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# A Habitat Suitability Index Model for Ruffed Grouse on the Cumberland Plateau

Melora Ann Doan

To the Graduate Council:

I am submitting herewith a thesis written by Melora Ann Doan entitled "A Habitat Suitability Index Model for Ruffed Grouse on the Cumberland Plateau." I have examined the final electronic 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 and Fisheries Science.

Ralph W. Dimmick, Major Professor

We have read this thesis and recommend its acceptance:

Dave Buehler, John Rennie, Mike King

Accepted for the Council:
Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

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David Buehler

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Accepted for the Council:

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Associate Vice Chancellor and Dean of the Graduate School

# A HABITAT SUITABILITY INDEX MODEL FOR RUFFED GROUSE ON THE CUMBERLAND PLATEAU

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

Melora A Doan
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# ABSTRACT

Two Habitat Suitability Index models were created for ruffed grouse (*Bonasa umbellus*) in the Cumberland Plateau physiographic region of Tennessee One model evaluated winter habitat and the other evaluated brood habitat. The model for winter habitat used four variables to evaluate habitat suitability, including proximity to evergreen shrub thickets, habitat diversity within home range size, ageclass of the overstory and overstory forest group. The brood habitat model used four variables to evaluate habitat for young broods, including proximity to daylighted roads, habitat diversity within home range, overstory ageclass, and overstory forest group. The models were applied to the currently inventoried portion (approximately 30%) of the Catoosa Wildlife Management Area.

These models were used to explore the assumption that there are two major limiting factors for grouse in Tennessee, winter habitat and brood habitat, and to determine the location of the best of these habitats in relation to each other on the Catoosa Wildlife Managment Area Very little of the currently inventoried area had high suitability under either model. On a scale of 0-1.0 where 1 0 is optimal habitat, the winter habitat model classified only 1 06% of the currently inventoried area greater than 0.75 The brood habitat model classified only 0 30% of the inventoried area greater than 0 75 Areas with HSI values above 0.75 for both models were often within home range size, but the scarcity of high quality habitat on Catoosa indicates grouse densities will remain low without increased forest management for their needs.

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# CHAPTER I

# INTRODUCTION

The ruffed grouse (*Bonasa umbellus*) has rapidly gained in popularity as a game bird in Tennessee in recent years (Tennessee Wildlife Resources Agency 1990a). The Tennessee Wildlife Resources Agency (TWRA) estimated that 20,000 grouse hunters participated in the 1990 grouse season. This number is expected to increase to over 24,000 by 1995 (TWRA 1990a) The gain in grouse popularity, however, has not been matched by increased understanding of ruffed grouse ecology in the southern periphery of its range (Boyd 1990) Although ruffed grouse habitat in eastern Tennessee is believed to have been stable for the past 25 years, the TWRA (1990a) noted ruffed grouse habitat is expected to decrease as a result of urbanization. Habitat for ruffed grouse may also decrease because of a decline in forest harvest on public lands Thus hunter demand for ruffed grouse hunting opportunities may exceed supply provided by the available habitat (TWRA 1990a)

Recent progress has been made in research concerning the ecology of ruffed grouse in Tennessee, especially from the Tennessee ruffed grouse serial reports (Longwitz 1985, Epperson 1988, Boyd 1990, Kalla 1991, Pelren 1991, Hollifield 1992). A study of the quality and quantity of ruffed grouse habitat in eastern Tennessee would greatly benefit resource managers as they plan for the future. To manage the ruffed grouse resource in Tennessee efficiently, all current and future data on Tennessee ruffed grouse need to be coordinated in a statewide database

Geographic Information Systems (GIS) provide long-term information storage and the means for updating, manipulating, analyzing and displaying wildlife-habitat relationships over time (Environmental Systems Resource Institute 1990, Williams 1986). GIS also have the ability to analyze large amounts of spatially referenced data efficiently and accurately (Williams 1986). GIS are used extensively by federal and state agencies for natural resource planning and evaluation State wildlife agencies use GIS most often for habitat mapping and developing land use inventories, but GIS are also useful for vegetation mapping, species distribution, preferred habitat, land ownership, and land development (Munroe and Decker 1991) A strength of GIS is the ability to quantify habitat interspersion and juxtaposition, which can be very important to species abundance and distribution (Heinen and Cross 1983, Cooperrider 1986, Morrison et al 1992). GIS use is most appropriate for long-term research areas where habitats change over a period of time (Williams 1986).

