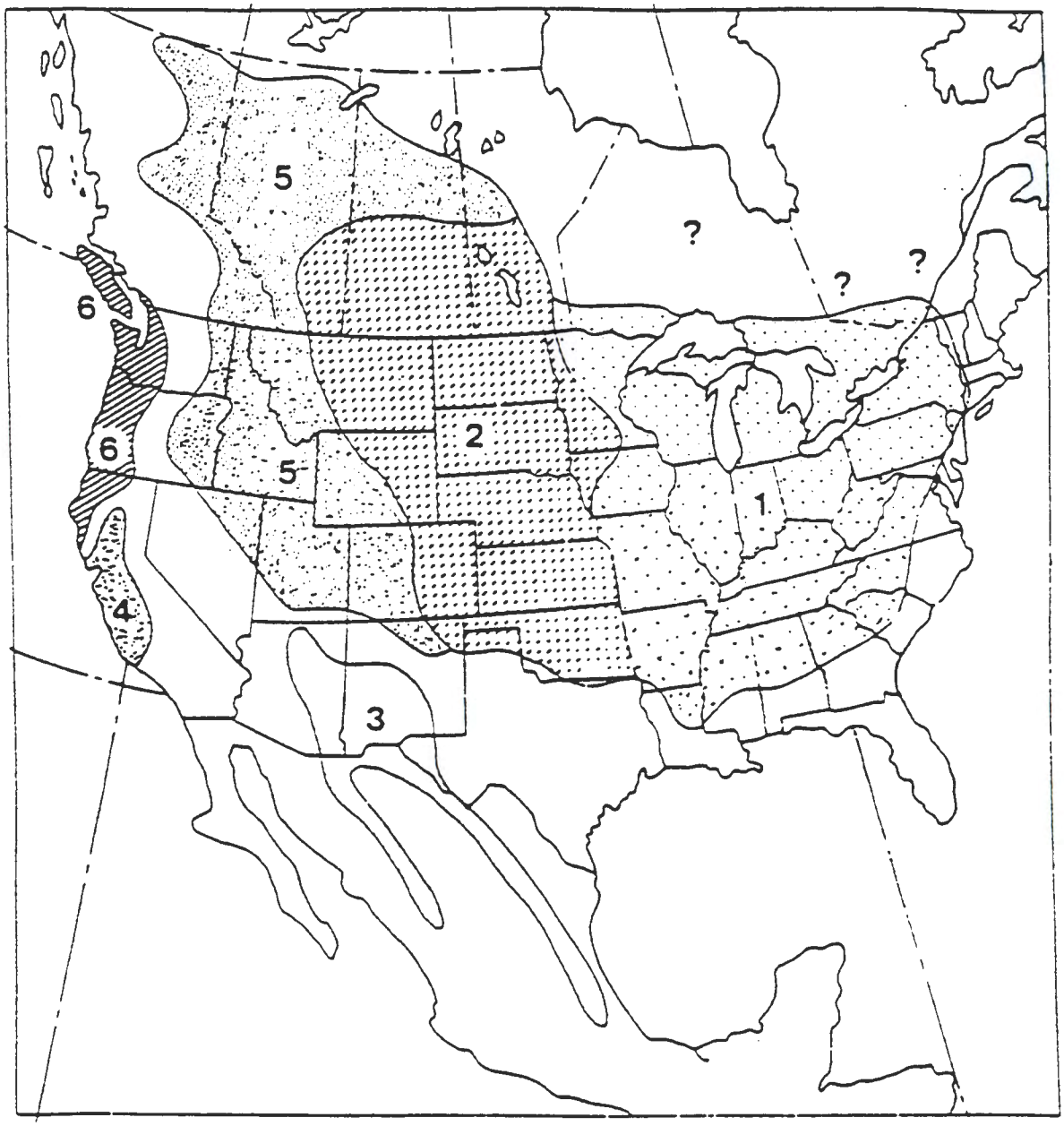
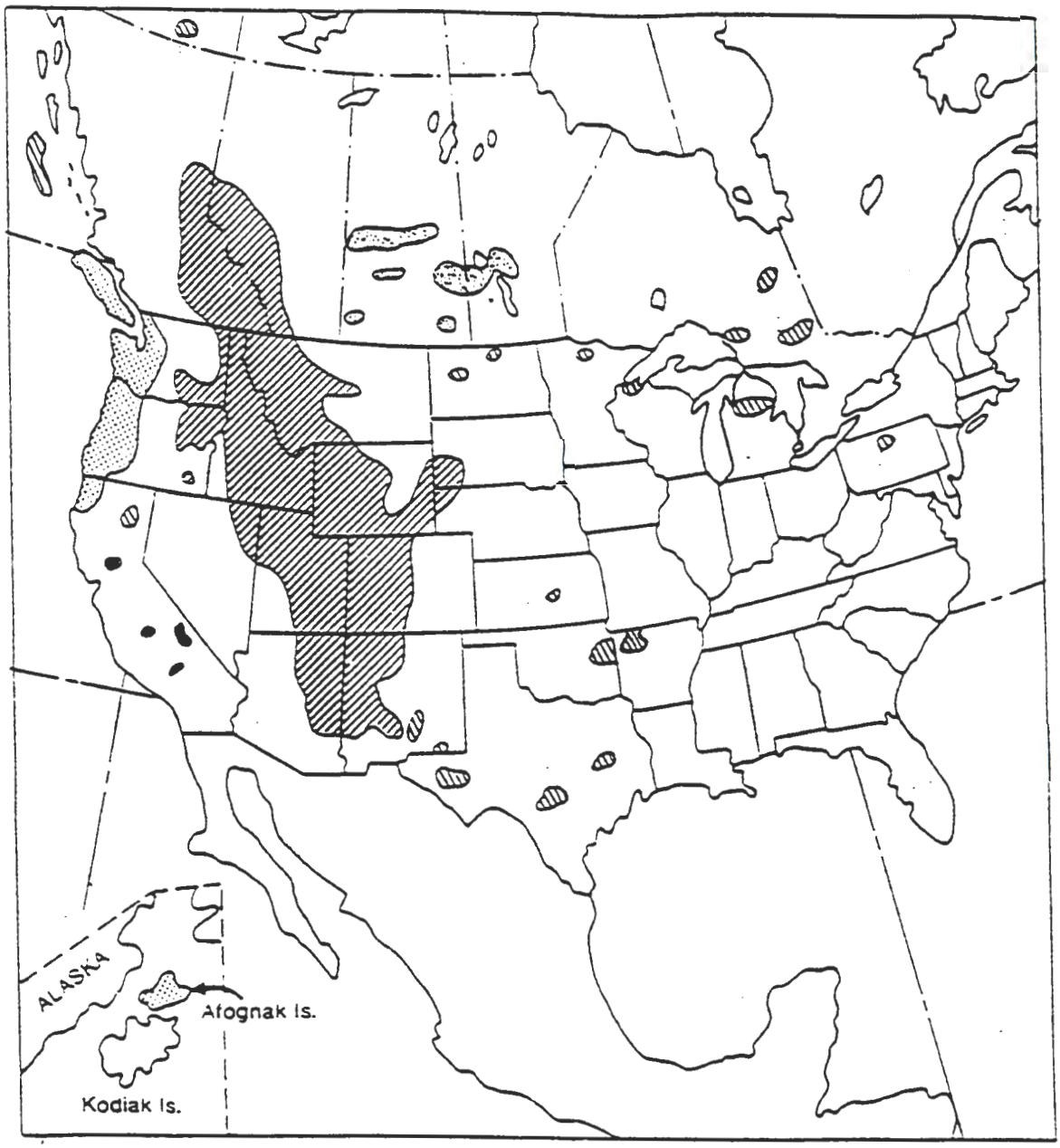


Figure 1. Original distribution of 1. Eastern elk, 2. Manitoban elk, 3. Merriam elk, 4. Tule elk, 5. Rocky Mountain elk, and 6. Roosevelt elk, based on available records. From Geist (1991) and the Wildlife Management Institute.



▨ Manitoban; ■ Tule; ▩ Roosevelt; ▨ Rocky Mountain;
▨ Rocky Mountain Transplants

Figure 2. **Present distribution of elk in North America. Updated from Geist (1991).**

that a Mr. Miles wrote to him "In 1865, I heard that an elk was killed in Obion county" (Murie 1951).

Eastern elk were once present in Georgia as well. William Bartram, noted naturalist, traveled throughout Georgia in the early 1770's and reported that a few elk remained in the mountains in the northern portion of the state (Bryant and Maser 1982).

Elk were found in North Carolina until the latter half of the 1700's (Oberholser 1905). Brickell (1737) wrote "These Beasts are plentifully to be met with in the Savannas near the mountains, and Heads of Rivers".

Elk have been extirpated from most of their former North American range due to over-exploitation, private ownership of land, and habitat destruction (Geist 1991). Today, with changes in land management practices, acquisition of large tracts of land by state and federal agencies, and strictly regulated game laws, millions of hectares of potential elk habitat are now available in the eastern United States. However, potential eastern elk habitat is disjunct from existing elk herds in the West. The isolated nature of eastern habitat makes natural dispersal unlikely, leaving reintroduction the only viable alternative for recovery. Great Smoky Mountains National Park, located in eastern Tennessee and western North Carolina, is one such area where land acquisition by the

National Park Service has created the potential for elk reintroduction.

Reintroduction is the placement of a species into all or a part of its historical range from which it has been extirpated, with the intent of establishing a free-ranging population (Gogan 1990). Extirpated native species could be reintroduced to portions of their original range for a number of reasons, including (1) increasing the opportunities for sport hunting, (2) expanding the range and increasing total numbers of a taxa known to be threatened or endangered, (3) protecting such taxon from natural or human-caused catastrophic events by establishing geographically isolated populations, and (4) restoring native species to selected areas to establish a more natural ecosystem (Gogan 1990). Because the welfare of the species is the foremost consideration, a species-oriented approach is usually taken (Kushlan 1980).

Justification for Reintroduction

Justifications for a reintroduction of elk into GSMNP are in three categories:

1) Ecological justifications:
   a) Reintroduction of elk would increase regional biodiversity and fill a niche that may have remained vacant in the Smokies ecosystem for more than 200 years.

b) A large grazing herbivore could help retain balds and other open areas in early successional stages through "natural" rather than "mechanical" means.

c) GSMNP may represent a core population for later expansions into other state and federal lands.

2) Aesthetic and ethical justifications:

a) The presence of elk in GSMNP would increase the quality of outdoor visitor experiences such as wildlife viewing, hiking, and camping.

b) Elk have intrinsic rights to exist within their historic range where suitable habitat occurs and human issues will allow reintroduction.

3) Economic justifications:

a) Visitors are presently asked to contribute money to park maintenance projects, "protect park resources and improve visitor services". Elk reintroduction is a popular project that has received widespread local and national media attention. Park visitors should be more likely to contribute to a popular new project than just maintaining the status quo. Elk reintroduction could be viewed as a source of revenue rather than an expense.

b) Elk reintroduction would bring long term financial support from the Rocky Mountain Elk Foundation for elk related projects or habitat projects, such as

prescribed burning and open area restoration; this would indirectly benefit elk.

c) Although hunting is illegal in the park, a cooperative reintroduction project with other state and federal agencies could provide hunting opportunities in the surrounding national forest and benefit the local economy.

Negative aspects of a reintroduction may be:

1) Project may not be successful and money spent would be wasted.
2) Would promote more illegal hunting.
3) May cause damage problems if elk leave the park and enter private land.

Justification for Current Study

Species-specific problems are widely recognized and are usually taken into consideration in a reintroduction program. However, this species-oriented emphasis, by its very nature, may have a serious drawback. Often, too little attention is paid to the effects of reintroduction on the receiving environment. When an organism is extirpated, the system changes with time because of both internal and external forces. The system into which an animal is reintroduced will probably be different than it was when the animal was extirpated, and the species' absence may in

itself have led to such changes. As a result an animal will seldom be reinserted into its vacant historic niche in a completely natural environment (Kushlan 1980).

According to Griffith et al. (1989), reintroduction of herbivores are most successful (77%) compared to carnivores(48%) and omnivorous (38%). Some past reintoductions of elk in the East failed due to a lack of appropriate planning. Had feasibility assessments and habitat evaluations been conducted before release, some of the failures might have been avoided.

Projects using federal funding are required, by the National Environmental Policy Act of 1969, to assess environmental impacts before starting a new project (Thomas 1982). Thus, Habitat Evaluation Procedures (HEP) were developed to assess wildlife habitat relationships and requirements.

Review Of Some Elk Reintroductions In The East

Alabama - Although the state is outside the historic range of eastern elk (Cervus elaphus canadensis), 55 Rocky Mountain elk (Cervus elaphus nelsoni) were introduced to Tuscaloosa, Sumter, Pickens, and Calhoun counties in February, 1916. The last known member of this herd was killed in 1921. Reasons for the lack of establishment were given as: intolerance of crop depredation, poaching, and disease (Allen 1965).

Arkansas - According to Arkansas' 1991 elk herd status report (Cartwright 1991), the U.S. Forest Service introduced Rocky Mountain elk in the Black Mountain Refuge in Franklin County, Arkansas in 1933 after the extinction of the eastern elk prior the 1840's. Three bulls and eight cows from the Wichita Mountains Wildlife Refuge in Oklahoma were released in Franklin County, Arkansas. Seventy five elk remained in and around Franklin by 1943. By 1948 the population had grown to 125 but reports indicated that the future of the herd did not look promising. The herd grew to 200 animals by the mid 1950's and then disappeared. The cause of the disappearance was not determined but there was considerable speculation that illegal hunting, natural mortality and loss of habitat eventually resulted in the loss of the herd.

Beginning in 1981 and continuing through 1985, 112 Rocky Mountain elk were released at 5 sites in Newton County, Arkansas. Elk were released on National Park Service lands along the Buffalo National Wild and Scenic River. One hundred five elk were from Colorado, and seven were captured in Nebraska. Many of the elk were ear tagged and tested for brucellosis and leptospirosis prior to release (Cartwright, M. 1993, Personal comm.).

Since initial stockings in the early 1980's, the herd has expanded its range to 58,682 ha (587.9 km^2). The range covers the upper and middle portions of the Buffalo National River and all of the Gene Rush Wildlife Management Area.

Elk commonly move onto private lands bordering National Park Service and Arkansas Game and Fish Commission lands. Since 1981 elk sightings have been documented in the following 10 counties: Newton, Searcy, Faulkner, Marion, Boone, Conway, Pope, Stone, Washington, and Van Buren. Elk sighted in counties other than Newton and Searcy appear to be transient animals (Francis, T. 1993, Personal comm.). Arkansas is considering a limited hunting season in the near future. Ground and aerial surveys reveal approximately 250 elk at present; this equates to 1 elk per 2.35 km2 (Cartwright, M. 1993, Personal comm.).

Florida - The state of Florida is outside the historic range for eastern elk. In 1968, 6 elk, used in a movie, were released on a ranch in Highlands County in southcentral Florida. As late as 1972, residents observed 11 elk in the same area. The last recorded sighting occurred in 1973 and no reasons were given for their final disappearance (Bryant and Maser 1982).

Kentucky - TVA Land Between The Lakes (LBL) has recently completed feasibilities and habitat evaluations for reintroduction of elk into a 283 ha enclosure (Long 1995a) and the 68,800 ha national recreation area (Long 1995b). Roads and fencing for the enclosed viewing were completed by January, 1996. In February, of the same year, 29 Manitoban elk (Cervus elaphus manitobensis) were translocated from Elk

Island National Park, in central Alberta. Plans for area-wide reintroduction are presently underway at LBL.

Louisiana - Only the northern part of Louisiana is within the historic range of eastern elk. An attempt to establish elk, in 1916, failed with no explanation for the lack of success (Lowery 1974).

Indiana - During the late 1950's and early 1960's, a reintroduction was attempted, but was later terminated in 1966 because the remaining habitat was determined to be of marginal quality (Bryant and Maser 1982).

Michigan - In 1915, seven to nine elk were released into Cheboygan County, on the Sturgeon River. The herd increased until the early 1960's at which time they numbered approximately 1,500. In 1965 and 1966 the population declined to an estimated 200-300 animals because of excessive harvesting, disturbance from human activities, habitat losses, and poaching (Bryant and Maser 1982). The herd has grown, since 1976, to a population of 1,000-1,200 elk and a limited hunting season has been restored (Parker 1990).

Minnesota - In 1915, approximately 13 elk were reintroduced into the state, increasing to 250 by the 1940's. By 1976, the herd was culled to 15 animals as a result of crop damages in the area. Today, no free-ranging elk are known to exist in the state (Bryant and Maser 1982).

Missouri - In 1951, ten elk were released into a 960 ha enclosure located on a military base. The herd increased to 103 in 7 years. In 1958, the military ordered the extermination of the herd because of overgrazed range and a lack of funds for supplemental winter feeding (Murphy 1963).

New Hampshire - Although New Hampshire is outside the historic range for eastern elk, 12 elk were introduced on Ragged Mountain in 1903. The herd thrived and by 1912 approximately 40 elk were reported in the area. In 1941, an open season was held due to crop depredation problems and 46 elk were killed. In 1955, sixteen elk were killed for the same reason. By 1976, the entire herd was thought to be exterminated (Bryant and Maser 1982).

New York - Elk were reintroduced to the state in 1893 and 1906. The herd seemed to be successfully established, but later declined with the last elk sighting reported in 1953. The loss was attributed to poaching and disease (P. tenuis) (Bryant and Maser 1982). New York state has applied for funding, from the RMEF, to conduct a feasibility assessment for a proposed reintroduction project in the near future (White, R. 1995, Personal comm.).

North Carolina - In 1920, an unknown number of elk were released on Mt. Mitchell, in Yancey County, by the North Carolina Game Division, predecessor of the Wildlife Resource Commission (NCWRC). Descendants of these elk were seen in

Nearby Avery County as late as World War II (1939-1945) (Dean 1984). However, none exist there today.

Pennsylvania - The state of Pennsylvania received stockings of Rocky Mountain elk beginning in 1913 and ending in 1926. One hundred seventy five elk were introduced from Yellowstone National Park. At first the herd prospered, and bulls were hunted from 1923-1931; 98 bulls were killed. Seventy-eight elk were killed due to crop depredation on crop lands.

In 1976, approximately 50 elk remained in Elk and Cameron counties (Bryant and Maser 1982). Today, the herd has grown to approximately 250 animals and crop depredation problems have been virtually eliminated due to elk-proof fencing, funded by the RMEF (Cogan, R. 1995, Personal comm.).

Tennessee - TVA Land Between The Lakes (LBL) has recently completed a feasibility and habitat evaluation for reintroduction of elk into the 68,800 ha National Recreation Area (Long 1995 b). The southern portion of LBL is located in Tennessee.

Virginia - The state of Virginia translocated 140-150 Rocky Mountain elk from Yellowstone National Park in 1917. The population grew at such a rate that, by 1922, hunting was warranted. Elk were hunted from that time until 1958. In response to crop depredation, an either-sex hunt was allowed in 1957. This control effort so depressed the herd

that it never recovered and by 1976 no huntable population existed (Bryant and Maser 1982).

Presently, a small herd of approximately 50 elk have reestablished in the state, after escaping from the "Arthur Godfrey Farm" in the late 1970's. Both red deer (Cervus elaphus elaphus) and American elk were known to be propagated at the farm. Thus, state officials are concerned that the escaped herd might be a hybrid mix of the 2 species. The current plan is to make no disposition of the herd until tissue samples can be obtained and genetic testing completed. The Virginia Department Of Game And Inland Fisheries has applied for funding from the Rocky Mountain Elk Foundation to conduct a feasibility assessment and habitat evaluation for another elk reintroduction project in the near future (Duncan, B. 1995, Personal comm.).

Wisconsin - An unknown number of elk were released into an enclosure in 1913 and maintained until 1932. At that time, 15 elk were released and the project was terminated (Bryant and Maser 1982). The fate of the released herd is unknown.

In 1990, a feasibility assessment for the reintroduction of elk was prepared, at the request of the Wisconsin State Legislature and Senator Joseph Strohl, by the Wisconsin Department of Natural Resources (WDNR) (Parker 1990). The feasibility recommended reintroduction and, in

1995, WDNR began reintroduction with the release of the first 25 elk translocated from the Michigan herd. Reintroduction will continue with the release of additional animals over the next several years.

Many past reintroductions in the eastern U.S. failed because of: 1) poor planning without benefit of a feasibility study or habitat evaluation, 2) attempted during the late 1800's and early 1900's before modern game laws were enacted or enforced, 3) attempted outside the historic range of elk, 4) lack of research to detect problems and implement solutions, 5) inadequate numbers released to establish a herd and maintain genetic viability, 6) releases in or near agricultural areas resulting in crop depredation, and 7) excessive bag-limits during legal hunts (Allen 1965, Bryant and Maser 1982, Cartwright 1991, Cogan, R. 1995, Personal comm., Dean 1984, and Parker 1990). Although existing elk herds in the East have experienced problems in the past, the herds in Arkansas, Pennsylvania, and Michigan are presently thriving due to: preparatory research, sound wildlife management practices, habitat recovery, and adequate protection.

The objectives of the HSI section of the present study were to:

1) develop an elk HSI model specifically for GSMNP with general application to southeastern United States. Wider application is possible because GSMNP contains

almost every forest type found throughout the Southeast.

2) document elk habitat needs in the Southeast.

3) describe application and evaluation of the habitat variables of the model and their assigned suitability index curves.

The objectives of the feasibility assessment, in general, were:

1) to evaluate elk habitat quality in GSMNP using an HSI model and other information.

2) to give recommendations as to the feasibility of an elk reintroduction program.

3) to provide recommendations on management practices to be used before and after reintroduction.

CHAPTER II

STUDY AREA

The study area is located in GSMNP along the state line ridge between North Carolina and Tennessee (Figure 3). Great Smoky Mountains National Park is the most heavily visited park of the national park system drawing nearly 10 million visitors annually. The Appalachian Trail extends some 113-116 km, within park boundaries, along this ridge from northeast to southwest. Altitudes average 1,524 m along a 80 km stretch of the main ridge. Elevations range from 2,215 m reached at Clingmans Dome, the second highest peak in eastern North America, to 290 m at the mouth of Abrams Creek (Harmon 1981). The study area includes 2,072 km^2 of eastern forest surrounded on three sides by national forest in 3 states (Georgia, North Carolina, and Tennessee) (Figure 4).