GIS based models are useful because of their ability to create customized resource maps to answer specific management questions GIS based models have been used to map habitat for individual species (Bruce 1992, Falconer 1992, Gagliuso 1991, Hodgson et al. 1988, Ormsby and Lunetta 1987), for guilds of species (Kempka et al. 1992), and for entire refuges for many species (GIS World Staff 1993). Palmeirim (1985) combined satellite imagery and GIS to manipulate vegetation data to create a map evaluating the quality of ruffed grouse habitat in Kansas This map was used to select potential reintroduction sites for ruffed grouse. Similar applications of such models may be used in Tennessee in attempts to increase ruffed grouse availability Williams (1986) successfully used a GIS model to characterize ruffed grouse drumming habitat in Pennsylvania to determine habitat quality and improve population survey efforts by identifying suitable habitat areas

Geographic information systems have been used in other upland game bird studies as well Donovan et al (1987) evaluated a GIS used to develop a HSI model for turkey (*Meleagris gallopavo sylvestris*) in Michigan, and noted the model was adequate for determining turkey brood rearing habitat. Perras et al (1988) used TM satellite imagery with GIS to map reproductive habitat available to woodcock (*Scolopax minor*) near Montreal, Canada. They found remote sensing was suitable for mapping woodcock breeding habitat. In a study of sage grouse winter habitat in Utah, Homer et al. (1993) determined that large scale remote sensing methods with a GIS for ancillary data could be linked to fine scale plant and animal patterns, such as those seen with sage grouse (*Centrocercus urophasianus*) and sage brush (*Artemesia* spp )

The TWRA created a model for ruffed grouse in the Catoosa Wildlife Management Area (WMA) on the Cumberland Plateau of Tennessee using GIS in 1979 (Lorenda Scharber, Tennessee Wildlife Resources Agency, GIS Division, pers comm 4/91). This model evaluated winter habitat only, and was very complex. Five variables evaluating food and four variables evaluating cover were combined in matrices to determine final habitat quality Since then, telemetry studies of grouse habitat utilization have been done in the Catoosa WMA (Longwitz 1985, Epperson 1988) These studies delineated more completely the necessary habitat components for ruffed grouse, and provided general information on variables for habitat modelling for this study Epperson's (1988) study also demonstrated significant differences in habitat utilization among age-sex groups. This, coupled with other researchers' determinations that winter habitat (Servello and Kirkpatrick 1987) and/or brood habitat (Stewart 1956, Kimmel and Samuel 1984) are limiting factors for southern grouse populations, suggested there may be merit in creating two HSI models for ruffed grouse in the Southeast: one for winter habitat for adults and one for brood habitat for family groups (females with broods).

This study updates TWRA's model for analyzing habitat suitability for ruffed grouse in the Cumberland Plateau physiographic region using the TWRA's existing GIS plus additional data gathered from Catoosa foresters. This project created two Habitat Suitability Index (HSI) models that estimate habitat quality rather than population density per se (Bart et al. 1984), and allow wildlife resources to be considered along with other aspects of project planning, such as engineering or economics (Schamberger and O'Neil 1985). Ultimately, these models may be used to create a map of the location and condition of ruffed grouse habitat over the entire Catoosa WMA, and provide the basis for future model application to the rest of the Plateau region of Tennessee.