Climate

The temperate forests of the study area are cooled in winter by air masses from the Arctic and warmed and drenched in summer by moist air from the Gulf of Mexico. Between these extremes, spring and fall have great variation in weather with sharp temperature changes between day and night. Both growing season and temperature decrease with elevation. Decreases in temperature range between



Figure 3. Great Smoky Mountains National Park, located in Tennessee and North Carolina.

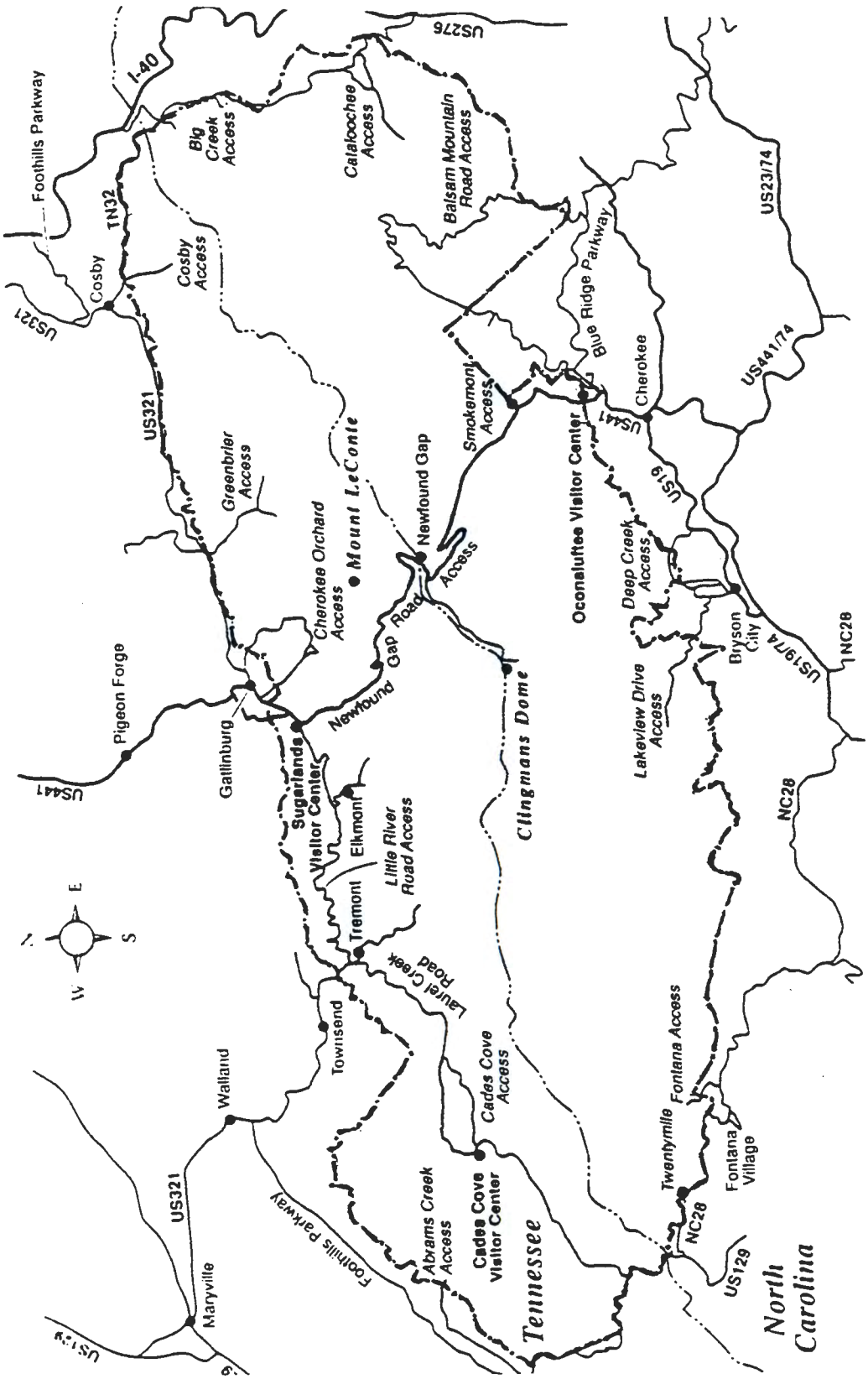


Figure 4. Great Smoky Mountains National Park study area.

2.3^{0}C\1,000 m in winter to 6.96^{0}C\1,000 m in summer (Harmon 1981). The higher altitudes of GSMNP receive 2.08 m annual average rainfall as compared to 1.4 m in the lower elevations.

Physiography, Topography, Geology, and Soils

The Appalachians are a long mountain range running northeast to southwest. The Great Smoky Mountains are made up of deposits that solidified, about 600 million years ago into rock (Precambrian sediments) that became known as the Ocoee Series. The series makes up the Snowbird, Great Smoky, and Walden Creek Groups. This group is a mass of clastic sedimentary, pebble conglomerate, and silty or clay-containing rocks (King et al. 1968).

Due to the ancient age of the rocks, no fossils are found. The Great Smoky Group is made up of three formations: the fine-grained Elkmont Sandstone on the bottom, the course-grained Thunderhead Sandstone in the middle, and the dark silty and clay-containing Anakeesta Formation that forms the steep-sided ridges and pinnacles of the surface (King et al. 1968).

Flora and Vegetation

The forest of GSMNP contain 1,500 species of flowering plants, 100 kinds of trees, 600 mosses, liverworts, and lichens, and 2,000 different fungi. Forest types of the

Southern Appalachian Mountains are unique and varied with a remarkable overlapping of forest habitats. This mountain range contains almost every forest type found in the eastern half of North America including mixed deciduous forest, boreal forest, and transition forest in the high country, and oak-hickory and pine forest in the lower elevations (Mackenzie 1991). Specific vegetation types found in GSMNP include: 1) spruce-fir, 2) northern hardwood, 3) cove hardwood, 4) mesic oak, 5) tulip poplar, 6) xeric oak, 7) pine-oak, 8) pine, 9) heath bald, 10) grassy bald, 11) grape thicket, 12) treeless (grass and etc.), and 13) water (Mackenzie 1991).

Forest of Lower Elevations At the lower elevations (below 914 m), the forests are recovering from extensive logging; these were the forests most accessible to humans during the past two centuries. Successional stages progress from pioneer species such pitch pine (*Pinus rigida*) to white (*Quercus alba*), chestnut (*Quercus prinus*), northern red (*Quercus rubra*), and black oaks (*Quercus velutina*).

In some areas climax closed canopy forests still exist and exhibit a shared dominance among species: sycamore (*Platanus occidentalis*), black tupelo (*Nyssa sylvatica*), black locust (*Robinia pseudoacacia*), silverbell (*Halesia carolina*), sugar maple (*Acer saccharum*), sourwood (*Oxydendrum arboreum*), yellow birch (*Betula alleghaniensis*),

magnolia (Magnolia fraseri), and three hickories - pignut (Carya glabra), red (Carya glabra var. odorata) and mockernut (Carya tomentosa). Because of its longevity, old growth yellow-poplar (Liriodendron tulipifera) are found in the closed canopy forest even though this tree is normally considered a pioneer species. Understory trees consist of dogwoods (Cornus florida), witch-hazel (Hamamelis virginiana) and others. Rhododendron (Rhododendron spp.), are abundant at all altitudes and in nearly every habitat (Mackenzie 1991).

Lower Slopes Pine-oak forest on the lower slopes and ridges (914-1,372 m) are closed canopy, but are more open than other lower elevation forests. The topography of lower slopes is not as steep as the ridges of higher elevations. Trees consist of scarlet (Quercus coccinea, white, chestnut, and black oaks mixed with pitch, Virginia (Pinus virginiana), table mountain (Pinus pungens), eastern white (Pinus strobus), and shortleaf (Pinus echinata) pines. Other species include red maple (Acer rubrum), sassafras (Sassafras albidum), serviceberry (Amelanchier arborea), and American chestnut (Castanea dentata). The understory is dominated by extensive thickets of mountain laurel (Kalmia latifolia). Eastern hemlocks (Tsuga canadensis) grow along the cooler and wetter environments of mountain streams (Mackenzie 1991).

Cove Forest Great Smoky Mountains National Park was established before the lumbering companies could remove all the virgin forest from the remote sheltered coves. Logging proved difficult, so these upland forest, below the 1,372-meter level, were left. These forests are so sheltered from wind, temperature extremes, and other environmental changes that many trees grow to greater sizes than anywhere else in the park. Some species attain record or near - record size; these include basswood (Tilia spp.), yellow-poplar, yellow buckeye (Aesculus octandra), mountain silverbell, eastern hemlock, white ash (Fraxinus americana), sugar maple (Acer saccharum), yellow birch (Betula alleghaniensis), American beech (Fagus grandifolia), northern red oak, black cherry (Prunus serotina), and cucumber trees (Magnolia acuminata) (Mackenzie 1991). Such trees as the yellow-poplar grow to thirty feet in circumference; the hemlock, twenty; the yellow buckeye, nearly sixteen; yellow birch, over fourteen, and sugar maple, more than thirteen. Some individual trees are over 500 year old.

There is often a dense understory of shrubs dominated the heaths. Numerous members of the heath family include: rhododendron (Rhododendron spp.), azalea (Rhododendron calendulaceum), blueberry (Vaccinium corymbosum), dog-hobble (Leucothe cateshaei), spotted wintergreen (Chimaphila maculata), sand myrtle (Leiophyllum buxifolium), trailing arbutus (Epigaea repens). The rosebay rhododendron

(Rhododendron maximum) forms dense thickets in protected ravines. The catawba rhododendron (Rhododendron catawbiense) occupies prominent ridges and balds (Mackenzie 1991).

Coniferous Forest The spruce-fir forest is found above 1,219 m to the highest elevations. This southern boreal forest contains red spruce (Picea rubens), Fraser fir (Abies fraseri), and yellow birch (Mackenzie 1991).

Due to destruction of Fraser fir by balsam woolly adelgid and decline of red spruce in spruce-fir forests, this area is undergoing extensive ecological changes. Most of the mature Fraser fir in the park have already been killed by woolly adelgid. Young Fraser fir are still abundant, but appear to succumb to the insects as they grow older (Nicholas, N.S. 1993, Personal comm.).

The openings created by the death of fir trees are susceptible to invasion by various shrubs, grasses, and forbs. The smooth blackberry (Rubus canadensis) invades in such dense stands that Fraser fir seedlings cannot out-grow the competition and are shaded out. Due to the severity of the climate at these highest altitudes, Fraser firs are the most dominant and abundant of the few species able to survive such harsh conditions. Thus, the combined influence of the balsam woolly adelgid and the smooth blackberry may

forever change the dynamics of succession in this ecosystem (Nicholas, N.S. 1993, Personal comm.).

Fauna

Great Smoky Mountains National Park contains approximately 50 mammals species, 80 reptiles species and amphibians including 22 species of salamanders, 70 species of fish, and 200 species of birds. Like the plants, many populations of animals have adapted to specific elevations in the Smokies. Although some animals, like black bears (Ursus americanus) and chipmunks (Tamias striatus), occupy several habitats, the wildlife populations of the summits differ considerably from those of the lowlands (Linzey and Linzey 1971).

Five indigenous mammal species have been extirpated during the past 200 years. Lost species include: panther (Felis concolor coryi or Felis concolor cougar), gray wolf (Canis lupus lycaon), fisher (Martes pennanti pennanti), bison (Bison bison bison), and elk (Cervus elaphus canadensis) (Linzey and Linzey 1971).

History and Land-use

Prior to the mid-1700's the area now comprising GSMNP was largely uninhabited; however, the Cherokee Indians lived nearby in such communities as Cherokee and along the Little Tennessee River (Linzey and Linzey 1971). Although few

Cherokees lived within park boundaries, their activities must have affected the ecology of the entire area.

During the early 1700's, long hunters invaded the Trans-Appalachian forest. As professional hunters and trappers, they slaughtered thousands of white-tailed deer for eastern American and European tanners who converted the raw skins into leather (Belue 1991).

During the mid- to late-1700's, the ecology of the area began to be altered more extensively when settlers started arriving in greater numbers. Their activities in clearing for homesteads and cultivation marked the beginning of a trend that was not reversed until acquisition of land for the Park commenced in the 1920's (Campbell 1969). Many of these early settlers lived alone in their coves, widely separated from their neighbors. But in places communities grew along water courses and in fertile coves. Oconaluftee and Cades Cove were the first to be settled. The largest concentrations were in Greenbrier Cove and the Sugarland and Cataloochee Valleys. The people of these communities banded together to build schools and churches.

Human habitation of the area increased throughout the nineteenth century, reaching a peak in the early 1900's, when the activities of logging companies drastically altered large tracts of land in a short time. Among the several companies, the Little River Lumber Company and the Champion Fiber Company were the largest operating in the Smokies.

Smokemont, Tremont, and Elkmont were company towns built to house workers. With the felling of the trees, the mountains were devastated by erosion and fire. By the time the Park was dedicated in 1940, it has been estimated that more than two-thirds of the land had been cut over. The remaining "primeval" areas (60,705 ha) were largely confined to the highest elevations, including two large areas - one around Mt. Guyot and the other immediately southwest of Cades Cove (Linzey and Linzey 1971). Geographic Information Systems (GIS) statistics for GSMNP lists 13.9% uncut, 29.04% light cut, 18.16% heavy cut, 22.69% undisturbed, and 16.21% settlements.

The idea for a national park in the Smokies originated in 1923 with Mr. and Mrs. Willis P. Davis. To create a national park in the Smokies, the land would have to be bought. The established boundaries of the park encompassed over 6,000 separate tracts of land, including large ranges owned by 18 timber and pulp companies, more than 1,000 small farms, 5,000 small lots, some of which had summer homes. In 1926, there were 7,300 people living in the proposed park area (Campbell 1969).

By 1934, enough land had been purchased and turned over to the federal government that, on 15 June, the U.S. Congress authorized the full establishment of the park (Campbell 1969). Since that time, the NPS has allowed most of the park's forest to return to an old-growth condition.

CHAPTER III

LITERATURE REVIEW

Food Requirements

Studies relating to food habits of eastern elk are limited and little research has been conducted on elk nutritional needs in general (Devlin and Tzilkowski 1986). Food habits tend to overlap those of all other ungulates. Elk are able to vary their diet on the same area according to season and availability. Food habits of Rocky Mountain elk are variable, as these animals are found among many different vegetation types in the United States and Canada. Elk may prefer to graze, yet large herds are found where browse constitutes a major portion of the diet (Nelson and Leege 1982). Although elk occur in diverse habitats and eat a variety of plant species, they nevertheless exhibit certain preferences on each of their ranges. Forage preferences vary among seasons and years, and appear to be strongly related to forage availability and phenology; these preferences, in turn, are influenced by weather conditions (Nelson and Leege 1982).

Western Elk Diets

Winter diet of elk is strongly influenced by forage

availability, as affected by snow conditions. Elk move to ranges where snow depth is minimal, and exist there on available forage. On predominantly grass ranges in Montana, elk primarily eat grass (Nelson et and Leege 1982). On winter shrub ranges in northern Idaho, the majority of the diet is woody plants (Nelson and Leege 1982). Where both grasses and shrubs are available, elk usually prefer grasses. Compared to foliage and browse, grasses, while adequate in protein, are relatively poor in calcium and phosphates. When grasses become less available due to utilization and/or deep snow, shrubs become more prominent in the diet of elk (Claar 1973, Singer 1975). When snow depth further limits availability of shrubs, elk increase consumption of conifers (Hash 1973). Arboreal lichens comprise a portion of the diet when elk winter in mature conifer forests (Bohne 1974, Hash 1973).

Grasses and shrubs constitute >50% of the winter diet of western elk. The diet of Roosevelt elk in Oregon and White River elk in Colorado consists of 56% browse (Harper 1971, Boyd 1970). Browse constituted 92% of elk diet in the Lochsa River area of Idaho (Hash 1973). However, grass may constitute 65-100% of the winter diet on grassland ranges (Rognrud and Janson 1971). In winter, elk subsist on all available forage types. However, woody browse is commonly the major source of forage available to elk (Parker 1990).

The spring diet reflects a transition from winter to summer foods, with grasses often being most preferred (Winkler 1985). As summer nears, forbs are preferred, although leaves and browse species may be readily consumed. Fall diet often reverts to predominately grass and browse. Elk tend to utilize open grassy habitats in spring and fall (Winkler 1985). The main sources of summer forage are forbs, woody twig growth, leaves, and warm season grasses (if available) (Winkler 1985).

Eastern Elk Diets

Elk herds in the Northeast use open areas during late spring and mid-fall in order to take advantage of the availability of cool season grasses (Beyer 1987, Devlin and Tzilkowski 1986, Drake 1985, and Parker 1990). However, elk in the Southeast might use openings in the early spring and late fall due to an earlier spring and a later fall. Beyer (1987) indicated that elk in Michigan used open areas 26% of the time in spring and 22% in fall. Summer and winter use of open areas was only 6% and 9%, respectively. Devlin and Tzilkowski (1986) found that grasses found in open areas comprised 85% of the late spring diet of elk in Pennsylvania.

Whereas bison, antelope and horses have adapted to open plains and life in big herds, such is not the case with cervids. Deer species are tied closely to woody and

herbaceous vegetation, which excludes them from grassy steppes and deserts but not tundra (Geist 1991). The reason is probably the inordinate requirement deer have for minerals for antler growth. Elk cannot eat enough grass to grow normal antlers (Geist 1991).

An elk herd in Missouri was confined in a 960 ha oak-hickory forest with only approximately 10 percent of the area in grassy clearings. Acorns and grass were found to be the most preferred foods in the fall diet (Murphy 1963). Similar observations of fall diet were reported from the Arkansas elk range (Cartwright, M. 1993, Personal comm. and Francis, T. 1993, Personal comm.).

In Missouri, the October-November diet consisted of acorns of at least 4 species and accounted for 50% of the total volume. Grasses of 8 species were identified and constituted 37% of the total volume. Most common were small crabgrass (Digitatia ischaemum), crabgrass (D. sanguinalis), and cheatgrass (Bromus spp.). Coralberry (Symphoricarpos orbiculatus), Korean lespedeza (Lespedeza stipulacea), and aster (Aster spp.) were other important foods, constituting 6, 2, and 2%, respectively, of the total volume (Table 1). The above mentioned foods made up 97% of the total volume with forbs of 31 species and a small amount of twig browse composing the remainder. The degree of utilization indicated that the population density (one elk per 9.3 ha) was near the carrying capacity of the range (Murphy 1963).

Late summer and fall are critical periods for deer and elk because of the need to accumulate body fat for winter survival (Mautz 1978). In Pennsylvania, grass use by elk was highest in late spring and mid-fall (Devlin and Tzilkowski 1986). Cool-season grasses are those species adapted to rapid growth during the cool moist periods of the year and are usually dormant during hot weather.

Hunter et al. (1979) indicated the current season's growth of woody plants was an important source of food for elk in Pennsylvania during winter. The most heavily used plants in Pennsylvania were: aspen (Populus grandidentata and P. tremuloides), fire cherry (Prunus pennsylvanica), black cherry (Prunus serotina), red maple (Acer rubrum), white oak (Quercus alba), juneberry (Amelanchier arborea), sassafras (Sasafras albidum), witch hazel (Hamamelis virginiana), and blackberry (Rubus allegheniensis) (Table 1). In Pennsylvania, red maple and aspen were major components of the winter diet and beech (Fagus grandifolia) and sweet fern (Comptonia peregrina) were not preferred by elk (Hunter et al. 1979).

The most intensive browsing of woody plants occurred in open cover types where current growth of woody plants was vigorous and available (Hunter et al. 1979). The dense stands of large sapling-sized aspen were of little value to elk as a source of winter food. Stand density might have

been a psychological or physical deterrent to feeding. Open areas were possibly preferred over the dense aspen stands due to ease of movement and better visibility (Hunter et al. 1979). The low use of dense stands by elk was consistent with findings in Michigan, where Spiegel et al. (1963) noted that elk avoided dense pole stands. Elk sign disappeared as stand density per 0.4 ha approached 1,000 trees of 2.54 cm d.b.h. or more.

Preferred spring food species in Virginia included: black locust (Robinia pseudoacacia), scarlet oak (Quercus coccinea), wild cherry (Prunus spp.), sassafras (Sassafras albidum), wintergreen (Gaultheria procumbens),and galax (Galax aphylla). The summer food species most utilized was New Jersy tea (Ceanothus americanus). Preferred fall foods included: grasses (poaceae), New Jersy tea (Ceanothus americanus), galax (Galax aphylla), wintergreen (Gaulteria procumbens), oak (Quercus spp.), blueberry (Vaccinium spp.), gill fungus (Agaricaceae spp.), huckleberry (Gayluacia spp.), sourwood (Oxydendrum arboreum), pokeberry (Phytolacca decandra), and greenbrier (Smilax spp.). Preferred winter foods were wintergreen (Gaultheria procumbens) and galax (Galax aphylla) (Baldwin and Patton 1938) (Table 1).

In Michigan, elk tended to utilize all classes of available forage, but were especially attracted to new herbaceous growth in spring and fall (Moran 1973). Of 22 woody plant species identified in early winter rumens, White

cedar (Thuja occidentalis), wintergreen (Gaultheria procumbens), and eastern hemlock (Tsuga canadensis) were most frequent (Table 1). There was a pronounced shift in forage class consumption associated with weather and snow cover. Bark-stripping was a common winter feeding habit leaving permanent scars over heavily occupied elk range. Bark-stripping and browsing retarded woody succession in some areas, while increasing and prolonging available browse (Moran 1973).