The objectives of this study were:

1) To create two habitat models for ruffed grouse in the Cumberland Plateau physiographic region, one for adult birds during the winter season and one for females with broods (family groups) during the brood period, and
2) To create habitat maps based upon these models for the Catoosa Wildlife Management Area

# CHAPTER II

# HABITAT ESSENTIALS

To manage habitat for ruffed grouse initially requires determining where grouse prefer to live and what they prefer to eat. Beyond this, it is also important to learn what factors limit grouse populations. Both winter habitat and brood habitat have been proposed as limiting factors for grouse in the southern portion of their range (Stewart 1956, Kimmel and Samuel 1984, Norman and Kirkpatrick 1984).

## I. Winter Habitat

Winter habitat includes both food and cover necessary for over-winter survival and strength into the reproductive season. Grouse in poor physical condition at the end of winter do not engage in breeding (Gullion 1984a). The adult ruffed grouse is primarily vegetarian, and catholic in its tastes During the fall season when foods are most abundant (Gullion 1966b), grouse have been reported to eat over 300 plant species (Gross 1937). However, the winter season is the most critical for food, and the variety of plant materials eaten at this time reflects the grouse's attempts to maximize energy intake Foods that are high in fat and calories are selected (Korschgen 1966, Huff 1973). Buds, twigs, and catkins are the most common winter foods of northern grouse all winter

(Svoboda and Gullion 1972). In particular, northern grouse heavily utilize catkins and buds from certain male aspen (Gullion 1984a) Southern grouse primarily eat fruits, ferns, and leaves from herbaceous and woody plants during winter (Stafford and Dimmick 1979, Seehorn et al. 1981, Norman and Kirkpatrick 1984, Servello and Kirkpatrick 1987). Heavily utilized foods include greenbrier, honeysuckle, and evergreen leaves (Stafford and Dimmick 1979, Seehorn et al 1981). Servello and Kirkpatrick (1987) showed that the southern grouse diet changed from primarily soft fruits (e.g., greenbrier, dogwood, grape, honeysuckle) at the beginning of winter to primarily evergreen leaves (mountain laurel, Christmas fern) by late winter, when food sources are scarcest Servello and Kirkpatrick (1987) calculated southern grouse must utilize evergreen leaves for approximately six weeks in late winter; this time could double in years of poor soft mast production

The amount of evergreen leaves in the diet may be the key to ruffed grouse nutrition and survival in the Southeast. These forages are high in phenolics, potentially toxic compounds that can interfere with protein digestion and absorption (Forbes and Bechdel 1931, Bump et al. 1947, Armstrong et al 1974) This has prompted some researchers to speculate that winter diet may limit southern grouse populations (Servello and Kirkpatrick 1987, Hewitt et al. 1994).

Foraging in aspen provides several advantages for northern grouse The buds and catkins are high in protein, low in secondary metabolites (such as phenolics), and are easy to procure in a limited time. Aspen buds and twigs are 12-13% protein, and have 3-4% phenolic levels The evergreen leaves utilized by southern grouse (primarily Christmas fern and mountain laurel) have 8-9% and 10% protein, respectively. The phenolic levels of these forages are extremely high compared to aspen materials, at 42% and 34%, respectively (Doerr et al. 1974, Servello and Kirkpatrick 1987).

Preferred male aspen twigs are stout, and allow for easy movement along the branches to get buds. Plus, each twig provides 5-8 buds. This ease of movement and food gathering conserves body heat and energy Feeding times are also low, averaging 17 minutes per foraging period, limiting exposure to predators (Doerr et al. 1974, Gullion 1984, Huempfner and Tester 1988)

In comparison, southern grouse are estimated to require foraging times greater than 100 minutes per day (under ideal conditions) to satisfy energy requirements (Hewitt 1994) Grouse cannot subsist on a diet high (>40%) in evergreen foliage (Bump et al. 1947, Servello 1985, Hewitt 1994). Servello and Kirkpatrick (1987) suggested that grouse may even eat less in late winter to avoid a continuous high intake of evergreen leaves. However, broadleaf evergreen forages are important because their large leaf size allows high feeding rates High feeding rates decrease foraging time, thereby lowering energy expenditure and exposure to predation (Hewitt 1994).