Woody plants comprise the bulk of the diet of Michigan elk in winter (Siegel et al. 1963). Preferred species were red and sugar maple (Acer saccharum), juneberry, basswood (Tilia americana) (browsed and barked), and several species of cherry, willow and young aspen, (browsed) (Table 1).

Arkansas has extensive amounts of open areas dispersed throughout the elk range and thus, reported little or no effect on plant succession (Cartwright, M. 1993, Personal comm. and Francis, T. 1993, Personal. comm.).

Table 1. Preferred foods of elk in eastern herds.

Season	Herd	Food Item
Fall	Arkansas	Acorns
	Missouri	Acorns
		Small crabgrass
		Crabgrass
		Cheat
		Coralberry
		Korean lespedeza
		Aster
	Pennsylvania	Fescues
		Bromegrasses
		Bluegrasses
		Wheatgrasses
		Canarygrasses
	Virginia	Grasses
		New Jersey tea
		Galax
		Wintergreen
		Oak
		Blueberry
		Gill fungus
		Huckleberry
		Sourwood
		Pokeberry
		Green brier
Winter	Michigan	White cedar
		Wintergreen
		Eastern hemlock
		Red maple
		Sugar maple
		Juneberry
		Basswood
		Cherries
		Willows
		Aspen (young)
	Pennsylvania	Aspen
		Fire cherry
		Black cherry
		Red maple
		White oak
		Juneberry
		Sassafras
		Witch hazel

Table 1 Continued.

Season	Herd	Food Item
		Blackberry
		Oaks
Winter	Virginia	Wintergreen
		Galax
		Pine
Spring	Pennsylvania	Fescues (Festuca spp.)
		Bromegrass (Bromus spp.)
		Bluegrass (Poa spp.)
		Wheatgrass (Agropyron spp.)
		Canarygrass (Phalaris spp.)
	Virginia	Black locust
		Scarlet oak
		Wild cherry
		Sassafras
		Wintergreen
		Galax
Summer	Virginia	New Jersey tea

Water Requirements

The extent to which elk are dependant on free water is difficult to assess, even experimentally. There is sufficient research, however, to indicate that lactating females probably have seasonal dependency on water (Marcum 1975, Miller 1974, Thomas et al. 1976). Rocky Mountain elk distribution was limited to within 805 m of water (Nelson and Burnell 1975). Elk use of summer range was curtailed severely beyond 805 m from water (Nelson and Burnell 1975, Mackie 1970).

Cover Requirements

While food variety is a criterion for determining elk use of an area, cover is a more important factor (Davis 1977). Optimal cover provides the benefits of both thermal and hiding cover and forage during periods when food in other areas is unavailable due to weather or human disturbance (Wisdom et al. 1986).

Thermal cover is a feature of habitat that provides elk protection against adverse weather - either extremely high or low temperatures. Thermal cover can be a timber stand with overstory for protection against winter cold and summer heat or it can be a topographic feature, such as a small basin situated to afford protection from chilling winds (Skovlin 1982).

In Michigan, winter range that has a winter cover suitability (thermal) of 1.0 on at least 10% of the area is considered optimal elk habitat (Beyer 1987). Thermal cover is a forest stand $\geq$12.2 m in height with tree canopy cover of $\geq$70%; this is achieved in many closed sapling-pole stands and by all older stands unless the canopy cover is reduced below 70%.

Hiding cover is not defined in terms of stand structure. Any vegetation capable of hiding 90% of a standing adult deer or elk at $\leq$61 m qualifies as hiding cover (Thomas et al. 1979).

Area Requirements

Elk were extirpated from GSMNP more than 150 years ago, thus, seasonal habitat use is unknown. Although western elk may migrate 64.5 km to 96.8 km annually, reintroduced eastern herds are nonmigratory and exhibit little seasonal movement (Adams 1982).

The size of home ranges for elk varied depending on habitat and season. In Michigan, average winter home range covered 30.2 km^2; mean home range of males in rut was 53.8 km^2 and non-rut was 94.0 km^2. Cows during rut averaged 27.1 km^2 and non-rut was 64.4 km^2 (Beyer 1987).

In Pennsylvania, male elk ranged over 27.2 km^2 to 86.8 km^2 and averaged 53 km^2. Areas used by females ranged from 6.5 km^2 to 44 km^2 and averaged 17.5 km^2. Distances across the home range varied from 8.8 km to 20.8 km and averaged 16.3 km for males, and 4.8 km to 12.8 km for females, with an average of 6.8 km. The average distance traveled between sightings was 8.3 km for males and 3.6 km for cows. The largest single movement was 19.2 km (Cogan 1987). Study of range expansion in New Zealand revealed that elk populations expanded their range by an average of 805 m per year (Caughley 1963).

Van Manen (1991) defined minimum area requirement (MAR) as follows: the minimum contiguous area of habitat needed for a species to successfully live and reproduce. Witmer and Cogan (1989) credited the success of the Michigan herd

to the large size of the management area (1,554 km^2). They further suggested the failure of the Pennsylvania elk herd to expand beyond 150 animals was due, in part, to efforts to restrict the herd to 518 km^2. According to Witmer and Cogan (1989), one key component for a successful reintroduction is a management area of adequate size (518+ km^2). The MAR depends on two basic factors: 1) minimum viable population size (MVP); and 2) population density in study area, as a function of habitat quality (Van Manen 1991).

The minimum viable population (MVP) is defined as the threshold number of individuals necessary to ensure the persistence of a subpopulation in a viable state for a period of several hundred years (Smith 1992). Conservation geneticists consider a minimum viable population to be around 500 individuals with an absolute minimum of 50. Any smaller populations are subject to serious genetic drift and loss of genetic variability needed to track environmental changes (Smith 1992). Griffith et al. (1989) found 20-40 animals were adequate for the re-establishment of a native game species. A minimum of 20 elk comprise founder populations of translocated Tule elk in California. The optimal number of elk for reintroduction is 50 (Parker 1990). Whitmer (1989) listed adequate numbers (20+) of animals released as one of the key components of a successful release.

Self sustaining populations most often result from translocations in which the number of founders is large. Griffith et al. (1989), in a review of species translocations, found that successful translocations release more animals than unsuccessful translocations. The study suggest 15 and 75 as the minimum numbers of male and female elk needed to avoid inbreeding. Inbreeding can result in loss of genetic heterozygosity, and thus vigor. The study further recommended 150-750 as the number of elk to avoid genetic drift and loss of rare alleles.

Southern deciduous forests may have greater carrying capacity than northern boreal forest. The density of Michigan elk, 20 years after reintroduction (1930), was estimated at approximately 1.16 elk/km^2 with 300-400 elk inhabiting 310-350 km^2 (Shapton, 1940). By 1958, the density increased to 1.2 to 1.6 elk/km^2 with 900-1,000 animals occupying 1,000 km^2 of available habitat (Moran 1973). The winter survey of 1990 revealed 0.8 elk/km^2 estimated population with 918 elk on 750 km^2 of prime range (1,500 km^2) (Parker 1990).

The carrying capacity of Riding Mountain National Park, Manitoba, was believed to be 2 elk/km^2. Densities of.8-1.6 elk/km^2 have been maintained since 1950, following an eruptive phase of the 1940's in which a high of 4 elk/km^2 was reached (Blood 1966).

Murphy (1963) found that a group of elk in Missouri, confined by an 2.4 m high chain-link fence to a 960 ha oak-hickory forest with approximately 10 percent of the area in grassy clearings, had a population density of one elk per 9.3 ha or 11 elk/km^2. Utilization indicated this density was near the carrying capacity of the range (Murphy 1963).

Special considerations

Slope. In western elk populations, due to ease of accessibility, a slope of 0-30 percent (0- 27 degrees) receives heavy use, 30-60 (27- 54 degrees) percent moderate use, and 60-90 percent (54-81 degrees) little use. Greater than 90 percent (81 degrees) receives practically no use (Edge et al. 1987, Skovlin 1982) (Table 8, Appendix A).

Elevation. In males, 1 cal of heat is liberated for every calorie stored as fat. Thus, formation of body fat for winter survival is energetically expensive. In mountainous habitats, the cooler temperatures of higher elevations dissipate large amounts of body heat for elk (Geist 1982). On western Montana winter range, elk generally preferred upper, middle, and lower slopes, in decreasing order (Beal 1974). Elk tended to prefer upper slopes regardless of season (Skovlin 1982).

In general, high altitude forage has less fiber and is more digestible than plants growing in lower altitudes (Nelson and Leege 1982). As altitude increases, the

quantity and quality of the forest shrub and forb layers improves accordingly. The abundant and highly digestible high-altitude vegetation permits high food intake and rapid digestion (Nelson and Leege 1982).

Road Density and Human Disturbance. Consideration of road density and human disturbance applies only in areas where elk are hunted or poached in significant numbers. For unhunted herds of elk, vehicular traffic does not seem to be a source of disturbance (Wisdom et al. 1986). Unhunted elk in Rocky Mountain National Park were very visible and disturbed little, if any, by normal on-road visitor activities (Schultz and Bailey 1978). Elk, in roadless areas, usually moved out of open areas when approached by people. However, harassing elk in 2 meadows on alternate weeks during winter and spring did not affect their distribution or observability on winter ranges. Wisdom et al. (1986) indicated that, in such areas, habitat effectiveness as influenced by roads would remain at an optimum level (1.0 SI value) when conducting an evaluation.

Human activity such as cross-country skiing and snowshoeing probably does not negatively impact elk. Elk in Alberta were not significantly influenced by cross-country skiing. However, elk did tend to move away from areas near heavily used trails during the ski season (Ferguson and Keith, 1982).

Elk in Montana tended to stay 457 - 914 m from logging activity, but moved into logging areas during nonactive periods (Edge and Marcum 1985). Elk may become habituated to logging activity that occurs over a long period of time (Beall 1976).

In hunted populations, elk usually maintain an 805 m buffer zone between the herd and roads or human disturbance areas (Ward 1976). Lyon (1983) rated the effect of road density in hunted populations (Table 9, Appendix A).

Agricultural Damage. In Michigan, there were only a few instances reported in which serious crop damage occurred; these sites usually bordered on heavily used summer elk range (Moran 1973). A present, Michigan farmers cite damage most often to alfalfa, beans, and corn. No record of estimated lost value of crops is kept in Michigan (Parker 1990).

The agricultural areas on the fringe of elk range in Michigan are heavily hunted. The area between the elk range and agricultural areas is known as "the X-zone". Managers strive to remove all elk from this area during the annual hunting season. A special October hunt to reduce elk in the agricultural areas was initiated, in addition to the regular December season. Hunting permits for this special hunt are awarded by lottery (Parker 1990).

In Pennsylvania, elk found better foraging opportunities on private land than public land (Witmer and Cogan 1989). Only 2% of open areas were found on public land, whereas 15-20% of private land was in an open condition. Corn, hay, and oats were the most commonly damaged crops. Fence damage was also occasionally reported (Parker 1990). Recently, crop damage was almost eliminated by fencing key row cropped fields (Cogan, R. 1995, Personal Comm.). In Arkansas, "To date, no serious depredation or nuisance problems have been documented" (Cartwright 1991). Although much of the Arkansas range is located on private property, this absence of depredation is due, in part, to the lack of row crops grown in the area.

Mortality Factors

Arkansas has documented a total of 31 elk mortalities since 1981. From carcasses retrieved, poaching accounted for 11 (35.5%); 5 (16.2%) were attributed to traumatic injuries with most occurring immediately following stocking, 5 (16.2%) to meningeal worm infections, 3 (9.7%) to leptospirosis, 6 (19.4%) to unknown causes and 1 (3.0%) to road kill (Cartwright 1991).

Pennsylvania's overall losses of non-hunted elk average 11%/year. Of this, 1%/year was attributed to the brainworm *P. tenuis*, poaching = 3%/year, crop damage kills = 3%/year,

and other diseases, dog kills, vehicle kills and winterkills = 4%/year combined (Parker 1990).

Michigan had mortality rates of 30-46% for 1963-65. Mortality for the early pregnancy to 0.5 year interval ranged from 18-26%; age class 0.5 to 1.5 ranged from 12-20%. Major sources of mortality prior to the advent of legal hunting included: 1) illegal shooting, 2) disease, 3) car or train collision and 4) malnutrition of small calves (Parker 1990).

Predation. In Idaho, Schlegl (1976) working with radio-collared calves of less than one week of age found that about half were killed, mainly by black bears, in the first two - three weeks of life. Predation stopped after cows and calves began grouping when calves reached two to three weeks of age. However, the study area was later found to contain an unusually high density of bears (Taber et al. 1982).

Poaching. Poaching of elk contributed to substantial reduction in the Michigan elk herd during the 1960's and herd growth in Pennsylvania seemed to be limited by illegal shooting. Law enforcement programs, including stiff fines and penalties, and an active public information and education campaign have successfully reduced poaching losses in Michigan (Parker 1990).

Disease. Diseases and parasites are a major concern for reintroduction. At least four major diseases of elk should be considered in this assessment: neurologic disease attributed to Parelaphostrongylus tenuis, leptospirosis, brucellosis and bovine tuberculosis. Two diseases and one parasite of secondary importance may also be a factor: anaplasmosis, hemorrhagic disease, and the large liver fluke (Fascioloides magna) (Appendix B-1).

Neurologic Disease. Neurologic disease is probably the most detrimental disease considered in an eastern reintroduction project. Historic evidence indicates P. tenuis may make such an reintroduction impossible (Greer et al. 1982). However, recent research indicates different conclusions (Cartwright 1991, Cartwright M., 1993, Personal Comm., Cogan, R. 1995, Personal Comm., Parker 1990, Raskevitz 1984, Samuel et al. 1992, and Woolf et al. 1977).

According to Anderson (1972), the neurotropic parasite P. tenuis (meningeal worm) is a nematode that infects white-tailed deer. P. tenuis causes little clinical disease in it's normal host, the white-tailed deer. However, P. tenuis larvae migrating through the central nervous system of other ungulates, such as elk, moose (Alces alces), caribou (Rangifer tarandus), fallow deer (Dama dama), mule and black-tailed deer (Odocoileus hemionus), resulting in pathologic lesions so severe that death usually results. In

ungulates that are considered abnormal hosts, clinical disease occurs from abnormal migration of larvae through the spinal cord of infected animals. P. tenuis is enzootic in the deciduous forest biome and deciduous - coniferous forest ecotone of eastern North America and common as far west as Saskatchewan, Canada, and eastern Oklahoma. Pre-colonial distribution of P. tenuis is not known (Anderson and Prestwood 1981). However, Brickell 1737 indicated that elk in western North Carolina were "subject to Epilepsy or falling sickness". This passage might indicate indigenous eastern elk were subject to neurologic disease resulting from P. tenuis infection as early as 1737. Despite such infections, he wrote that elk were plentiful "in or near the mountains". Transmission of the parasite is dependent upon availability of terrestrial gastropods of suitable species, which may impose a barrier to the spread of P. tenuis in the areas where proper gastropod hosts are not found (Raskevitz, 1984).

There are obvious important disease implications for elk where they share range with white-tailed deer. Observed signs of neurologic disease include: staggering, circling, listlessness, exclusion from herd, and tolerance of man (Olsen and Woolf 1978). The current status regarding the significance of P. tenuis in elk is unclear. In two other cervid species, woodland caribou and moose, the parasite is highly pathogenic. However, elk appear more tolerant than

caribou or moose (Parker 1990). There is speculation that the parasite may be refractory in elk - it causes the problem but does not necessarily cause death. Experimental infection of elk has resulted in eggs of the parasite being passed, with only mild clinical disease produced. A P. tenuis prevalence level of 64% has been recorded in some elk populations that share range with white-tailed deer, indicating that the presence of the parasite in elk is not always fatal (Woolf et al. 1977).

In a study in Alberta, twenty-six elk calves were exposed to 15-300 infective larvae of meningeal worm. All 13 elk exposed to $\geq$125 larvae developed neurologic disease and died: 2 shed larvae in feces prior to death, meningeal worm established infection in all 8 elk exposed to 25 or 75 larvae: 6 calves developed neurological signs (4 recovered, 2 died), the remaining 2 elk did not exhibit any clinical signs. Seven elk given 25 or 75 larvae shed larvae in feces. None of 5 elk exposed to 15 larvae developed clinical neurological signs or shed larvae (Samuel et al. 1992).

Raskevitz (1984) studied habitat use by deer and elk on sympatric range enzootic for P. tenuis in Oklahoma. The purpose was to determine infection rates of gastropods on an Oklahoma range with 80-100% of deer infected. A similar infection rate for parts of eastern Tennessee near the GSMNP was found (Comer et al. 1991). The presence of first stage P. tenuis larvae in feces were determined using the Baermann

technique. Gastropods were collected and digested in pepsin to determine the presence of second and third stage P. tenuis larvae. Gastropods collected from herbaceous vegetation had an infection ratio of 0.03 larvae/gastropods.

These papers indicate that an elk would need to ingest large numbers of gastropods to develop fatal infections: 500 ingested gastropods would result in 0% loss, 833-2,500 gastropods would produce 25% losses, and 4,167 and higher would produce 100% fatal infections. Samuel et al. (1992) states, "The ability to survive exposure to small numbers of meningeal worms may explain the persistence of the few remnant populations of elk in eastern North America".

Michigan DNR reports approximately 1% of Michigan elk die from P. tenuis infection annually. Pennsylvania also reports that neurologic disease due to P. tenuis takes an annual toll of 1%/year (Parker 1990 and Cogan R. 1995, Personal Comm.). Similar mortality rates were reported from P. tenuis in Arkansas. Five deaths from P. tenuis were documented, from 1981 to 1991, from a herd of 150-200 animals (Cartwright 1991 and Cartwright, M. 1993, Personal Comm.). Some elk populations are reported to have been limited by this parasite. In a captive elk population in Pennsylvania 52% of male and 68% of female elk examined were found to possess histologic lesions; the elk and deer population densities of this area were 12.5-25/km^2 and 475/km^2, respectively. This suggests that, while neurologic

disease did not cause rapid declines in the herd, it did have a limiting effect on the population (Olsen and Woolf 1978). As indicated above, losses of Michigan elk, which share range with high numbers of deer average only a 1% loss per year. Data establishing the percentage of elk lost to P. tenuis were baised on limited sample sizes.

Brucellosis. Brucella abortus is the most common bacterial species causing brucellosis, or Bang's disease, in bison, cattle, and elk. Brucellosis is characterized by abortion and infertility in cattle herds.

Brucellosis is a contagious disease, however, most infected animals develop antibodies in the bloodstream which persist for variable periods of time. Although, abortion does occur, it is usually limited to the first calf after contracting the disease. Infected animals shed organisms from the mouth, through milk, during breeding, and in birth fluids at the time of parturition. Transmission of the bacteria usually occurs by mouth, contamination of eyes or wounds, or during genital contact (Kistner et al. 1982).

Bovine brucellosis is the subject of a cooperative state-federal Brucellosis Eradication Program which, since it's start in 1934, has reduced the occurrence of brucellosis in cattle to less than 0.5% nationwide (Davidson and Nettles 1988). There is no practical treatment for brucellosis in domestic and wild animals. In domestic

animals, elimination of infected animals and vaccination of noninfected animals are the only practical controls at present. Brucellosis persists in the bison and elk herds in Yellowstone (Kistner et al. 1982).

The GSMNP does not contain B. abortus at this time (Wathen and New, 1989). Tennessee state records indicate the park has been brucellosis-free since the disease was eradicated in the Cades Cove cattle herd in 1972.

Bovine Tuberculosis. Bovine Tuberculosis (TB) (Mycobacterium bovis) has been reported in Rocky Mountain elk, bison, and moose under semi-wild conditions. TB is still found occasionally in the United States despite more than 50 years of effort devoted to eradication. TB is foundprimarily in cattle, but bison appear quite susceptible and probably are capable of serving as reservoirs. Research has shown that cervids native to the United States are less susceptible than cattle. However, when cervids are infected they frequently succumb to a rapidly progressive infection; TB is probably self-limiting in native deer and elk (Kistner et al. 1982).

In the fall of 1990, Canadian authorities found game farm elk shipped from Montana to Alberta to have severe infections of TB. Investigation in Canada and the United States uncovered a web of animal movements and many elk, fallow deer, red deer, llama, and cattle with confirmed or

suspected infection. Canadian authorities have identified fourteen known infected herds in the provinces of Alberta, Saskatchewan, and Ontario. The United States has had 23 elk and deer herds confirmed positive for TB in 13 states (Doster 1993).

Infection from TB in free-ranging native elk has not been detected. The National Bovine Tuberculosis Eradication Program applies only to cattle and bison, at present. Federal authority does not exist for cervidae, and therefore, each state must apply their existing regulations individually. A standardized improved skin test for TB in cervidae now exists (Doster 1991). At present, TB has not been detected in deer or swine in southeastern United States (Davidson and Nettles 1988).

CHAPTER IV

METHODS

HSI Model

Standards for the Development of Habitat Suitability Index Models (USFWS 1981) was published, as part of Habitat Evaluation Procedures (HEP), to serve as a manual for the development of an HSI. Measurements of habitat quantity and quantity are combined to compute habitat units using the following equation (USFWS 1981):

Habitat Units (HU) = Habitat quality (HSI) x Habitat area

The habitat area is the total area of all cover types that are used, or could be used by the target species (USFWS 1981).

The Habitat Suitability Index (HSI) is defined as a numerical index that represents the capacity of a given habitat to support a selected species (USFWS 1981). The model is based on the measurements of habitat variables to standardize habitat quality. The HSI is determined by combining various Suitability Index (SI) values for habitat variables. SI values represent the ratio of a value of interest divided by a standard of comparison. The value of interest is the measured habitat condition of the variable

and the standard of comparison is the optimal habitat condition for the same variable (USFWS 1981). The SI and HSI are defined as values between 0 and 1.0, with 1.0 representing optimal habitat and 0 representing totally unsuitable habitat (USFWS 1981). A direct linear relationship is assumed to exist between the HSI value and carrying capacity; a unit change in HSI corresponds to a unit change in carrying capacity (USFWS 1981).

The present study: 1) developed an HSI for the evaluation of elk habitat in the Southeast, 2) identified weak habitat components which can be managed to increase habitat quality in the future, 3) minimized financial risk, and 4) provided the basis for an experimental release protocol.