Hewitt (1994) noted two ways foraging habits could limit ruffed grouse populations in the south One, limited high quality habitat means more grouse must use poorer quality habitat This raises risks of predation due to longer foraging periods and/or foraging in less protected areas Nutrient deficiency can also result from lower quality plants in poor habitat. Hewitt (1994) found Virginia grouse forage more than 5 hours/day, supporting this hypothesis. Thompson and Fritzell (1987), and Kurzejeski and Root (1988) in Missouri noted lower survival rates of grouse with the greatest daily movements. Ultimately, grouse in poorer habitats will have lower survivorship. Thus, the proportion of a landscape in high quality habitat can determine grouse density

Secondly, southern grouse diets have low protein.energy ratios (Servello and Kirkpatrick 1987). Phenolics in evergreen forages may intensify the problem by interfering with protein digestion. Beckerton and Middleton (1982) showed protein deficiencies led to reduced clutch size and chick survivorship in grouse. Moss et al (1974) postulated that maternal nutrition should determine chick survival in tetraonids. However, no research has investigated whether low protein in winter actually reduces reproductive success of ruffed grouse in spring

Winter cover provides grouse with a place to hide from predators as well as to conserve body heat and energy. Grouse do not put on fat reserves in the fall that will last the entire winter (Gullion 1984b) Thus, grouse remain active and meet energy demands by increasing metabolic rates (necessitating increased feeding) and decreasing nocturnal body temperatures. Heat loss is reduced through selection of micro-habitats (e g , evergreen shrubs or trees, snowburrowing) [Thomas et al 1975, Gullion 1984b, Thompson 1987, Thompson and Fritzell, unpubl data (cited in Thompson 1987)]. Northern grouse have highest survival in sapling alder, aspen, and upland brush habitat, but snow roosts provide the most benefits. Snow roosts completely conceal grouse from predators and afford great thermal advantages Ruffed grouse lack sufficient feather insulation to stay warm below -7°C Cold temperatures cause heightened metabolic rates, which in turn increases energy requirements and causes stress over extended periods (Barber 1989). However, snow drift temperatures rarely fall below -7°C, even when the ambient air temperature is much colder (Gullion 1970). Snow blocks airflow, reducing windchill Snow burrow sites averaged 6.7°C warmer than other roosting sites in Minnesota (Gullion 1970) The longer a grouse can snow roost, the better its chances of survival (Gullion 1970).

Wherever snow is inadequate for burrowing, such as in the south, grouse seek the best insulation they can find This is often provided by conifers (Thompson 1987). Habitats with dense understories and thick overhead cover as well as areas with thick grasses and sedges at ground level are also used Blown or tipped treetops are favorites, as well as wherever direct sunlight gets through the canopy (Barber et al 1989). White and Dimmick (1978) observed transplanted grouse in western Tennessee used brushy areas from clearcuts, abandoned farmland and shrub thickets of mountain laurel for winter cover Thompson (1987) ascertained metabolic rates of grouse dropped 33% in snow cover, 19% in red cedar canopies, 18% on the ground under cedars, and only

6% in deciduous trees. This was in comparison with open air metabolic rates with temperatures ranging from 20°-0°C and 3 m/s wind speed Wind speeds in cedar tree and ground roosts dropped 75% compared to open areas, while deciduous roost wind speeds dropped 50% (Thompson 1987). Although grouse in the south cannot obtain the high energy savings provided by snow, their micro-habitat selection is very important to their survival.

## II Brood Habitat

Brood habitat must also provide sufficient food and protective cover. Barber et al. (1989), and Berner and Gysel (1969) stated the brood season is the most critical in the life of the ruffed grouse, and that good brood habitat is essential to productive grouse range. Bump et al. (1947) noted 87% of annual reproductive potential was lost during the brood season. Barrett (1970) further suggested the most critical time for grouse chicks is the early brood period Ruffed grouse chicks are heavily dependent upon insects during their first five weeks (Johnsgaard et al. 1989). Although many researchers have demonstrated the importance of insects to young grouse chicks (Bump et al. 1947, Stewart 1956, Hungerford 1957, Berner and Gysel 1969, King 1969, Thompson 1987), only a few studies have examined which habitats support the most insects as well as the most favored taxa (Kimmel and Samuel 1978, 1984, Hollifield 1992)

Areas that produce the most insects contain large quantities of herbaceous vegetation in the groundstory (Healy 1985, Hollifield 1992). Healy

(1985) found arthropods were numerous only in sites containing high quantities of succulent ground cover. Hollifield (1992) revealed that arthropods had highest abundance on managed (planted to clover or orchard grass) logging roads and in mature hardwood stands with herbaceous ground cover Harris (1981) and Baake (1980) found broods selected areas with greater numbers of species in the groundstory. Godfrey (1975) discovered that brood-preferred lowland habitats contained twice the number of herbaceous species as uplands. Broods in North Carolina were found in mature forest with abundant groundstory vegetation (Hein 1970). As is true for wintering adults, foraging broods are exposed to predation and inclement weather. Better habitats allow decreased foraging times and probably increase survival rates Kimmel and Samuel (1984) demonstrated young (2-4 weeks) broods in poor quality habitat foraged 7.4-9 0 hours per day, but broods in high quality habitat foraged only 3.7-5 1 hours per day.

Universally preferred insect taxa include Hymenoptera, Coleoptera, and Lepidoptera (Bump et al. 1947, Stewart 1956, King 1969, Kimmel and Samuel 1984) Other groups can be locally important (Homoptera, Diptera, Araneae) (Stewart 1956, King 1969, Kimmel and Samuel 1984) Harris (1981) observed his monitored broods moved to uplands to take advantage of an outbreak of fall canker worm (*Alsophila pometaria*). Harris (1981) suggested grouse chicks are opportunists, and that localized food abundance governed family group movements Stewart (1956) also noted an abrupt change in habitat use patterns when broods moved to uplands to take advantage of ripening blueberries.

Many authors have observed that good brood habitat is typified by vegetative diversity (Bump et al 1947, Stewart 1956, Sharp 1963, Hein 1970, Godfrey 1975). Microhabitat selection is important to broods for adjustments to temperature changes, wind direction and velocity, precipitation and relative humidity (Barber et al. 1989). Many researchers have reported conflicting results concerning patterns of brood habitat use; microhabitat selection is probably partially responsible for this, as may be different approaches to habitat classification. Broods have been observed using upland areas and avoiding lowlands (Schladweiler 1965, Hein 1970). However, Godfrey (1975) and Fisher (1939) noted broods used lowlands. Some authors have found changes in brood habitat use over time. Stewart (1956) and Polderboer (1942) noticed broods moved from lowlands to uplands as they matured Other researchers discovered just the opposite (Hungerford 1951, Eng 1959, Barrett 1970). Still other researchers have found no clear pattern of brood habitat use (Bump et al. 1947, Maxson 1978, Harris 1981).

Broods find shelter from predators in high stem density areas (Polderboer 1942, Bump et al. 1947, Kubisiak 1978, Thompson et al. 1987). While high stem densities are preferred, the ground level must be open Areas with dense grass, timber slash, or woody sprouts are difficult for grouse broods to move through. Habitat structure seems to be more important than species composition. Maxon (1978) observed dense fern cover was ideal for brood movement The ferns provided a nearly closed canopy approximately .5 m from the ground, yet underneath were easy to move through. Ferns and *Rubus* spp. were the most abundant ground level plants associated with broods in Hein's (1970) study Berner (1969) showed family groups preferred dense groundcover .2-1 0 m in height.