There are two existing Habitat Suitability Index Models for elk. One model was developed to evaluate habitat in the Michigan elk range (Beyer 1987), and another to evaluate elk habitat in western Oregon (Wisdom et al. 1986).

Geographic Area. The geographic area of model applicability included the entire GSMNP. The study area encompassess 2,072 km^2 of eastern wilderness surrounded on three sides by an additional 12,432 km^2 of national forests.

The larger the desired area of geographic applicability, the more difficult it is to construct a model that yields consistently reliable results. To increase

homogeneity, the study area was divided into 10 forest types, after combining some of the 13 forest types listed in the GIS data base for GSMNP (Mackenzie 1991) (Table 2).

Cover Types. The study area contained 10 different vegetation types and water. The vegetation map of GSMNP, based on Landsat Thermatic Mapper data, revealed the percentage of vegetation types covering the park's 202,350 ha (Table 2; MacKenzie 1991).

These areas were further subdivided into "open areas" and "forested areas". Due to destruction of Fraser fir (Abies fraseri) by balsam woolly adelgid (Adelges piceae) and decline of red spruce (Picea rubens) in spruce-fir forest, this cover type was considered open area (less than 60% canopy closure). The spruce-fir forest, grassy balds, treeless areas, and grape thickets were classified as open areas (3.19%). All other cover types, excluding water (0.88%), were classified as forested areas (95.93%).

Season. This model was developed to evaluate year-round habitat requirements of elk.

Verification Level

The HSI Model was developed to evaluate the potential for reintroduction of elk into Great Smoky Mountains National Park. The variables and graphs identified in this

Table 2. Vegetation types and percentages for Great Smoky Mountains National Park.

	Vegetation type	Percentage
*	Spruce-Fir	2.32
	Northern Hardwood	9.41
	Cove Hardwood	33.43
	Mesic Oak	10.28
	Mixed Mesic	15.96
	Tulip Poplar	2.66
	Xeric Oak	10.02
	Pine-Oak	2.44
	Pine	11.17
**	Heath Bald	0.58
*	Grassy Bald	0.03
*	Grape Thicket	0.16
*	Treeless (grass & ect.)	0.68
	Water	0.88
		100.00
	Total open area	3.19
	Total forested area	95.93
	Total water area	0.88
		100.00

* Combined as open areas ** Combined with forested area

model are the result of: 1) a literature review; 2) field tours; 3) interagency discussions; and 4) on-site data collection and evaluation.

1) A literature review was completed during September 1992 to March 1993 and consisted of gathering all pertinent information related to elk reintroduction in the Southeast. Sources included: refereed professional journals, theses and dissertations, books, federal and state agency reports, symposium proceedings, agency newsletters, and others.

2) Field tours and 3) interagency discussions included trips to Arkansas and Pennsylvania to observe existing eastern herds of elk. Discussions were conducted with biologist Mike Cartwright, Arkansas Game and Fish Commission (1991); Tim Frances, National Park Service, Buffalo National River (1991); and Rawley Cogan, Pennsylvania Game Commission (1993). Questions for discussion were prepared in advance and included the following:

1. Is the habitat and climate of the elk ranges in Arkansas and Pennsylvania comparable to that of GSMNP?
2. What are their long and short term goals for elk?
3. Why was Arkansas' first reintroduction attempt, in 1933, unsuccessful?
4. How were successful reintroductions conducted?
5. How have elk dispersed and increased their range since reintroduction?

6. What seasonal habitat use patterns and food sources have been observed?
7. What is the present population size and density?
8. What is the potential for future herd expansion?
9. What are the major mortality factors?
10. What is the known percentage of annual loss to P. tenuis?
11. What disease testing was used before reintroduction?
12. What field research has been conducted on elk and their range?
13. What are public attitudes concerning elk in the area surrounding the elk range?
14. Is crop damage a problem on private land near the elk range?
15. Are there future plans for hunting elk?

Variables regarding habitat evaluation were the result of discussions and classes with University of Tennessee staff including: Dr. Michael R. Pelton, Dr. S.E. Schlarbaum, Dr. David A. Buehler, and Dr. Frank T. Van Manen from the Department of Forestry, Wildlife, and Fisheries and Dr. Joseph D. Clark of the National Biological Service Unit. Discussions concerning disease implications for elk in GSMNP were conducted with Dr. John New of the University of Tennessee College of Veterinary Medicine. 4) On-site data

collection and evaluation consisted of information taken from 100 sample plots within the study area. This model has not been verified with field data from elk populations in southeastern United States.

Model Assumptions

The following assumptions were necessary to implement this HSI model: 1) the HSI value is linearly related to carrying capacity; 2) the habitat variable curves represent actual species-habitat relationships; 3) where habitat variables are not independent of one another, relationships can be described through mathematical equations; 4) stated mathematical relationships are correct; and 5) the entire model is used to evaluate the area (USFWS 1981 and Van Manen 1991).

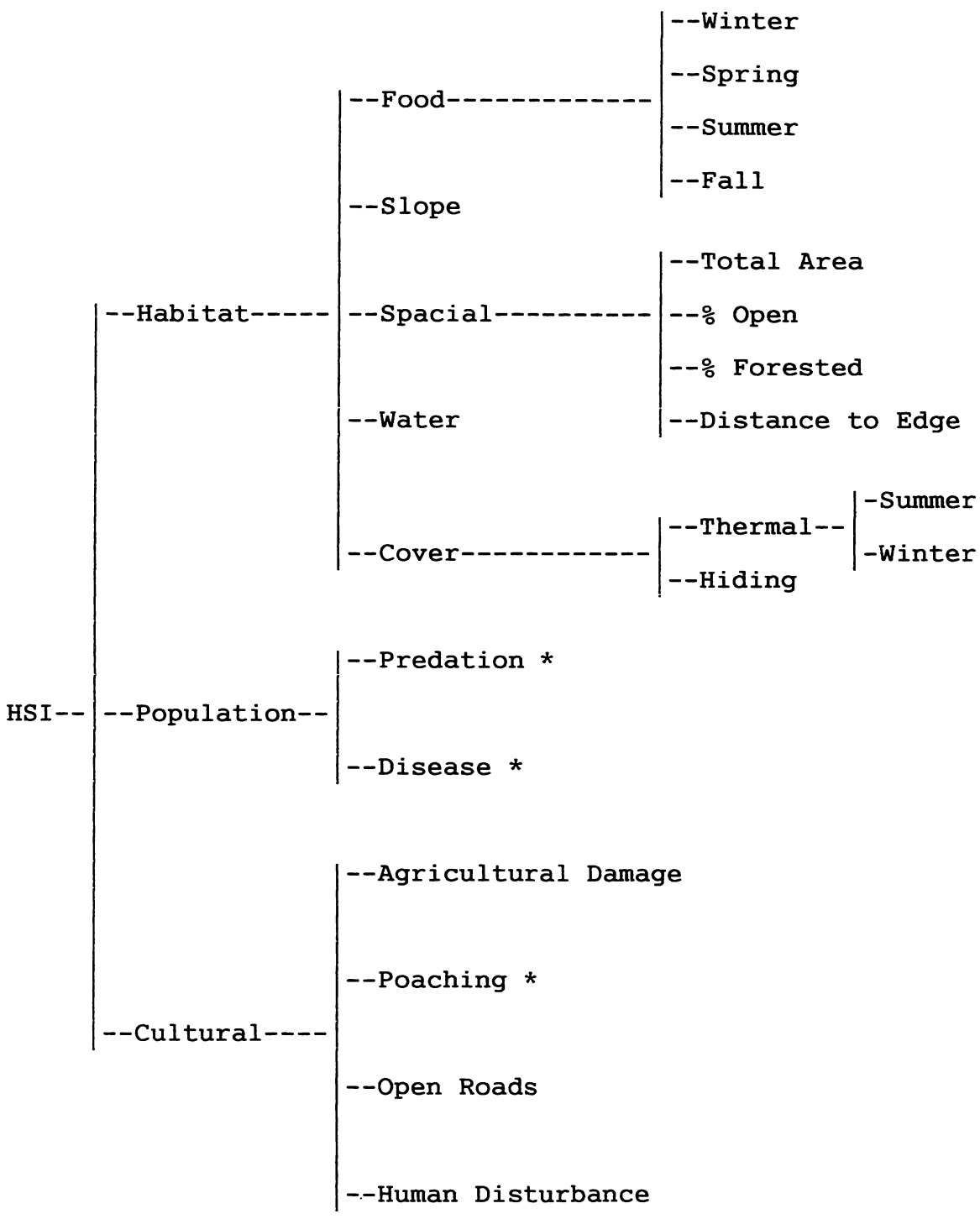
MODEL DESCRIPTION

Variables used in the development of this HSI were derived from personal communication with experts and a literature review of elk habitat research with special emphasis on studies dealing with eastern herds. Habitat studies conducted in eastern states were of special interest because these areas are geographically closer and contain habitat most similar to that of GSMNP. In the southern Appalachian region, the suitability of an area as elk habitat is a function of area size, temporal and spacial

distribution of food and cover, topographical features, and protection from human impacts (Figure 5). Adequate habitat size (518 km^2) was determined as a prerequisite for evaluation (Figure 6; Witmer and Cogan 1989).

The model was subdivided into forest area and open area, each having a separate set of variables. Forested compartments were further divided according to forest type. HSI values for the different variables can be determined for each cover type. HSI values will facilitate recognizing the suitable habitat versus unsuitable areas within the evaluation area. Habitat improvements can be directed to less suitable areas.

The model for forested area was based on the evaluation of three variables associated with food and water, one to evaluate cover requirements, one related to topography, one related to interspersion of cover types, and three related to human influences. The model for open areas was based on the evaluation of two variables for food and water, one related to cover, one associated with topography, and three related to human influences. When this HSI model is used to evaluate other potential elk reintroductions in the Southeast, all variables will not apply to any one evaluation area. The evaluator should choose only those variables deemed critical to that area. When certain needs are obviously met in great abundance, those variables can be eliminated from the evaluation to simplify the procedure.



* Not measurable within the scope of an HSI.

Figure 5. Identification of variables for elk Habitat Suitability Index model and feasibility study for Great Smoky Mountains National Park, using a tree diagram.

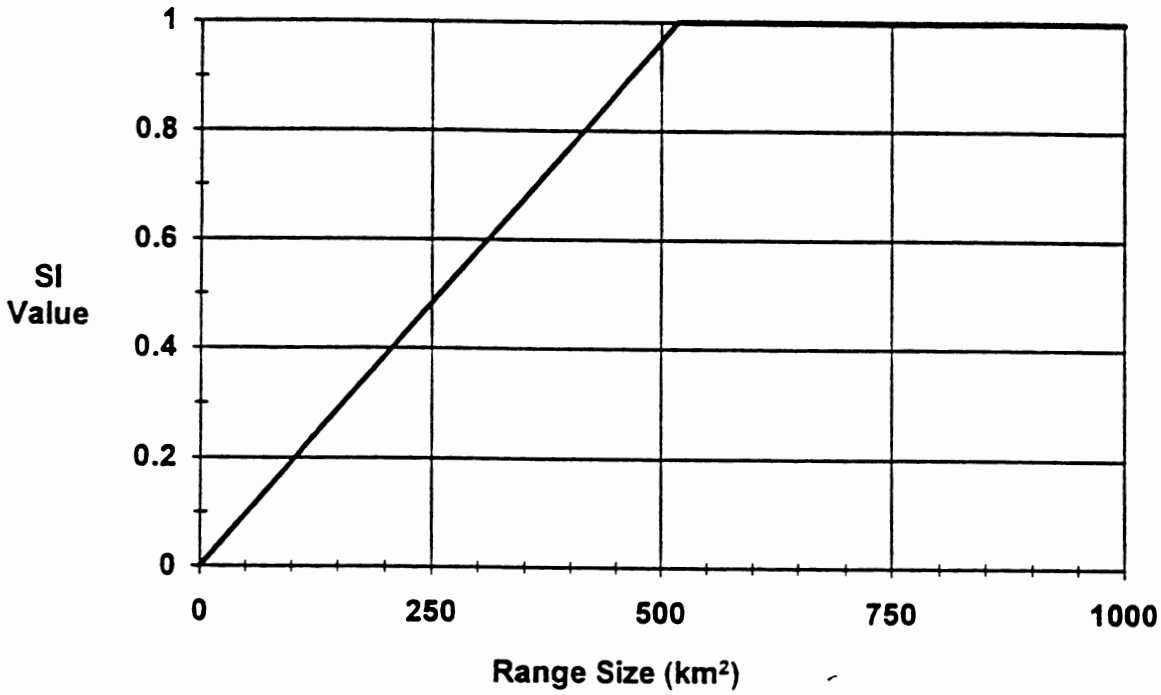


Figure 6. Relationship between range size and the elk suitability index to evaluate minimum area requirements. To be used as a precursor to habitat evaluation.

Food

Fall Food. Fall food is critical for elk because of the animals' need to accumulate body fat for winter survival (Mautz 1978). Elk are northern cervids adapted to live through long winters. The species has a relatively high food intake during summer and fall and relies on fat deposits for overwintering. A 260 kg female can survive 72 days on body fat alone (Geist 1982).

Acorns and grass make up most of the fall diet of elk in eastern deciduous forests. The fall diet of elk in Missouri consisted of: acorns (50%), grass (37%), and forbs and a small amount of browse composing the remainder (13%). Food habits of elk in the Northern Great Plains (Wind Cave National Park, South Dakota) differed from those reported in eastern regions in that forbs were the dominant forage class in the fall diet. The forbs eaten were of high nutritional value (Wydeven and Dahlgren, 1983). Thus, the percentage of use for grass and forbs might vary depending on the area. Assessing the potential for fall mast production (acorns), grass availability, and forb production will give a measure of the fall food supply.

Winter Food. Winter food for elk in eastern habitats consists mostly of new growth of woody tree and shrub browse with a small amount of evergreen forbs (Hunter et al. 1979, Moran 1973). Assessing the potential for woody

tree and shrub browse production should reveal the winter food supply.

Optimal elk habitat is assumed to have 15% of the area in cover types that have a winter food suitability rating of 1.0 (Beyer 1987).

Spring Food. Spring food for eastern elk herds consists of winter foods (woody tree and shrub browse), forbs and grass (Winkler 1985). Woody tree and shrub browse are utilized during early spring. Later, early forbs and cool season grasses are eaten during the late spring green-up period. Although grass is only heavily utilized for a short time between late spring and early summer, grass seems to be an important part of the diet (up to 85%) during this critical period (Devlin and Tzilkowki 1986). Spring food availability can be determined by assessing the presence of winter food (woody tree and shrub browse), plus early forbs and cool season grasses. Optimal elk habitat is assumed to have 10% of the area in cover types which have a spring food suitability rating of 1.0 (Beyer 1987).

Summer Food. Summer foods consist of forbs, woody twig growth, and leaves (Winkler 1985). Summer food can be assessed by determining the presence of forbs, woody twig growth, and leaves.

Forested Area Food Production In most habitats, the quantity of biomass is not considered limiting or restrictive to elk needs (Wisdom et al. 1986). In contrast to forage quantity, the palatability, digestibility, and nutritional content of food within the forage area are key variables to an evaluation of forage quality and are considered potentially limiting factors to elk productivity (Trainer 1971, Mereszczak et al. 1981, and Starkey et al. 1982). Only food sources below 2.3 m in height should be considered (Nelson 1982).

"Optimal cover" provides both food and thermal cover requirements in forested habitats. Optimal cover is defined as a forest stand with : 1) four layers consisting of overstory canopy, sub-canopy, shrub layer, and herbaceous strata; and 2) an overstory canopy that can intercept and hold a substantial amount of snow or provide dense summer shade, yet has dispersed, small openings of less than .051 ha. These criteria are generally achieved when the dominant trees average 53 cm diameter breast height (d.b.h.) or greater, have 70 percent or greater crown closure, and are in the large sawtimber or old-growth stand condition (Witmer and deCalesta 1985).

When considering vegetational strata, $\geq$25% of the sample plot area should contain forb, shrub, or midstory layers, <25% coverage by these three layers is not a significant food source. The canopy layer should have $\geq$60%

closure to be a significant source of food, $\geq$70% is optimal. Less than 60% canopy closure should be considered open area. Four vegetational layers provide both high quality food potential and thermal (1.0). Three layers provide reduced yet high quality food potential or thermal cover (0.8). Two layers provide reduced thermal cover and greatly reduced food potential (0.3). One layer is not a significant source of food, producing thermal cover only (0.1).

Vegetational strata should be used to evaluate forested habitat only (Figure 7). Equation 1 shows variable 1 (SI_{V1}) and the suitability index for the vegetational strata component (CI_{VS}).

$$CI_{VS} = SI_{V1} \quad (1)$$

Mast Production Although oak mast is considered a valuable source of fall forage, acorn production is not deemed critical for elk survival in any given area. Oak mast should not be considered a "necessity", but rather an "extra" in elk habitat evaluation. Elk can survive well in forest types having no oak component if sufficient browse is available (Nelson and Leege 1982).

The potential for oak mast production in the Southern Appalachian region is impossible to predict within the scope of this HSI. Although past studies indicated a correlation between tree size, age, or basal area and predictable mast

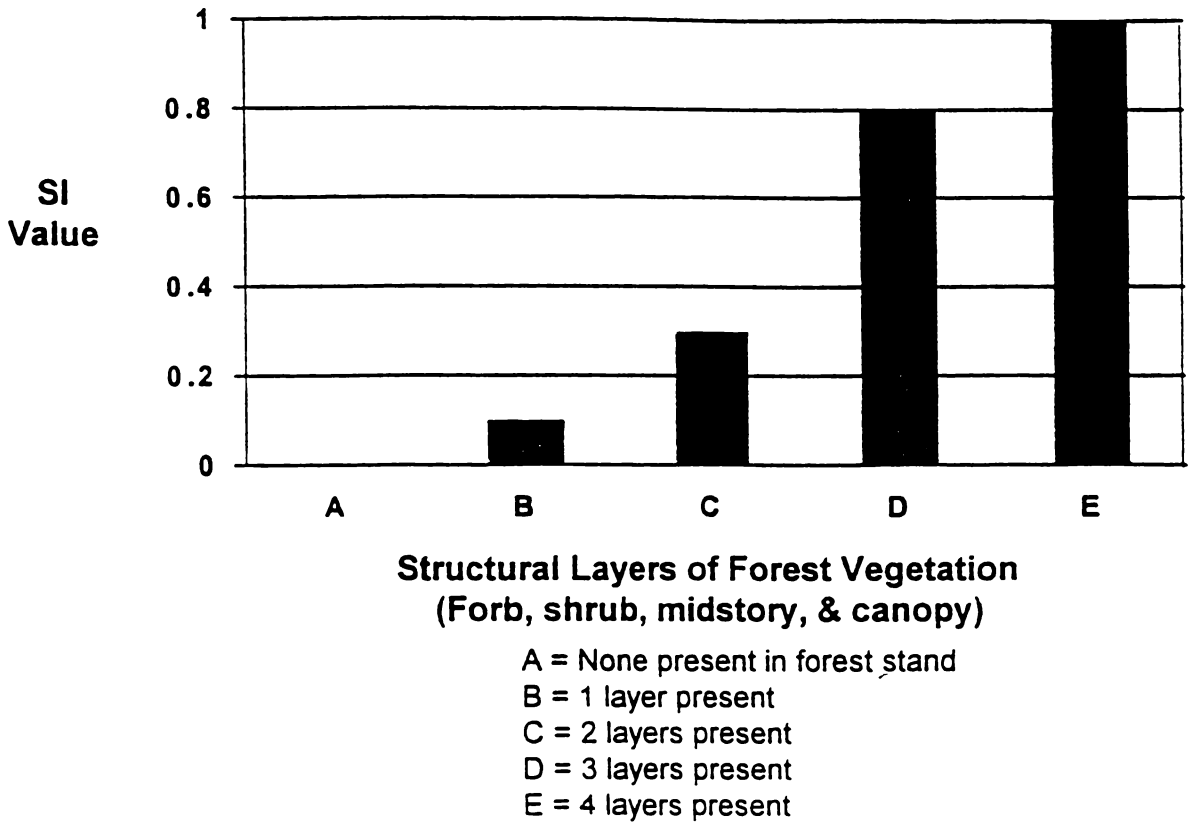


Figure 7. Relationship between vegetational strata in the evaluation area and the elk suitability index (SI_{V1}) to evaluate food availability in the forests of the Southeast.

production (Downs 1944), recent research has revealed that no reliable correlation actually exist. The most commom thread of information among mast researchers are observations of variations in mast production (Whitehead 1989, Downs and McQuilkin 1944, Christisen 1955, Christisen and Kearby 1955, Gysel 1956, Whitehead 1969, and Strickland 1971). The causes of such variability are not well known (Whitehead 1989, Gysel 1958, and Williamson 1966). Mast production varies widely among trees, species (oaks), locations and years (Beck 1989, Whitehead 1989, Schlarbaum, S. and Langdon, K. 1994, Personal Comm.). " All we can hope do is provide the capacity or potential for mast production" (Beck 1989).

Thus, we can only make the assumption that a forest type containing an oak component has some mast production potential. In areas were the lower vegetational strata have been removed by over-browsing or other causes and an oak component is present, an SI value of 0.8 should be assigned to the sample based on oak mast potential alone. Although oak mast alone will not produce an optimal year-round food supply, the potential for a high quality fall food source exist in areas having an oak component (0.8). One or more oaks of any species identified in the sample plot (minimum 16 oaks\ha) will verify the existence of an oak component.

The oak mast variable should only be used to evaluate forest habitat (Figure 8). Equation 2 shows variable 2

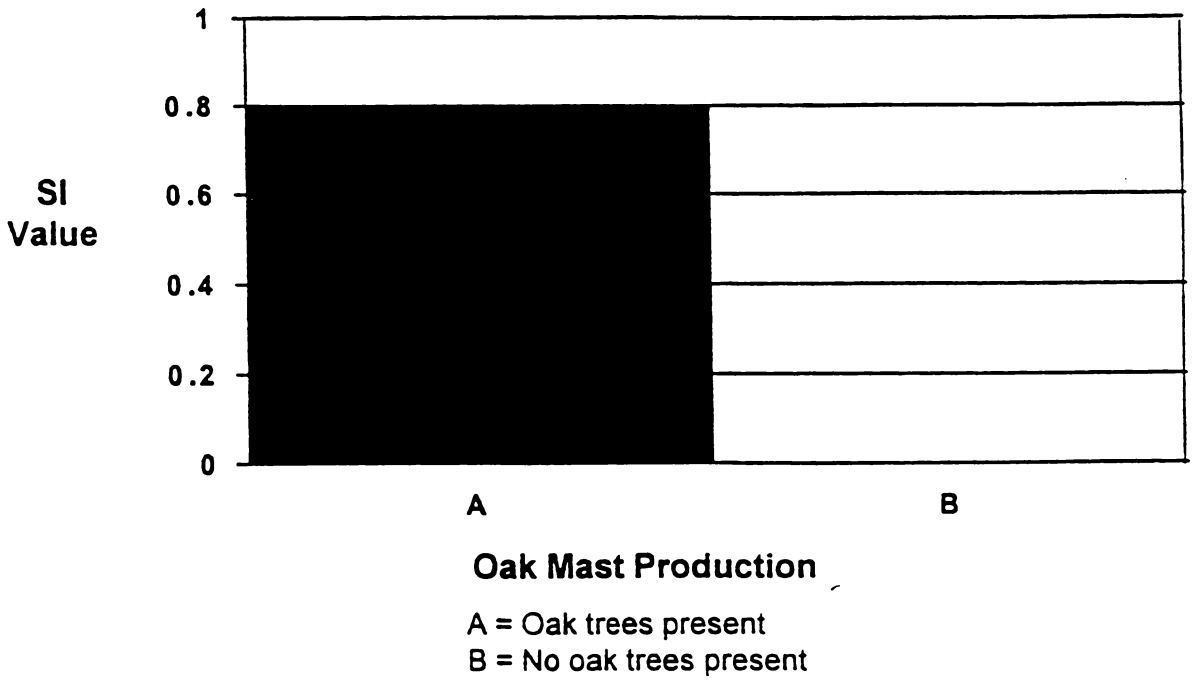


Figure 8. Relationship between mast production in the evaluation area and the elk suitability index (SI_{V2}) to evaluate food availability in the forests of the Southeast.

(SI_{V2}) and the suitability index for the Mast Production component (CI_{MP}).

(2)

$$CI_{MP} = SI_{V2}$$

Open Area Food Production The most critical period for food production in open areas is late spring prior to green-up. Cool season grasses are the first vegetation to produce fresh growth in early spring and furnish elk with needed nutrition after the winter (Beyer 1987, Devlin and Tzilkowski 1986, Drake 1985, Parker 1990, and Winkler 1985). Warm season grasses, forbs, and shrubs provide food as the growing season progresses. Thus, openings containing cool season grasses are optimal with warm season grasses, forbs, and shrubs furnishing additional high quality forage as the growing season progresses.

The open area food production variable should be used to evaluate open area habitat only (Figure 9). If more than one vegetation type occurs within the same opening, the percentage coverage of each vegetation type should be estimated and a weighted mean used as the SI value. Equation 3 shows variable 3 (SI_{V3}) and the suitability index for the opening vegetation component (CI_{OV}).

(3)

$$CI_{OV} = SI_{V3}$$

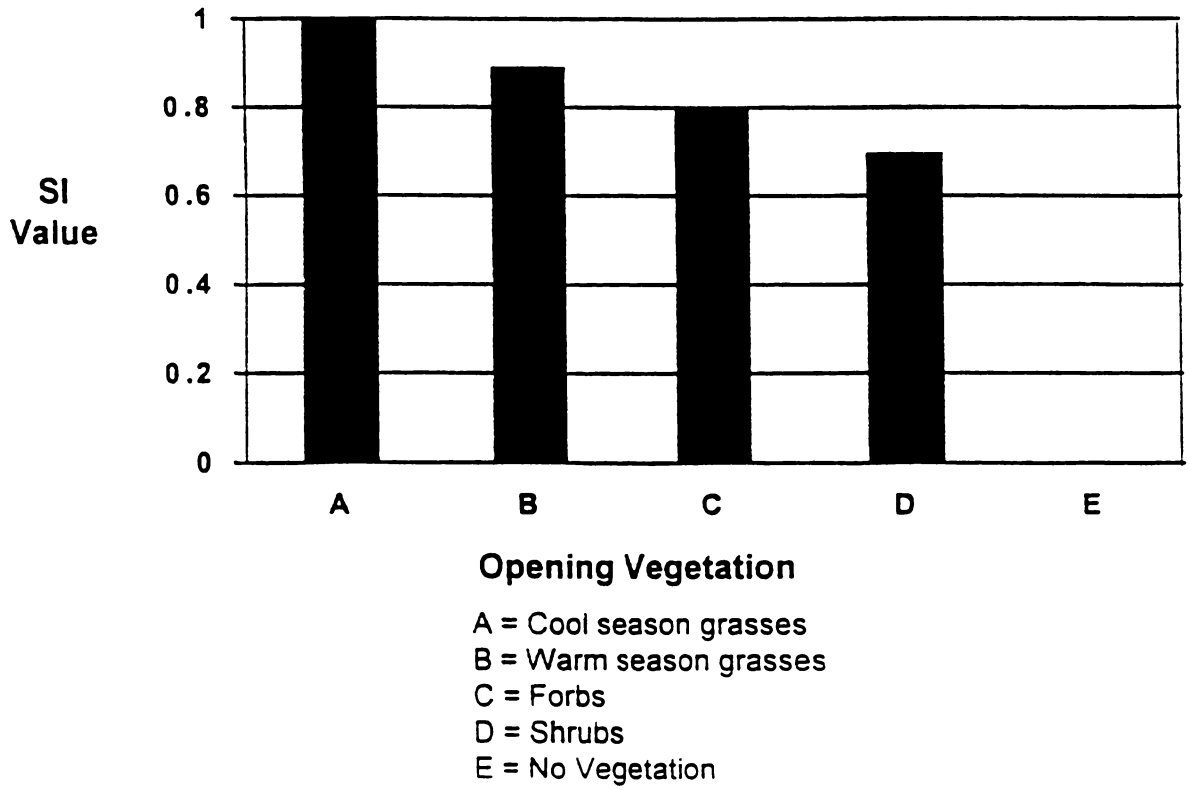


Figure 9. Relationship between opening vegetational composition in the evaluation area and the elk suitability index (SI_{V3}) to evaluate food availability in open areas of the Southeast.

Cover

Winter thermal cover is not applicable to elk living in the southern Appalachian region. Summer thermal cover was discussed as a function of optimal cover above. Hiding cover requirements should be evaluated for both forested and open areas.

Forested Area Cover Hiding cover is not defined in terms of stand structure. Any vegetation capable of hiding 90% of a standing adult deer or elk at $\leq$61 m qualifies as hiding cover (Thomas et al. 1979). Sight distance, the technique for measuring hiding cover in forested habitats using a sight distance board, is primarily a function of tree stems/ha in older stands having high density crown cover and a clean forest-floor understory. In open or younger stands with crown cover less than 75 percent, sight distance is often related to the shielding effects of low-growing vegetation (Skovlin 1982).

The sight distance variable should only be used for forest habitat evaluation (Figure 10). Equation 4 shows variable 4 (SI_{V4}) and the suitability index for the sight distance component (CI_{SD}).

$$CI_{SD} = SI_{V4} \quad (4)$$

Open Area Cover The majority of elk use of open areas occurs within 91 m of the edge of cover. Medium use occurs

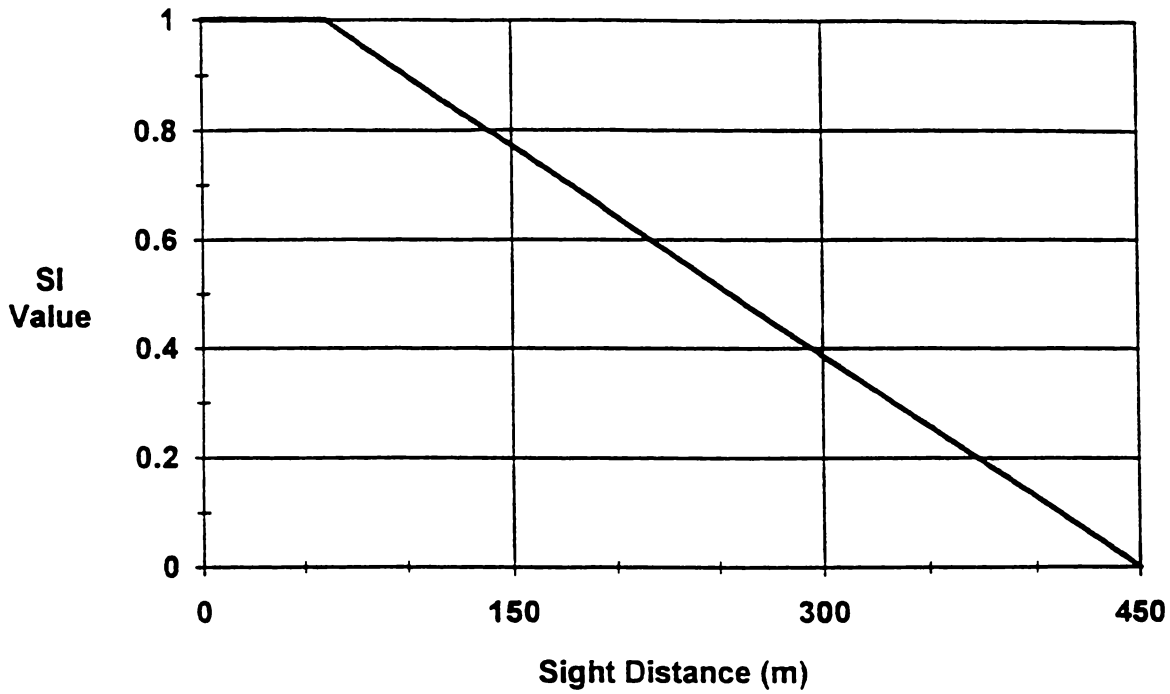


Figure 10. Relationship between sight distance in the evaluation area and the elk suitability index (SI_{V4}) to evaluate cover availability in the forests of the Southeast.

from 91 m to 150 m and low use from 150 m to 600 m (Wisdom et al. 1986).

The distance to cover variable should only be used to evaluate open habitat (Figure 11). Equation 5 shows variable 5 (SI_{V5}) and the suitability index for the opening cover component (CI_{DC}).

(5)

$$CI_{DC} = SI_{V5}$$

Water

Distance To Water

Optimal elk habitat should have a water source within 805 m. Both Nelson and Burnell (1975) and Mackie (1970) showed that elk use of summer range was curtailed severely beyond 805 meters from water.

In eastern habitats, sources of drinking water with a minimum depth of 0.61-0.91 m can serve as a source of protection. Elk often move into shallow water to escape packs of dogs or other predators (Geist 1991). Having longer legs, elk can stand on the bottom and strike swimming attackers with their front hooves .

The distance to water variable can be used for both forest and open habitat (Figure 12). The suitability index for the protection cover component (CI_{DW}) is shown in equation 6.

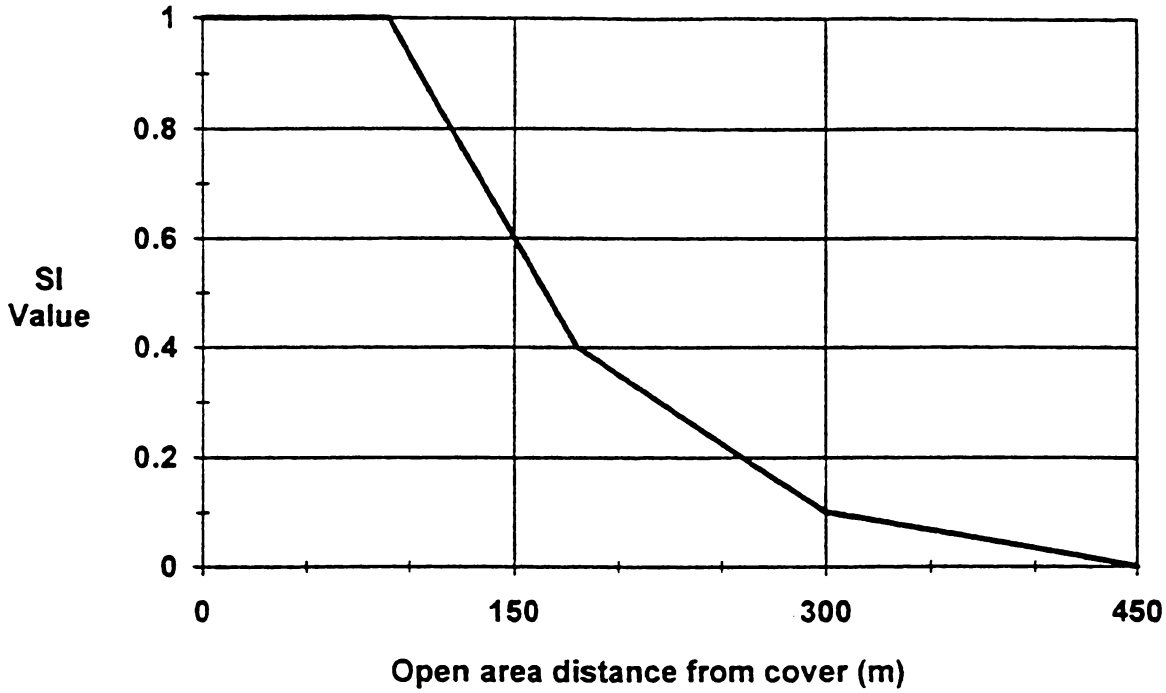


Figure 11. Relationship between opening cover (distance to cover) in the evaluation area and the elk suitability index (SI_{V5}) to evaluate cover availability in the open areas of the Southeast.

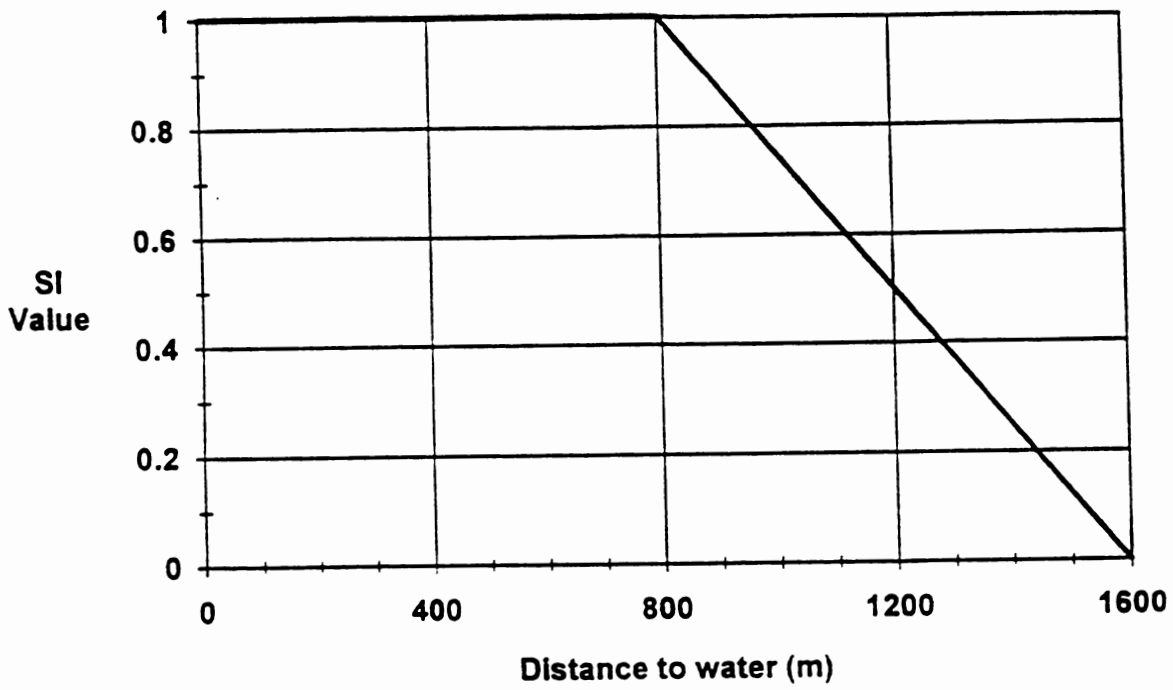


Figure 12. Relationship between distance to water in the evaluation area and the elk suitability index (SI_{V6}) to evaluate water availability in the Southeast.

(6)

$$CI_{DW} = SI_{V6}$$

Topography

Slope

Slopes of 0-27 degrees receive heavy use, 27-54 degrees moderate use, 54-81 degrees little use, and greater than 81 degrees practically no use (Edge et al. 1987, Skovlin 1982). This variable is applicable to both forest and open area habitat (Figure 13). The suitability index for the slope component (CI_S) is shown in equation 7.

(7)

$$CI_S = SI_{V7}$$

Spacial

Distance From Edge Into Forest

In western states most elk use of cover occurs within 274 m of the edge with open areas (Wisdom et al.1986). However, in eastern habitats, optimal cover, which provides both food and cover, lure elk much greater distances from edge. In the deciduous forests of Arkansas and Pennsylvania, elk travel indeterminate distances into forested areas and make seasonal use of all such areas within their range (Cartwright, M. 1993, and Cogan, R. 1995, Personal comm.). Thus, distance traveled into forest areas away from edge would only be limited by individual home

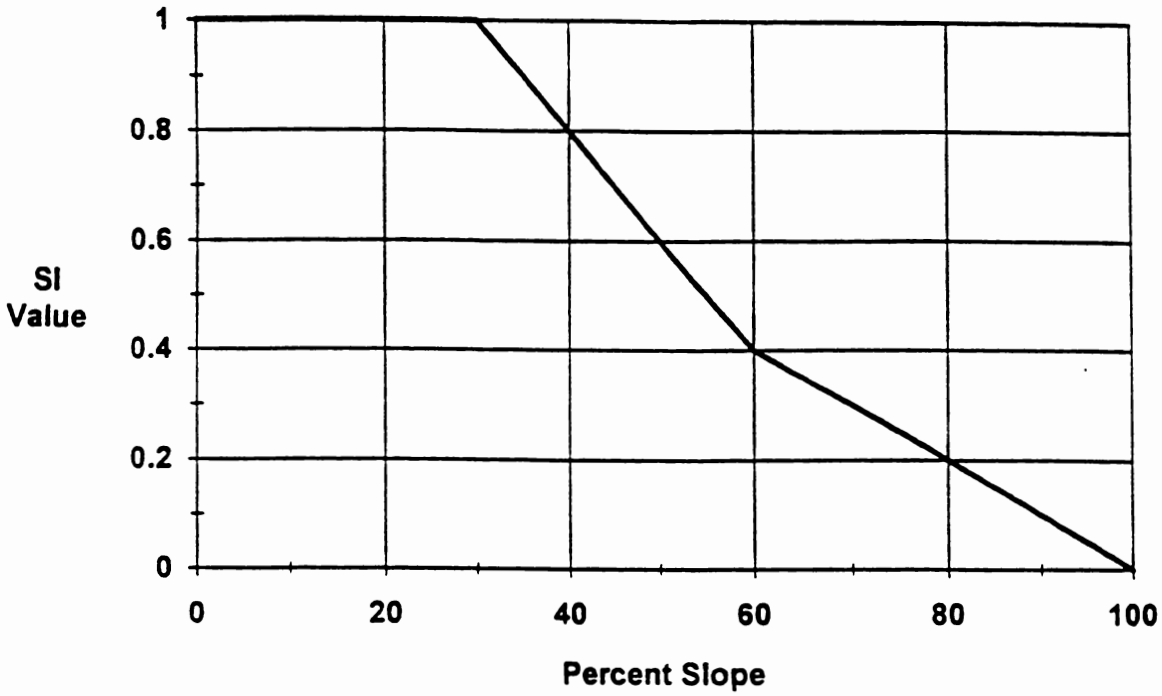


Figure 13. Relationship between slope in the evaluation area and the elk suitability index (SI_{77}) to evaluate topography in the Southeast.

range boundaries. In Pennsylvania, the average distance traveled between sightings was 8.3 km for males and 3.6 for females. The largest single movement was 19.2 km. Average distance across home range was 16.3 km for bulls and 6.8 km for cows (Cogan 1987). Elk would be expected to have approximate average movements up to 8 km in all directions from openings, assuming an opening would determine the center of the home range.

This variable is only applicable to forest habitat (Figure 14). The suitability index for distance from edge component (CI_{DE}) is presented in equation 8.

(8)

$$CI_{DE} = SI_{V8}$$

Percentage Openings

In western states, optimal elk habitat is composed of 30-60% open foraging areas (Witmer and deCalesta 1985). Open forage areas consist of openings, clearcuts, or burns (Beyer 1987). In eastern habitats, 10-60% openings is optimal (Beyer 1987 and Cogan, R. 1995, Personal comm.) (Figure 15).