# CHAPTER III

## STUDY AREA

The models used in this study were created for the Catoosa Wildlife Management Area (WMA) specifically, but with consideration for their application to the rest of the Cumberland Plateau region Catoosa WMA encompasses 32,400 ha in Cumberland, Fentress, and Morgan counties near Crossville, Tennessee (Fig. 1). Catoosa WMA is in the Cumberland Plateau physiographic region of Tennessee, and is ecologically representative of this region (State Game and Fish Commission 1954, Epperson 1988) Topography is gently rolling, with sandstone-derived soils of moderate to low fertility (State Game and Fish Commission 1954). The area is 98% forested with approximately 52% in hardwoods, 41% in mixed pine and hardwoods, and 5% in pure yellow pine stands Two percent of the area is in wildlife openings planted to various grains and grasses. Major tree species include black oak (*Quercus velutina*), chestnut oak (*Q. prinus*), southern red oak (*Q. falcata*), scarlet oak (*Q. coccinea*), white oak (*Q. alba*), beech (*Fagus grandifolia*), yellow poplar (*Liriodendron tulipifera*), hickory (*Carya* spp.), shortleaf pine (*Pinus echinata*), Virginia pine (*P. virginiana*), and eastern white pine (*P. strobus*) (State Game and Fish Commission 1954). A more detailed description of the Cumberland Plateau can be found in Longwitz (1985) and Epperson (1988).