(9)

$$CI_{PO} = SI_{V9}$$

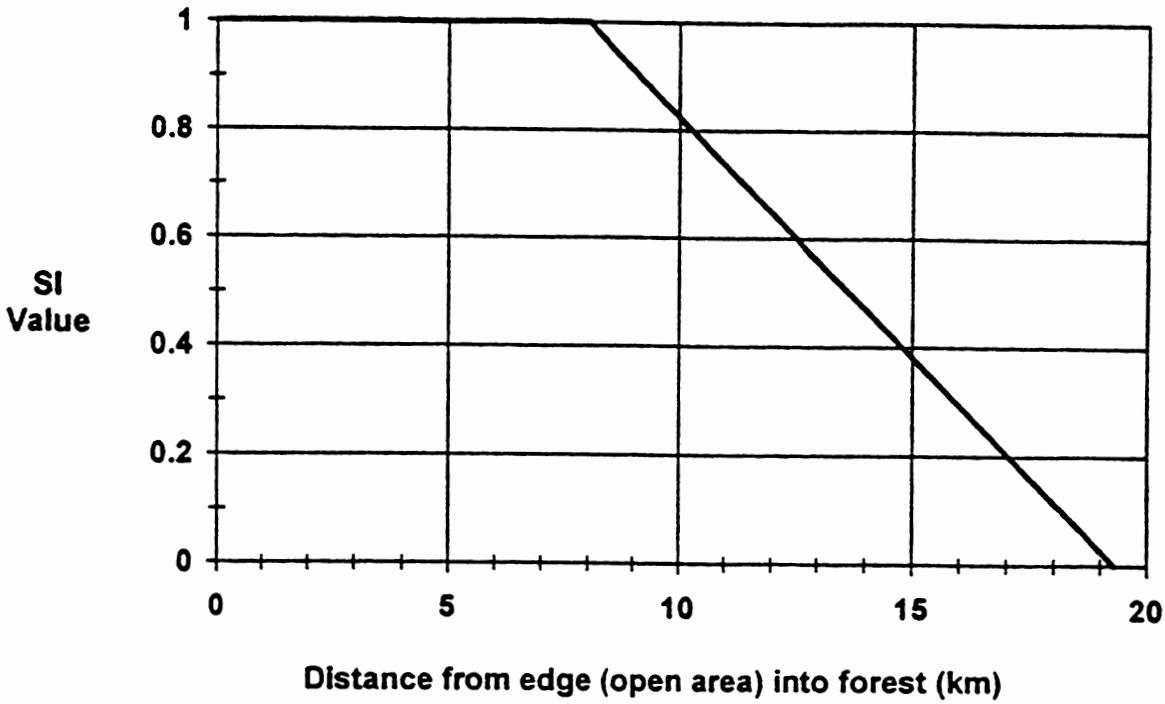


Figure 14. Relationship between distance from edge in the evaluation area and the elk suitability index (SI_{V8}) to evaluate spacial factors in the Southeast.

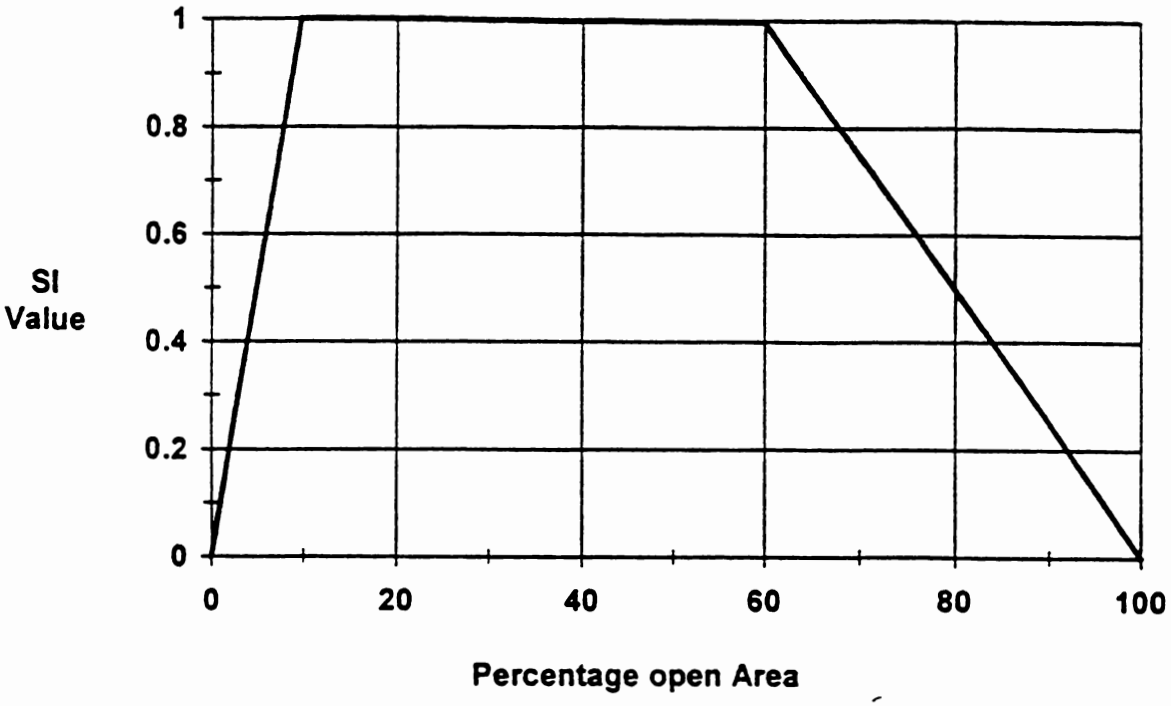


Figure 15. Relationship between percentage openings and the elk suitability index (SI_{vg}) to evaluate spacial factors in the Southeast.

Percentage forest

In western states, optimal elk habitat is composed of at least 40% cover areas (Witmer and deCalesta 1985). In eastern habitats, 40-90% forested area is optimal (1.0 SI Value) (Beyer 1987 and Cogan, R. 1995, Personal comm.) (Figure 16).

(10)

$$CI_{PF} = SI_{V10}$$

Human Impact

Distance To Row-cropped Agricultural Areas

Distance to row-cropped agricultural areas is a function of home range size. Moran (1973) indicated that, in Michigan, there were only a few instances in which serious crop damage was reported; depredation sites usually bordered on heavily used summer elk range.

In a study of elk movement in relation to crop damage in Pennsylvania, Drake (1985) found that bulls traveled more often and longer distances from their centers of activity than did cows. Bulls made nearly twice as many significant movements as cows, 30 and 16, respectively. The average distance traveled was more than twice as much for bulls (8.48 km) as for cows (3.36 km). The largest single movement determined during the study was 19.2 km. Moran (1973) reported a maximum movement of 19.2 km for a marked cow in Michigan. "The Rocky Mountain elk in Pennsylvania's herd

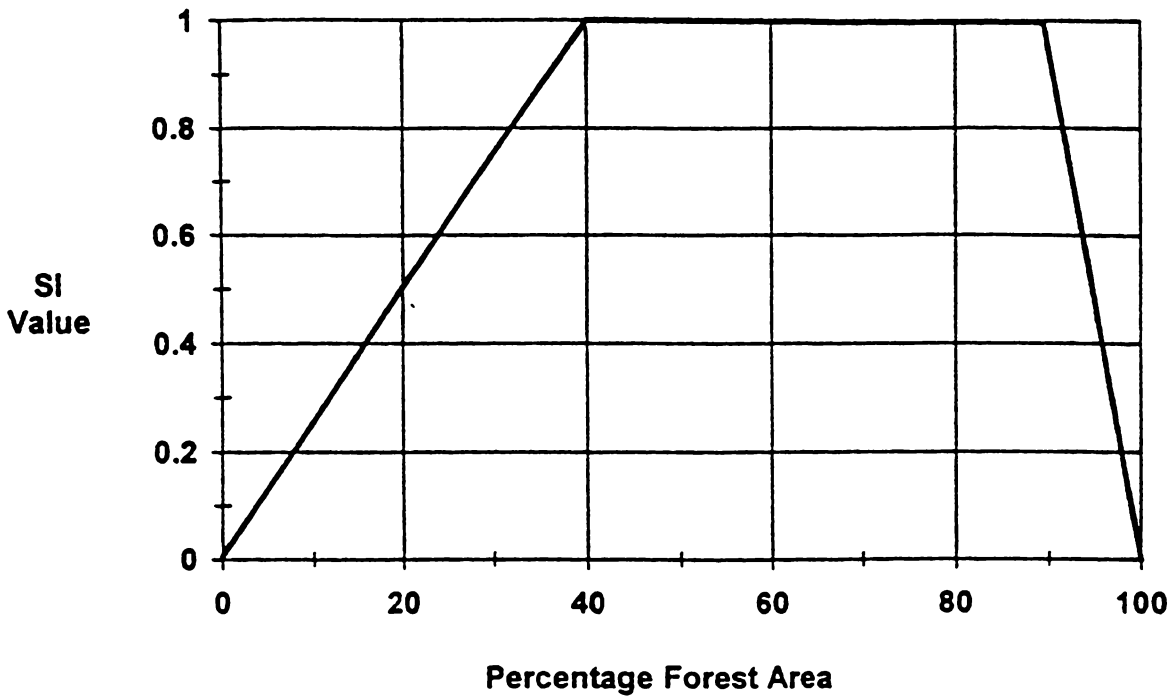


Figure 16. Relationship between percentage forest and the elk suitability index (SI_{V10}) to evaluate spatial factors in the Southeast.

should be capable of easily moving to whatever portion of the range (32 km long by 16 km wide) they desire or leave the range should they so choose. Perhaps the most surprising thing is that they so seldom do" (Drake 1985).

This variable can be used for both forest and open area habitat (Figure 17). The suitability index for the distance from agriculture (CI_{DA}) is shown in equation 11.

(11)

$$CI_{DA} = SI_{V11}$$

Distance From Roads And Human Disturbance

In hunted populations, elk usually maintain a 805 m or 0.8 km buffer zone between the herd and roads or human disturbance areas (Ward 1976). This variable is not applicable in national parks and other unhunted or low poaching areas. National park elk become habituated to road traffic and normal human activity.

The distance from roads and human disturbance variable is applicable to both forest and open area habitat (Figure 18). The suitability index for distance from road component (CI_{DR}) is presented in equation 12.

(12)

$$CI_{DR} = SI_{V12}$$

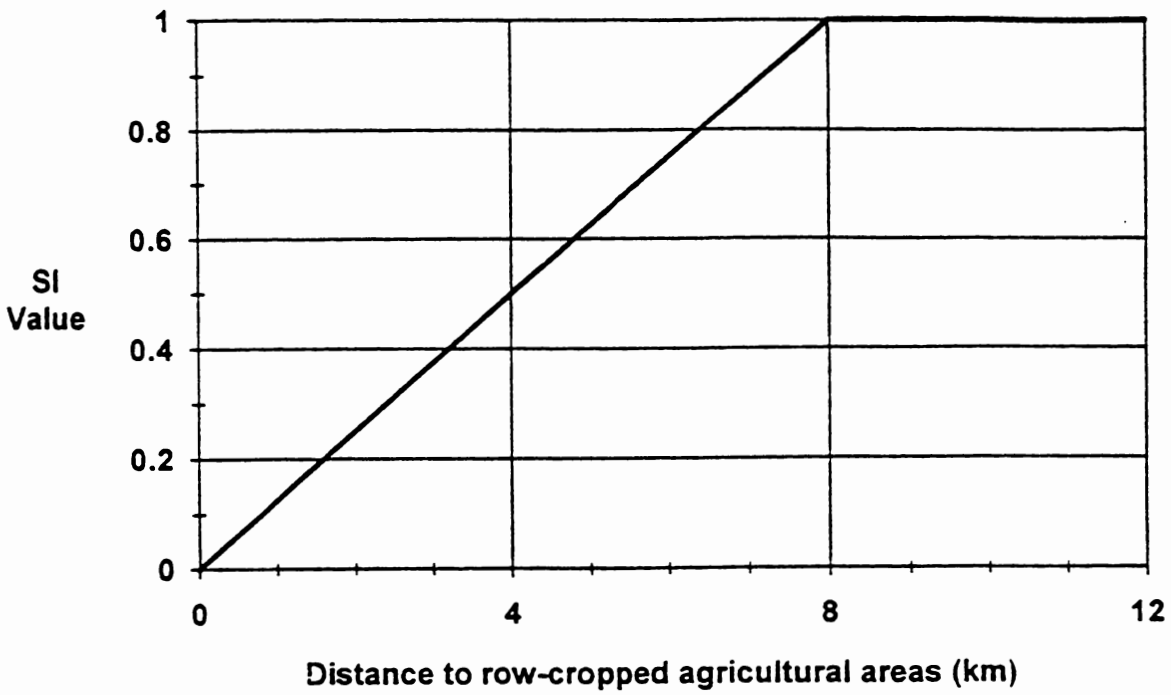


Figure 17. Relationship between distance to row-crops in the evaluation area and the elk suitability index (SI_{V11}) to evaluate human influences in the Southeast.

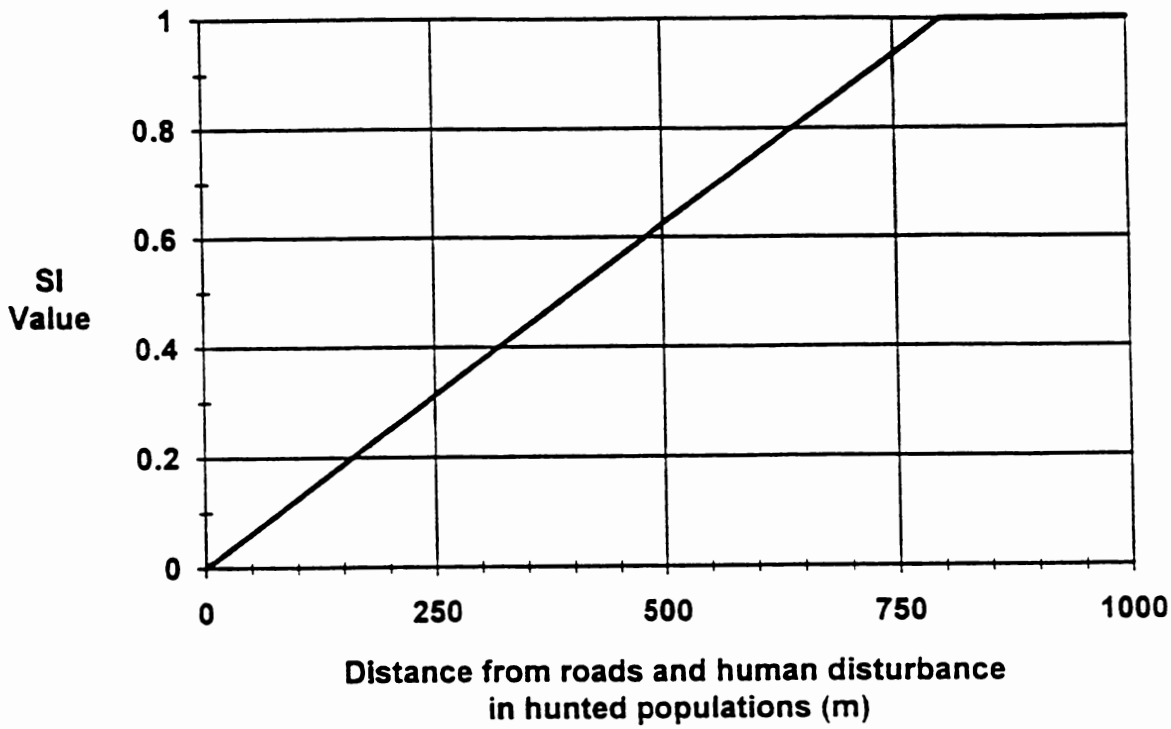


Figure 18. Relationship between distance from roads and human disturbance and the elk suitability index (SI_{V12}) to evaluate human influences in the Southeast.

Road Density

Optimal elk habitat, in hunted or highly poached areas, contains 0 km/km^2 of road. Moderate use habitat contains 1.24 km/km^2 and lowest use areas have 3.72 km/km^2 (Lyon 1983; Table 9, Appendix A). The road density variable is not used for national parks or areas without hunting or high poaching. Elk in these areas become habituated to road activity.

This variable can be used with both forest and open area habitat (Figure 19). Equation 13 shows variable 13 (SI_{V13}) and the suitability index for road density (CI_{RD}).

(13)

$$CI_{RD} = SI_{V13}$$

Overall HSI Determination

If all variables are used, the equation to obtain overall habitat suitability index (HSI) for forested habitat is shown below. Due to the weak compensatory relationship between variables, the geometric mean is used. Geometric means are influenced more by low values for one of the variables (USFWS 1981). When considering SI_{VS} and SI_{MP}, forest habitat can be optimal with either four vegetational layers or oak mast present. Both are not necessary, thus, only the variable with the greater SI value was used in HSI calculation.

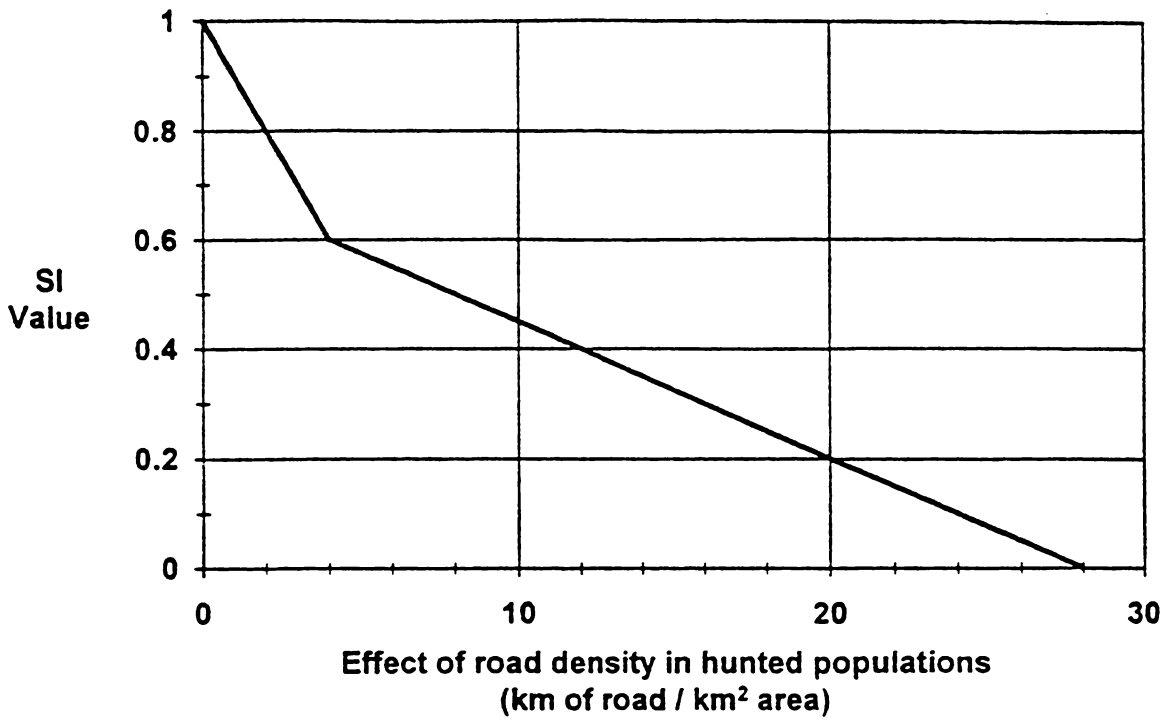


Figure 19. Relationship between road density and the elk suitability index (SI_{V13}) to evaluate human influences in the Southeast.

(14)

$$HSI_F = [(SI_{VS} \text{ or}^1 SI_{MP}) \times SI_{SD} \times SI_{DW} \times SI_S \times SI_{DE} \times SI_{PF} \times SI_{DA} \times SI_{DR} \times SI_{RD}]^{1/9}$$

Assuming all variables are used, the equation for overall habitat suitability index (HSI) for open habitat is shown below.

(15)

$$HSI_O = (SI_{OV} \times SI_{DC} \times SI_{DW} \times SI_S \times SI_{PO} \times SI_{DA} \times SI_{DR} \times SI_{RD})^{1/8}$$

Model Application

This model describes an elk habitat evaluation applicable for the Southeast which includes Tennessee, Kentucky, Virginia, West Virginia, western North Carolina, northern South Carolina, and northern Georgia. Figures 20, 21, and 22 are respectively; a tree diagram for identification of variables, a diagram of logic for use of the HSI, and a decision diagram. The model was developed specifically for application in Great Smoky Mountains National Park, although basic concepts may be generally applicable to other regions of the Southeast.

This model was designed to evaluate elk habitat with

[1] The greater of the two.

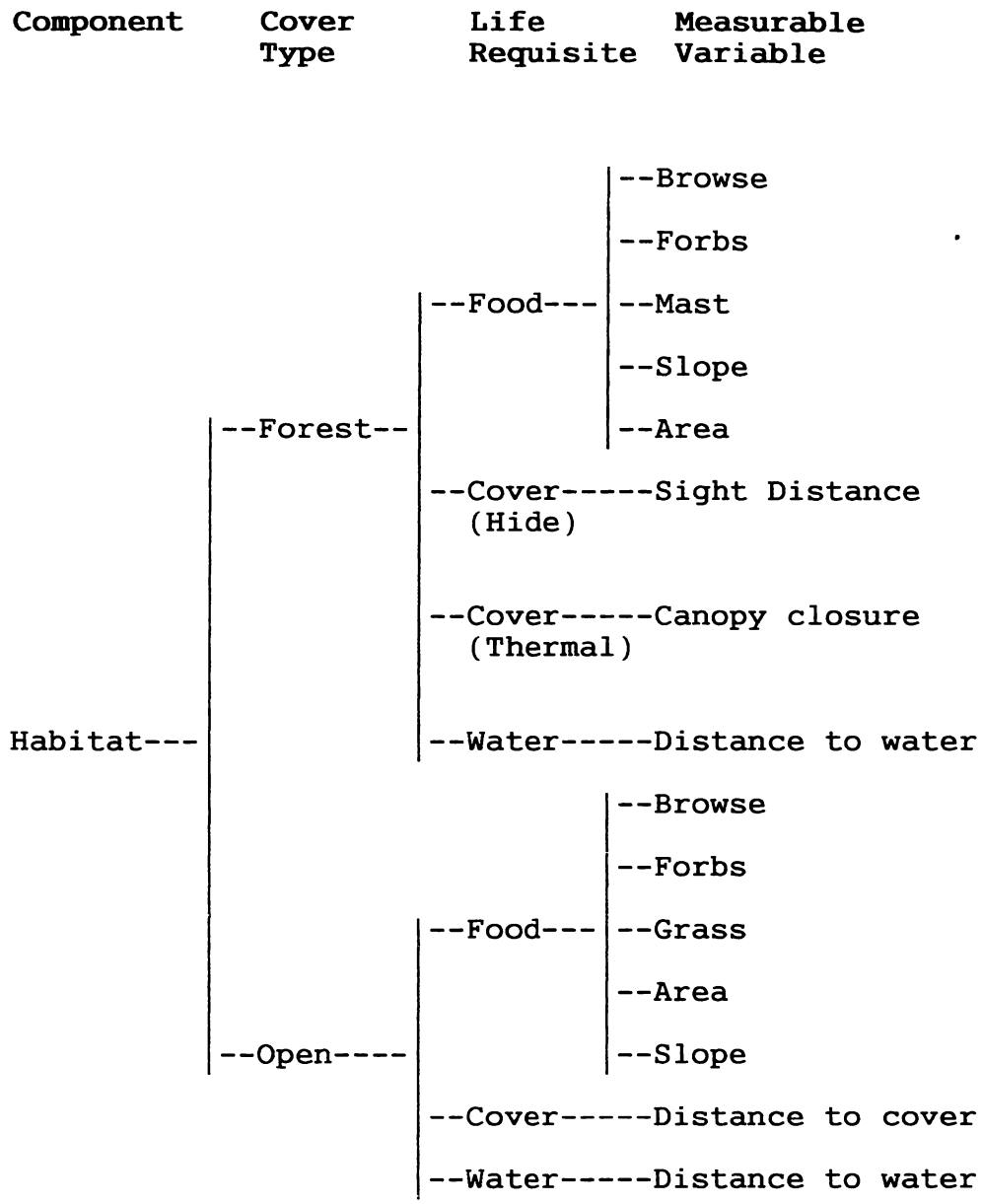


Figure 20.

TREE DIAGRAM FOR IDENTIFICATION OF MEASURABLE HABITAT VARIABLES DURING ALL SEASONS

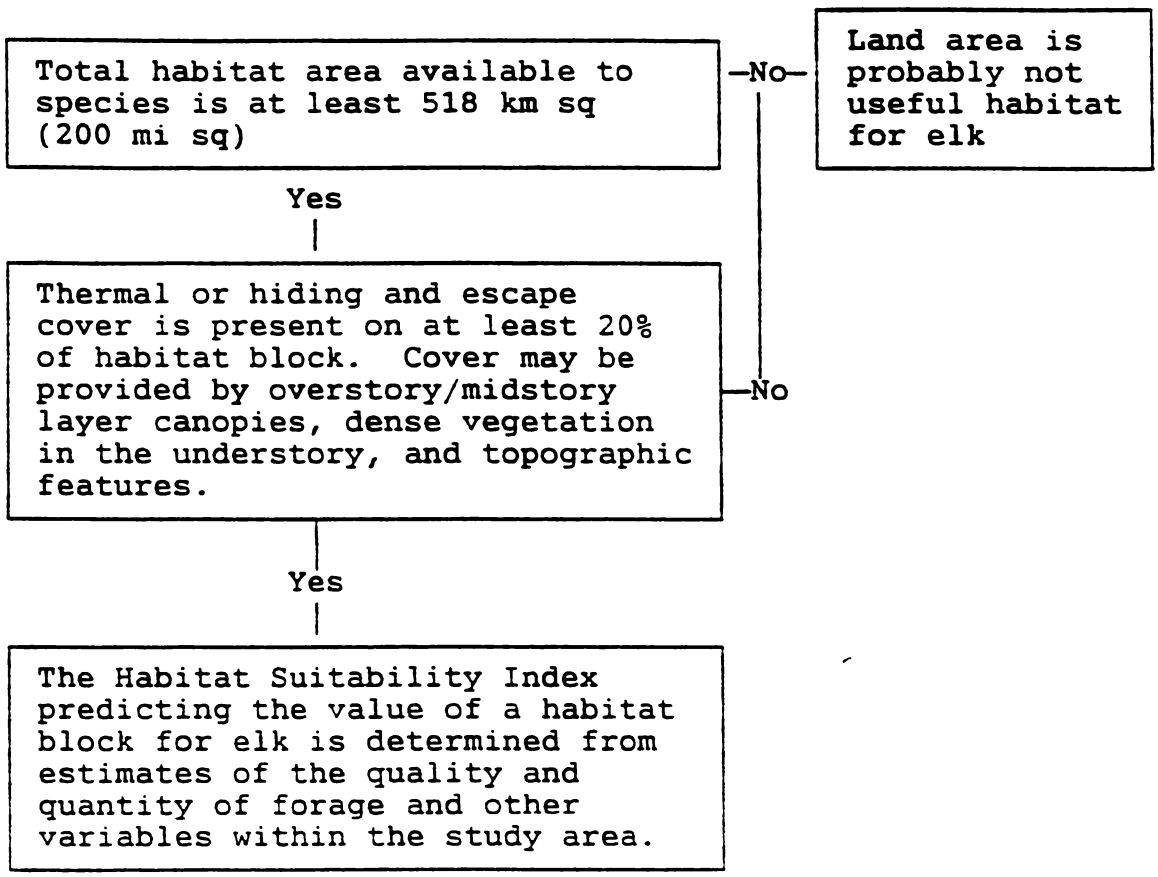


Figure 21.

Logic used to develop HSI model for elk based on the relative quality and quantity of suitable forage present in evaluation area.

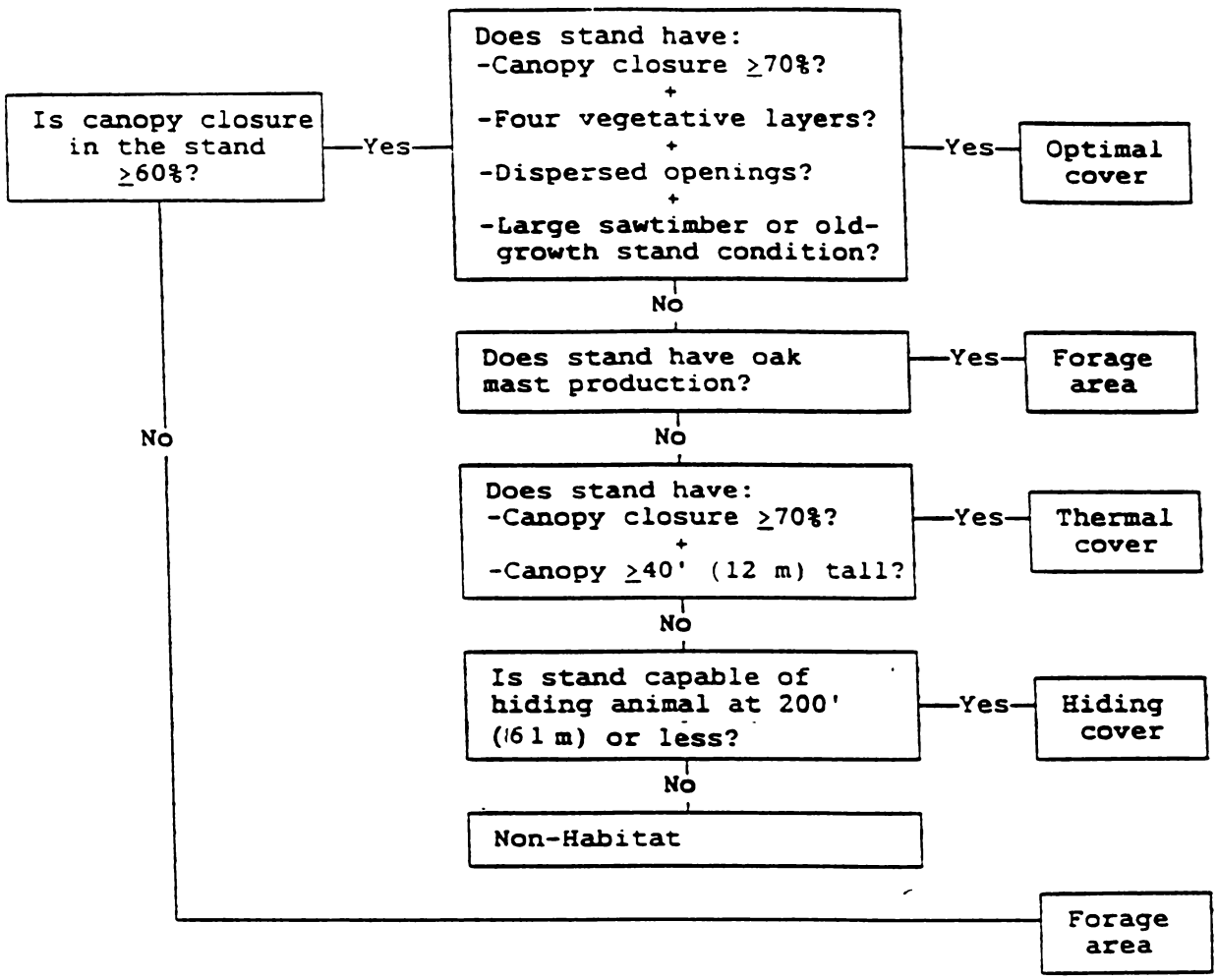


Figure 22.
A decision diagram for classification of forage areas and cover types for elk in the Southeast, based on Witmer et al. (1985).

limited budget and time constraints. The accuracy and replicability of the HSI values can be optimized if all applicable variables, based on detailed field data, are used to evaluate an area large enough (see minimum area requirements) to support a viable elk population. Although elk herds in eastern states are not wide ranging, HSI users are advised to take the contextual setting of the evaluation area into consideration by carefully evaluating adjacent areas using applicable variables. "Distance to row-cropped areas" should be given special consideration when evaluating habitat near the study area.

Instead of time sampling, some variables were given values by consulting USGS maps or using GIS (Geograpic Information Systems). Definitions of variables, suggested measurement techniques, and evaluation are presented in Tables 3 and 4.

Limitations of the current model

Due to restrictions inherent in all quantitative habitat models such as its simplification of natural systems and often limited data, HSI models never completely simulate actual species-habitat relationships (Van Manen 1991). The HSI model does not describe specific ecological processes within an ecosystem, nor is it intended to.

The present model was developed for use in the southeastern United States. The study area contains some of the most unique and diverse habitat found anywhere in the

Table 3. Definitions of variables, evaluation areas, and suggested techniques for use in the elk HSI model for forested areas in the southeastern United States.

Variable and Definition	Evaluation area	Suggested technique
Vegetational Strata (V_1)	Entire forested area	Releve plots
Mast Production (V_2)	Cover types with oak mast species	Releve plots
Sight Distance (V_4)	Entire forested area	Sight distance profile board
Distance to Water (V_6)	Entire forested area	GIS USGS Maps
Slope (V_7)	Entire forested area	GIS Clinometer Abney level
Distance from Edge (V_8)	Entire forested area	GIS USGS Maps
Percentage Forested Area (V_{10})	Entire forested area	GIS
Distance to Ag Areas (V_{11})	Entire Forested area	GIS USGS Maps
Distance from Roads & Human Disturbance (V_{12})	Entire forested area	GIS USGS Maps
Road Density (V_{13})	Entire forested area	GIS USGS Maps

Table 4. Definitions of variables, evaluation areas, and suggested techniques for use in the elk HSI model for open areas in the southeastern United States.

Variable and Definition	Evaluation Area	Suggested Technique
Opening Vegetation (V_3)	Entire open area	Releve plots
Opening Cover (V_5)	Entire open area	Field Measurements
Distance to Water (V_6)	Entire open area	GIS USGS Maps
Slope (V_7)	Entire open area	GIS Releve plots Clinometer Abney Level
Percentage Open Area (V_9)	Entire forested area	GIS
Distance to Ag Areas (V_{11})	Entire Forested area	GIS USGS Maps
Distance from Roads & Human Disturbance (V_{12})	Entire forested area	GIS USGS Maps
Road Density (V_{13})	Entire forested area	GIS USGS Maps

eastern portion of the continent. An HSI is usually developed in an area containing a population of the target species. Elk were extirpated from the study area and the nearest herds are presently found in Arkansas and Pennsylvania. Thus, most of the suitability index curves were derived from data acquired from western herds living in quite different habitat and the few data taken from eastern herds. The assumptions and the suitability index curves need to be verified with carefully designed studies and adequate field data. The reliability of the HSI values depends on the quality of the input data. The verification process may lead to refinement and restructuring of the model. Index curves may need to be adjusted and variables deleted or added.

Field use of the HSI, at TVA Land Between The Lakes (LBL) in Tennessee and Kentucky, revealed information which prompted an adjustment in the SI graph for one variable (percentage forest area) shortly after the preliminary results of this study were reported. This report reflects that adjustment, but reveals no significant change in the final results.

At present, predicting the potential for oak mast production in forest types containing an oak component is impossible. No variable has been found that will accurately predict long-term acorn production. If such a variable is identified in the future, the HSI (mast production) should

be adjusted to supply a greater range of values for that variable.

Although altitude is important in the evaluation of elk habitat, this variable was not considered separately because the effect of altitude should be reflected in the quality of other resources.

Some of the values incorporated in this HSI were taken from data acquired from research conducted on western herds. Future studies of eastern herds may reveal dissimilar data due to differences in habitat, climate, altitude, food sources, and etc. Thus, the HSI for southeastern habitat should be adjusted to reflect greater accuracy.

Vegetational Sampling

An elk HSI model for the Southeastern United States was developed to evaluate elk habitat quality. Seven variables for forested area and five variables for open area identified in this model were measured (Tables 5 and 6).

Sample blocks were selected to represent all cover types. Criteria for selecting location points included: (1) accessibility by road or trail, (2) road or trail surrounded on all sides by the selected forest type, (3) as much contiguous area as possible in the selected forest type, and (4) dispersed throughout the study area representing as many different areas of GSMNP as possible. Using these criteria,

Table 5. Definitions of variables, evaluation areas, and techniques used for the elk habitat evaluation for forested areas in Great Smoky Mountains National Park, TN/NC.

Variable and Definition	Evaluation area	Suggested technique
Vegetational Strata (SI_{V1})	Entire forested area	Releve methods
Mast Production (SI_{V2})	Cover types with oak mast species	Releve method
Sight Distance (SI_{V4})	Entire forested area	profile board
Distance to Water (SI_{V6})	Entire forested area	GIS
Slope (SI_{V7})	Entire forested area	GIS Clinometer
Distance from Edge (SI_{V8})	Entire forested area	GIS
Percentage Forested Area (SI_{V10})	Entire forested area	GIS
Distance to Ag Areas (SI_{V11})	Variable not used in GSMNP study	
Distance from Roads & Human Disturbance (SI_{V12})	Variable not used in GSMNP study	
Road Density (SI_{V13})	Variable not used in GSMNP study	

Table 6. Definitions of variables, evaluation areas, and techniques used in the elk habitat evaluation for open areas in Great Smoky Mountains National Park TN/NC.

Variable and Definition	Evaluation Area	Suggested Technique
Opening Vegetation (V_3)	Entire open area	Releve Methods
Opening Cover (V_5)	Entire open area	Field Measurements
Distance to Water (V_6)	Entire open area	GIS
Slope (V_7)	Entire open area	GIS Clinometer
Percentage Open Area (V_9)	Entire forested area	GIS
Distance to Ag Areas (V_{11})	Variable not used in GSMNP study	
Distance from Roads & Human Disturbance (V_{12})	Variable not used in GSMNP study	
Road Density (V_{13})	Variable not used in GSMNP study	

sample sites were selected using GIS and USGS topographic maps.

Each sample point was visited in the field as close to the mapped location as possible. At each location site, the sample point was determined by: (1) selecting a transect direction leaving the trail or road at a right angle, (2) traveling 25 to 50 m along the transect away from the trail to eliminate possible trail bias (distance traveled was randomly determined using a random number generator), (3) the sample point was determined by throwing an object backwards after turning several circles with eyes closed (Van Manen 1991). A 25x25 m plot was established using the sample point as the northwest corner. Some variables were more accurately determined using GIS.

Variable Measurements

Forested Area. The number of vegetational structural layers (SI_{V1}) was measured by observing the number of vegetation layers (overstory, midstory, shrub layer, or forb layer). Midstory was etermined to be the area between the tallest shrubs and the the canopy. Percentage of coverage was estimated for each vegetation layer in the plot. Sample plots with <60% canopy closure or other layers with <25% coverage were not considered to have that layer.

Oak mast production (SI_{V2}) was measured by counting the number of oak mast producing trees in each sample plot to

confirm the existence of an oak component (minimum 16 oaks\ha). Sight distance (SI_{V4}) was measured using a vegetation profile board in each of 100 plots (25mx25m). The reading was obtained by placing the profile board 61 m from the random sample point (northwest corner of plot) in a straight line with the southwest corner; this reduces subjectiveness to selection of the reading point (Van Manen 1991). If 90% or more of the profile board was hidden at this distance, sight distance was considered optimal (1.0). If less than 90% of the profile board was hidden at this distance (61 m), the board was moved further away in increments of 5 m until 90% concealment was achieved and the HSI value determined from those data.

Distance to water (SI_{V6}), slope (SI_{V7}), distance from edge (SI_{V8}), and percentage forested area (SI_{V10}) were determined using GIS.

Open Area. Opening vegetation (SI_{V3}) was assessed by recording the percentage of each opening vegetation type present (cool season grasses, warm season grasses, forbs, and shrubs) and calculating the mean SI value for the plot.

Distance from cover (VI_{V5}) was determined by measuring the distance from the sample site to the nearest edge. Distance to water (SI_{V6}), slope (SI_{V7}) (Table 8, Appendix A), and percentage open area (SI_{V9}) (Table 2) were determined using GIS.

CHAPTER V

RESULTS AND DISCUSSION

Assessment Results

One hundred plots were sampled for this study (80 forested and 20 open). Initially, 10 samples were taken from each of 9 forest types (spruce-fir, northern hardwood, cove hardwood, mesic oak, mixed mesic, tulip poplar, xeric oak, pine-oak, and pine) and 10 samples from open areas (grassy bald and treeless combined). Heath bald and grape thicket were included with open areas, but were not sampled due to the small percentage of the study area they represent (Table 2). All samples from the spruce-fir forest revealed less than 60% canopy closure, reclassifying this cover type as open area.

Forested Area Food Production

Vegetational Strata. Approximately 83.8% of the forested area of GSMNP has an optimal Suitability Index (SI) value of 1.0. The study area has an overall SI value of 0.94 for vegetational strata.

Mast Production. Approximately 39% of the sample plots were found to have an oak component (SI value of 0.8).

Overall Forest food production. Using the greater of the SI values for vegetational strata or mast production, forest food production had an overall SI value of 0.94. This value would indicate the forest areas of GSMNP have high potential for elk food production.

Open Area Food Production

With the exception of the Cades Cove area, openings were limited in both size and quantity. Approximately 40% of the open areas had an SI value of 1.0 and the overall SI value for opening vegetation was 0.87. Open areas of GSMNP should produce high quality forage for elk.

Forested Area Cover

Approximately 98.75% of forested areas had an optimal SI value of 1.0, with an overall mean SI value of 0.99 for forest cover. Lack of cover will not restrict elk habitat use in forested areas.

Open Area Cover

A total of 90% of the applicable area had an SI value of 1.0 and an overall mean SI value of 0.96 for opening cover. Available cover will not significantly restrict use of open areas by elk in GSMNP.

Distance To Water

In GSMNP, 99.96% (207,424 ha) of the total area was within 805 m of water (optimal 1.0 SI value and only .04% (76 ha) was less than optimal (0.9 SI value). The overall SI value for distance to water, in both forested and open areas, was 0.99. Lack of water will not restrict elk movements or use of habitat.

Slope

In the study area, 96.35% of the total habitat was optimal (1.0 SI value) and the overall SI value for slope, in both forested and open areas, was 0.99 (Table 8, Appendix A). Excessive slope will not restrict elk habitat use.

Distance From Edge Into Forest

Optimal elk habitat should be within 8 km of an open area. In GSMNP, 95.5% (198,075 ha) of the total area is located within 8 km of openings (1.0 SI value). Although some are small in size, existing openings are well dispersed throughout the study area. Only 4.5% (9,425 ha) of the total area was greater than 8 km from open areas. The overall SI value for distance from openings was 0.99.

Percentage Openings

The lack of dispersed open areas within GSMNP should limit carrying capacity and produce more intensive use of

existing openings, thus, keeping balds, grassy fields, and open areas in earlier successional stages. In the study area, only 3.19% of the total area was open habitat and the overall SI value for this variable was 0.32 (Table 2). The proposed new fire policy for GSMNP could produce more openings in the future. Thus, the SI value for this variable could improve over time.

Percentage Forested Area

In GSMNP, 95.93% (0.88% water) of the total area is forested and the overall SI value for this variable was 0.32. If future burns in the park produce more openings, the percentage of forested areas will be proportionately reduced and the SI value for this variable improved.

Overall Model

The suitability index values for the 10 variables used in this study resulted in an overall suitability index of 0.81 for forested habitat and 0.77 for open areas. These results indicate (overall) suitable habitat exists for elk in GSMNP. Because this study was the first time the HSI was used, more variables were used than may be necessary in future assessments. Although only 10 of 13 possible variables were used, even fewer may be necessary in future studies due to the high SI values found for such variables as distance to water (0.99), slope (0.99), and sight

distance (0.99) (Table 7; Table 10, Appendix A). These SI values might suggest similar values would generally exist for habitat throughout the Southeast. Thus, future research may indicate such variables can be eliminated to simplify the procedure.

Habitat Units

According to the overall HSI results, 414,591 habitat units [HU = HSI x habitat area (512,525 ac)] are available for elk in GSMNP (403,936 forested and 10,655 open). If accurate data were available, the theoretical carrying capacity of the study area could be determined. However, data are not available to establish the size of a self-sustainable population in the park due to the absence of the species in the area for the past 150 years. One might assume that 414,591 elk habitat units would support more than the minimum 50 animals required to maintain genetic viability.

In Missouri, elk confined to an area with 10% open grassy areas (minimum optimal HSI open area requirement) and 90% forested habitat (maximum optimal HSI forested area requirement), had a population density of one elk per 9.3 ha which utilization indicated was near the carrying capacity of the range (Murphy 1963). Thus, elk were using approximately 2.3 HU/animal of grassy openings. The lack of openings appears to be the most limiting habitat factor in

Table 7. Habitat suitability indices for all habitat variables, Great Smoky Mountains National Park.

Variable	Forested	Open
$V_{1\&2}$	0.94	NA
V_3	NA	0.87
V_4	0.99	NA
V_5	NA	0.96
V_6	0.99	0.99
V_7	0.99	0.99
V_8	0.99	NA
V_9	NA	0.32
V_{10}	0.32	NA
Overall	0.81[a]	0.77[b]

The overall combined weighted average SI value is 0.80.

[a] Using equation $(.94 \times .99 \times .99 \times .99 \times .99 \times .32)^{1/6}$

[b] Using equation $(.87 \times .99 \times .99 \times .99 \times .32)^{1/5}$

GSMNP. By extrapolating these data from Murphy 1963 to opening habitat units available in the study area (10,655/2.3), one might suggest a total carrying capacity of 4,633 elk for GSMNP under present conditions. However, free-ranging eastern herds have lower population densities: Arkansas had 1 elk/181 ha in 1989 (Cartwright 1991); Pennsylvania had 1 elk/234 ha in 1993 (Cogan 1993); and Michigan had 1 elk/169 ha in 1990 (Parker 1990). Lower densities in free-ranging elk are probably not due to habitat quality, but rather to human influences such as poaching, vehicle collisions, and crop depredation.

Mortality Factors

Mortality factors could not be measured within the scope of the HSI and were determined through the use of literature review, interagency discussion, and field observation. In this study the major mortality factors for consideration were predation, poaching,and disease/parasites.

Predation. There are only five major predators of elk to be considered; cougar (*Felis concolor*), gray wolf (*Canis lupis*), red wolf (*Canis rufus*), coyote (*Canis latrans*) and black bear (*Ursus americanus*). The gray wolf is not present in the park at this time, although the smaller red wolf is presently being reintroduced. GSMNP has 19 wolves loose in

the park with plans to release more in the future. Reported cougar sightings are occasionally received by park rangers but none have been confirmed. Thus, neither the wolf nor the cougar could be considered a serious threat to elk reintroduction.

The black bear is likely to be the most serious mortality factor in this reintroduction effort. The park contains from 400 to 600 black bears (McLean and Pelton 1992).

Losses to coyote predation can amount to 30% or more of the calf crop during the first weeks before cows rejoin the herd (Taber et al. 1982). One might speculate that similar losses could be expected from red wolf predation.

An elk herd in GSMNP would have calf mortality due to black bear and coyote predation. Loses would be impossible to predict with no standing crop of elk in the park. However, elk, coyote, and black bear have evolved and coexisted throughout the ranges of all three species. Thus, black bear and coyote predation was considered a natural mortality factor and may not be limiting to elk in GSMNP.

Poaching. Although poaching is a problem in other eastern herds, a herd within the GSMNP might have less pressure from illegal hunting; this would be a non-hunted herd with year-round protection. All hunting, of any species, is prohibited and fire arms are illegal within park

boundaries. The higher elevations where elk are likely to be found are located in the center of the park. Most poaching of other species occurs around the periphery of the park without the necessity of penetrating the deeper reaches of the area. To be successful, a poacher might have to hike as much as 16.1 km inside park boundaries, climb 1,219 to 1,829 m in elevation, chance the sound of a high-powered rifle, and carry a 227 to 363 kg animal the 16.1 km back without detection by park rangers. Poaching problems appear to be most intense near Bryson City and Cherokee, North Carolina. There is a conspicuous absence of white-tailed deer and other species in these areas. The areas recommended as initial relocation sites have substantial deer populations that are easily approached, indicating a lack of poaching activity. Rangers in these areas also report few poaching problems.

Disease. Four major diseases of elk were considered in this assessment: neurologic disease attributed to Parelaphostrongylus tenuis, leptospirosis, brucellosis and bovine tuberculosis.

Neurologic disease (P. tenuis) and leptospirosis are presently found in the park and control is not possible. However, known losses in Arkansas, Michigan, and Pennsylvania average 1%/year to neurologic disease and

approximately .5%/year to leptospirosis. One might speculate that similar losses can be expected in GSMNP.

The GSMNP does not contain B. abortus at this time. Tennessee state records indicate the park has been brucellosis free since the disease was eradicated in the Cades Cove cattle herd in 1972.

At present, TB has not been detected in deer or swine in southeastern United States. Tuberculosis infection in free-ranging native deer and elk was not detected by authorities. The National Bovine Tuberculosis Eradication Program applies only to cattle and bison, at present. Federal authority does not exist for cervidae, and therefore, each state must apply their existing regulations individually. A standardized improved skin test for cervidae now exists.

Every precaution should be taken to insure that elk are free of brucellosis and tuberculosis when they reach the release site. Additional testing for anaplasmosis and hemorrhagic disease should be conducted before shipment. Treatment for large liver fluke should be given, prior to shipment, if the parasite is known to occur in the donor herd.

Elevation. In GSMNP, high altitude ambient temperatures average 21.6 C^0 (12 F^0) cooler than lower elevations. Thus, altitude serves as summer and fall

thermal cover. The higher altitudes of GSMNP receive 2.08 m (82 in) annual average rainfall compared with 1.4 m (55 in) in the lower elevations. Elk in higher elevations of GSMNP have two options during severe winter weather: (1) seek thermal cover, or (2) move a short distance (1.6-3.2 km) to lower elevations where conditions are less severe.

Row-cropped Agricultural Areas. It is expected that elk herds in the GSMNP will prefer the higher altitudes which are located far from any agricultural areas. Observation reveals little in the way of large scale agriculture adjacent to the park. The park is surrounded on three sides by national forest with some light agriculture near the remaining border.

Fire History and Management

The myth of an unbroken primeval forest, extending across North America prior to European settlement, has been perpetuated in writings throughout the present century. Accounts of sixteenth, seventeenth, and eighteenth century explorers, however, document vast amounts of cleared land held by native Americans, who likely populated the continent in much higher numbers than have been traditionally accepted (DeVivo 1990).

Fire was the principal tool used by aboriginal inhabitants to clear vegetation (DeVivo 1990). In the Great

Smoky Mountains, fires were set at frequent intervals to encourage the growth of certain species, such as blueberries (Vaccinium vacillans), which were useful for human consumption as well as wildlife habitat (Lindsay 1976). Native Americans, living in the eastern woodland, set fires periodically to burn accumulated litter and undergrowth and encourage grassland (Thompson and Smith 1970).

According to Sondley (1930), expansive grassland communities existed in the Asheville basin at the dawn of White settlement:

> "Most of the lands on and near the French Broad River ....were prairies....At the mouths of the smaller streams in that region tributary to the French Broad River were large canebrakes extending for miles up those tributaries."

Lorimer (1980) determined that the area now known as Joyce Kilmer Memorial Forest in southwest North Carolina was the site of drastic disturbance as far back as 1550. Possibly a fifteenth- to sixteenth-century native American settlement was located in the area and the pioneer species, yellow poplar, later invaded and reclaimed the openings after the area was abandoned (DeVivo 1990).

Perhaps the most extensive use of fire by the aboriginal inhabitants was in the preparation of land for agriculture. After undergrowth was burned, larger trees were killed by girdling. Planting began when sunlight

passed through the dead branches (Brown 1948). Accounts of travelers documented the abundance of cultivated fields and grasslands throughout the Cherokee country. De Soto, in 1540, marched for a day through cultivated fields in southwestern North Carolina (DeVivo 1990). The botanist William Bartram, during his travels in 1775, reported extensive open prairies and fields of corn along the Little Tennessee River (Harper 1958).

Present NPS policy limits forest management practices. The elk habitat improvement goals of such projects should include expansion of open areas, greater oak mast production, and improvement of understory browse. Prescribed burning and natural fires (lightning) are the only tools available for achieving these goals.

NPS fire policies have evolved from no management at all, through the full suppression of fires, to the sophisticated application of scientifically-based fire management strategies (van Watendonk 1990). When Yosemite was set aside as a state reserve in 1864 and Yellowstone as a national park in 1872, there were no efforts to control fires. An era of full fire suppression began when Yellowstone passed to the U.S. Army in 1886 and later, to the National Park Service in 1916. Everglades National Park was the first to experiment with prescribed burning in 1951. In 1963, the Leopold Report influenced the Park Service to reevaluate its fire policies. NPS policy revisions in 1968

allowed the use of fire as a management tool and led to the development of the first wilderness fire management program, in Sequoia and Kings Canyon National Parks. The Yellowstone fires of 1988 led to an examination of NPS fire policy which affirmed the current policy but recommended refinements in implementation (van Watendonk 1990).

A fire management plan is presently under development, by GSMNP, which would allow the use of prescribed burns and lightning-caused fires to burn in certain areas if conditions meet strict guidelines (Nat. Park Serv. 1995). The new policy would benefit the park ecosystem in the following ways: 1) create more dispersed open areas for elk and other opening-dependant species of plants and animals, 2) encourage reproduction of fire-dependant species, 3) reduce dangerous fuel loads, 4) stimulate fresh tender regeneration of forest understory, and 5) encourage establishment of fire-tolerant oak mast producing species by reducing understory and midstory competition from fire-intolerant species (Van Lear 1990).

Ecological Effects of Elk Reintroduction

Grassy balds are found scattered across the higher peaks in GSMNP. Many of these grassy areas are now kept in this earlier stage of succession by artificial clearing of brush by park personnel. Reintroduction of elk might preserve these balds through natural grazing. Others

believe that more natural elk pastures can be created through controlled prescribed burning, producing forest openings much like those originally created by lightning fires (Langdon, K. 1994, Personal comm.).

Pennsylvania elk showed a high preference for blackberry as a food source (Devlin and George 1979). As the Fraser fir trees in the spruce-fir forest of GSMNP die from the effects of the balsam woolly adelgid, blackberry invade the new openings in such dense stands that they prevent regeneration of Fraser fir seedlings (Nicholas, N.S. 1993, pers. commun.). Thus, one might speculate that elk feeding on blackberry may aid the regeneration of Fraser fir seedlings.

Conclusions

1. A habitat evaluation was conducted to study the potential reintroduction of elk (wapiti) into Great Smoky Mountains National Park.
2. The study area size exceeds minimum area requirements.
3. The quality and quantity of food in both forested and open habitats appears to be adequate.
4. The ratio of open areas to forested habitat (10% to 90%, respectively) is not optimal in all parts of the study area. Although openings are well dispersed throughout the area, only 3.19% of the total is open habitat. Areas with reduced carrying capacity, due to a

lack of open area, can be increased to optimal with the addition of new openings and/or enlargement of existing ones. Under existing park policy, only naturally occurring fires or prescribed burning can be used to increase openings. Presently, the lack of open areas is a significant limiting factor.

5. Availability of hiding and escape cover seems to be sufficient for both open and forested areas.
6. Slope appears to be acceptable within the study area.
7. Availability of water seems to be satisfactory.
8. Mortality factors such as predation, poaching, and disease appear to be within acceptable limits.
9. The overall HSI values, for forested and open areas, are 0.81 and 0.77, respectively. The overall values represent both quantity and quality of habitat available to elk in GSMNP. Habitat Evaluation Procedures (HEP) reveal a total of 414,591 habitat units (HU=HSI x habitat area) available for elk in GSMNP (403,936 HU forested area and 10,655 HU open area).

CHAPTER VI

SUMMARY AND RECOMMENDATIONS

1. Continue with phase II of the feasibility by conducting an experimental release of 15-20 elk, equipped with radio collars, to validate the findings of the HSI and phase I feasibility.
2. Due to the lack of open areas, the most likely habitat for successful reintroduction will be near existing openings. Experimental release sites (two) should include Cades Cove, the spruce-fir forest, or Cataloochee. To reduce travel time between sites, Cades Cove and the spruce-fir forest would appear to be the 2 best selections.
3. Future fire policy should reflect the need to create more openings in the study area.
4. Translocation of elk should occur in late fall after cows are bred. Bulls should have antlers removed before shipment. Standard cattle trailers can be used to transport elk.
5. Brucellosis and tuberculosis testing should be conducted at the site of acquisition or as required by state law. Although TB has not been detected in free-ranging elk herds, stocking animals should come from an accredited TB and brucellosis-free herd.

6. Although holding elk in the area for 3-7 days prior to release is desirable (soft release), an immediate hard release seems to work well with this species. However, holding animals for 7 or more days could facilitate identification and treatment of stress-related illnesses before release.
7. The experimental release should take place in 2 groups of 6 or 9 elk, maintaining a 1:2 sex ratio.
8. Experimentally released elk should be monitored and thoroughly documented using standard procedures.
9. Involvement of local residents, sportsmen, and interested groups will be essential to the success of an experimental release project.

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APPENDICES

APPENDIX A

SLOPE, ROAD DENSITY, AND HABITAT INDICIES TABLES

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Table 8.

GIS slopes for Great Smoky Mountains National Park

Degrees of slope	Hectares	Percentage
Background	903.150	0.00
0 (flat)	21099.689	6.21
1	13617.720	4.01
2	9856.890	2.90
3	10254.600	3.02
4	10506.510	3.09
5	12323.340	3.63
6	12896.820	3.80
7	13891.500	4.09
8	15436.170	4.54
9	17839.439	5.25
10	16382.250	4.82
11	17037.541	5.01
12	16926.570	4.98
13	17965.801	5.29
14	15980.490	4.70
15	15311.430	4.51
16	14007.330	4.12
17	13769.190	4.05
18	12354.930	3.64
19	9929.790	2.92
20	8482.320	2.50
21	7011.360	2.06
22	5921.100	1.74
23	4913.460	1.45
24	4344.030	1.28
25	3832.920	1.13
26	3039.120	0.89
27	2466.450	0.73
28	2016.900	0.59
29	1796.580	0.53
30	1517.130	0.45
31	1277.370	0.38
32	1095.930	0.32
33	928.260	0.27
34	740.340	0.22
35	524.880	0.15
36	503.010	0.15
37	418.770	0.12
38	379.080	0.11
39	292.410	0.09
40	209.790	0.06
41	157.950	0.05
42	116.640	0.03
43	102.060	0.03

Table 8 continued.

Degrees of slope	Hectares	Percentage
44	85.860	0.03
45	63.990	0.02
46	49.410	0.01
47	44.550	0.01
48	34.020	0.01
49	24.300	0.01
50	12.150	0.00
51	10.530	0.00
52	8.100	0.00
53	2.430	0.00
54	1.620	0.00
55	0.000	0.00
56	1.620	0.00
57	1.620	0.00
58	1.620	0.00
60	1.620	0.00

Totals and percentages are based on non-zero points

Table 9.

Effect of road density in hunted populations

Km of road/km^2 area	Effectiveness rating
0.00	1.0
0.31	0.8
0.62	0.6
1.24	0.5
1.86	0.4
2.48	0.3
3.10	0.2
3.72	0.1

Table 10. Habitat suitability indicies for all sampled forest types, Great Smoky Mountains National Park.

Forest Type	Geometric Mean SI Values
Cove Hardwood	0.82
Mixed Mesic	0.82
Pine	0.78
Mesic Oak	0.82
Xeric Oak	0.81
Northern Hardwood	0.82
Tulip Poplar	0.82
Pine-Oak	0.82
Mean Forested SI Value	0.81
Open Area	0.77
Overall Weighted Mean SI Value	0.80

APPENDIX B

DISEASES OF SECONDARY IMPORTANCE

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B1. Diseases of Secondary Importance.....139

Appendix B-1.

Diseases of Secondary Importance

Leptospirosis. Second to neurologic disease in mortality potential is leptospirosis. This disease is not considered to be an important disease of elk (Parker 1990). However, because elk may act as a reservoir it should be considered in this study. More than 180 known serovars (serovarieties) of the spirochete bacterium Leptospira interrogans are known to cause this infection. These strains can be both pathogenic and nonpathogenic (Davidson and Nettles, 1988). Twenty-seven strains have been identified in the United States, many of which are pathogenic for domestic animals and humans. Twenty-four pathogenic serovars have been isolated from wildlife in the United States (Wathen and New 1989). Circumstantial evidence suggests good-host parasite adaption with little disease in native host within its enzootic area. Each strain may infect several species of animals, and there are certain serovar/host relationships that occur often. White-tailed deer in the Southeast routinely have antibodies to one or more serovars. However, research indicates that deer are rather frequently exposed to leptospirosis but are not very important in maintaining or spreading the organism (Davidson and Nettles, 1988). This disease is spread to new

host through contaminated food and water. As the animal drinks contaminated water or eats contaminated food, the bacteria enter through mucous membranes or cuts in the skin. The pathogens spread throughout the body by way of the blood stream during the first week. Tissues of the body most often attacked are the spleen, liver, and the kidneys (Wathen and New 1989). Most animals acquiring the infection, undergo a mild generalized infection, and recover. A localized low-grade infection in the kidneys (interstitial nephritis) often will persist, resulting in the passing of leptospiral organisms in urine. This urine is the primary source of infection for other hosts. Clinical signs of leptospirosis may include weakness, anemia, hemoglobinuria, and icterus. Abortion, infertility, and some mortality can be the result of this disease. Although leptospirosis is not considered to be a serious mortality factor in elk, Arkansas Game and Fish Commission reports that 9.7% of documented elk mortalities recorded since 1981 are attributed to leptospirosis. However, this loss represents only three documented deaths in ten years.

Anaplasmosis. This disease is caused by the rickettsia Anaplasma marginale which causes significant annual economic loss to the cattle industry. Infected cattle may have severe anemia, high fever, and icterus with death or chronic debilitation usually following infection (Davidson and

Nettles 1988). Transmission of anaplasmosis is determined by what arthropod vectors occur in the area. In the eastern half of the United States, the disease is transmitted primarily by blood-feeding flies which are rather inefficient mechanical vectors. Thus, white-tailed deer in this region have never been considered anaplasmosis reservoirs. However, black-tailed deer in certain areas of the West are important reservoirs because they are host of the tick Dermacentor occidentalis, which is an efficient biological vector (Davidson and Nettles 1988). Wathen and New (1989) suggest that white-tailed deer in Cades Cove are not seriously affected by this disease nor are they a likely source of infection for cattle. Kistner et al. (1982) concluded that Rocky Mountain elk probably do not serve as reservoirs for anaplasmosis.

Hemorrhagic Disease. Bluetongue (BT) and epizootic hemorrhagic disease (EHD) are closely related viral pathogens of ruminants. Deer, domestic cattle, elk, and pronghorn are susceptible to both agents. Bighorn sheep, domestic sheep, bison, and domestic goats are susceptible to BT but probably not to EHD (Kistner et al. 1982). Both diseases are transmitted by biting midges, usually Culicoides spp.. Outbreaks are limited to summer and autumn, and usually cease with the first killing frost. Cattle are the primary reservoir, but bison and perhaps

other ruminants play a secondary role. Disease seldom occurs in highly enzootic areas due to the native fauna's constant exposure to the pathogens (Kistner et al. 1982). Research indicates most elk show mild or inapparent clinical signs and are not major reservoirs for either virus (Murray and Trainer 1970 and Hoff and Trainer 1973).

Large Liver Fluke. This parasite is virtually nonpathogenic in native cervids. The primary importance of this fluke in elk appears to be limited to concern by hunters about the edibility of meat from infected elk. The parasite does not alter edibility of anything except the liver.

Elk imported from Elk Island National Park in Alberta, Canada to Land Between The Lake National Recreation area, Kentucky were treated for this parasite prior to shipment. The large liver fluke was known to existence in that herd.

APPENDIX C

DATA SHEETS

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Apendix C-1

DATA SHEET

Great Smoky Mountains National Park

Elk Habitat Evaluation

Date: _____ Sample No:____
___

Cover Type: _____

Elevation:_____ Aspect:_____

Location:

Forested areas

V1 Vegetational Structural Layers:

	% Ground Area Coverage				% Sight Board Coverage at 15m				
	0-25	25-50	50-75	75-100	0-20	20-40	40-60	60-80	80-100
Over.	____	____	____	____	____	____	____	____	____
Mid.	____	____	____	____					
Shrub	____	____	____	____					
Forb	____	____	____	____					

V2 Slope: Degree Of Slope_____

V3 Sight Distance:

	% Sight Board Coverage									
	0-10	10-20	20-30	30-40	40-50	50-60	60-70	70-80	80-90	90-1
m										
61	____	____	____	____	____	____	____	____	____	___
66	____	____	____	____	____	____	____	____	____	___
71	____	____	____	____	____	____	____	____	____	___
Ot	____	____	____	____	____	____	____	____	____	___

V4 Number Of Oak Mast Producing Trees:

Total Oaks Trees _____

Page 2

Open Areas

V1 Distance From Cover: Distance _____ m

V2 Slope: Degree Of Slope_____

Comments:

Variables listed below will not be measured in the field. These variables will be determined from GIS and USGS maps.

Forested areas

V5 Sample Site Distance From Edge: Distance _____ m

V6 Distance To Water: Distance _____ m

V7 Distance To Row-cropped Ag Areas: Distance _____ m

Open areas

V2 Distance To Water: Distance _____ m

V3 Distance To Row-cropped Ag Areas: Distance _____ m

VITA

James R.(Bob) Long was born in Etowah, Tennessee on 21 August 1942. He attended schools in Etowah City and McMinn County Public School Systems, where he graduated from Etowah High School in June, 1960. He entered Tennessee Wesleyan College, Athens, Tennessee during August of 1962 where in August, 1967 he received the Bachelor of Science in Biology with teaching certification in secondary education. After teaching until spring 1984, he opened a retail nursery and landscaping business in Athens, Tennessee. After selling his business in 1991, he entered the Masters program in Wildlife Science at The University of Tennessee, Knoxville. He returned to school to pursue an interest in rebuilding ecosystems, through reintroduction of extirpated species, in habitats where such actions are deemed feasible. The masters degree was received August, 1996.

He is presently working with other elk reintroduction programs at Land Between the Lakes National Recreation Area in Tennessee\Kentucky and Pisgah National Forest in North Carolina.