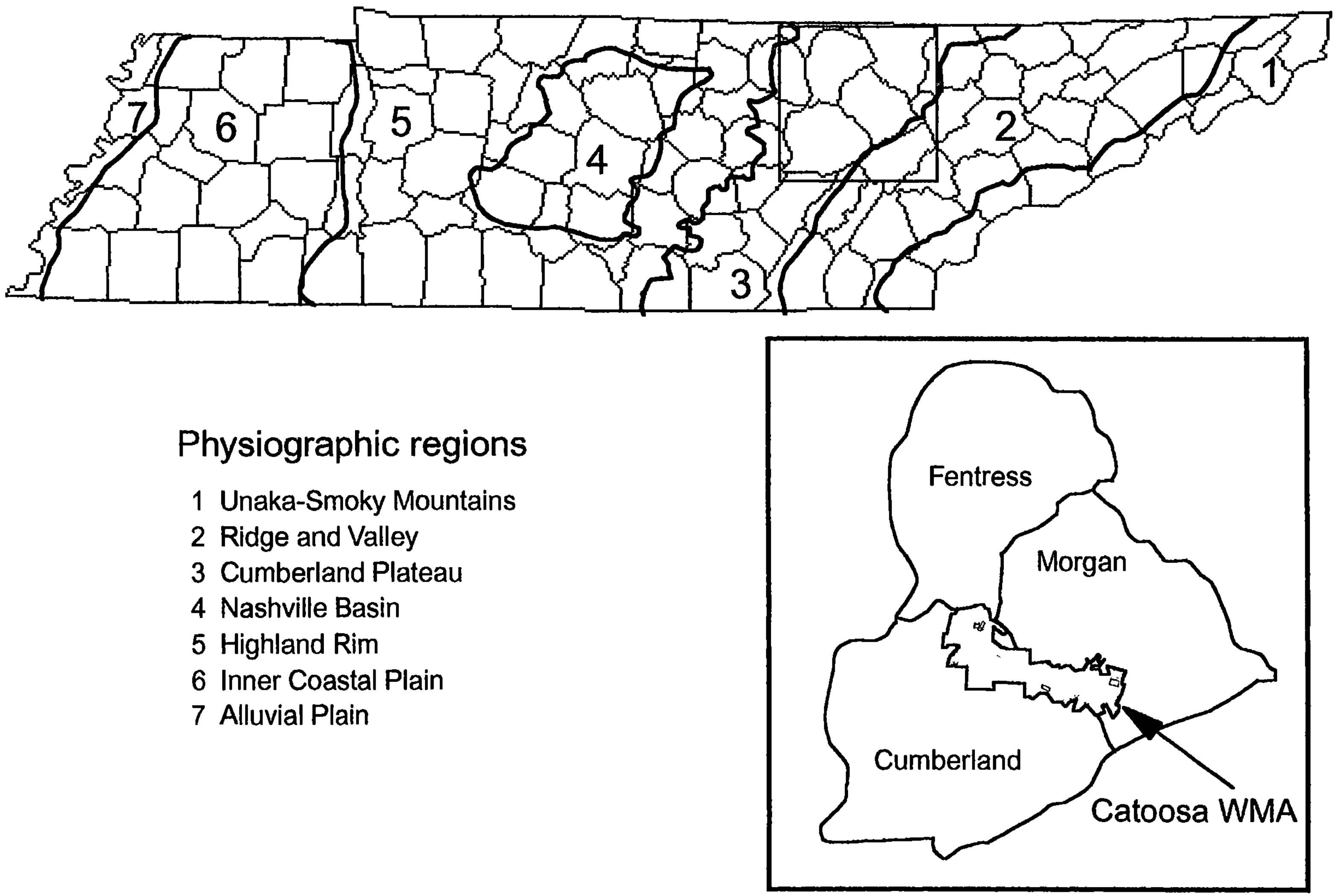



Figure 1 Location of the Catoosa Wildlife Management Area in the Cumberland Plateau physiographic region in Tennessee Taken from USDA-SCS map 4-R-37632, major land resource areas of Tennessee, June 1981

From 1910-1942, the Catoosa area was owned by a syndicate of three companies: the Tennessee Mineral and Lumber Company, the Barbour Coal and Coke Company, and the Morgan and Fentress Railway Company. The syndicate exploited the area for its mineral and forest resources; during the depression the land was burned over and openly grazed, while hunting and fishing were unregulated (Tennessee State Game and Fish Commission 1954) The forests were extensively cut over, and a poor, even-aged structured forest developed (Tom Hughes, Willamette Industries, Tennessee, pers comm 3/93) In 1942 the Tennessee Conservation Commission purchased the Catoosa area with intention of providing a productive land area for hunting then and in the future (Tennessee State Game and Fish Commission 1954)

Timber harvest on the area generates revenue and improves habitat for various wildlife species. From 1952-1961, TWRA harvested timber following selective management practices to improve the quality of the timber resource, emphasizing the removal of low quality trees and thinning areas with high timber volumes Clearcutting operations began in the late 1960's, and selective management was phased out in favor of even-aged management (Tom Hughes, Willamette Industries, Tennessee, pers. comm. 3/93). From 1977-1981, cutting decreased, and only a small volume of trees was removed in a series of firewood cuts (Dwayne Robinson, Tennessee Wildlife Resources Agency, Catoosa Wildlife Management Area, pers comm 5/93) During this time a new GIS and management plan were developed for the Catoosa area (Tom Hughes, Willamette Industries, Tennessee, pers comm 3/93). Since 1979 cutting has been performed for wildlife benefits and to provide revenue for continued management. Currently, 162-182 hectares per year are scheduled for harvest. The success of the new forest management plan can be seen in the increase in deer and turkey harvest over the past 16 years Deer harvest increased from 400 to 600 and turkey harvest increased from 30 to 90+ taken annually (TWRA 1990b). This same management appears to have been beneficial for ruffed grouse as well (Ralph Dimmick, The University of Tennessee, unpubl. data).

Management operations for wildlife include not only timber harvest, but also removing trees within 10 m of the roadedge ("daylighting") of the main and logging roads. These linear openings are planted with various mixtures of grass, grain crop, and clovers, including orchard grass, red, ladino, or kenland clovers, and wheat or rye. Every three years these strips are ploughed to remove woody and unwanted vegetation and reseeded. New linear openings are created at the rate of 20 ha per year by TWRA personnel (Dwayne Robinson, Tennessee Wildlife Resources Agency, Catoosa Wildlife Management Area, pers comm 5/93). Over 200 fields are also maintained for wildlife, either by sharecropping (with an agreement that some of the crop be left in the field), or as wildlife food plots Fields managed as food plots are also replanted every three years (TWRA 1990b)

Other forest management operations include controlled burning and commercial thinning Controlled burns are conducted to prepare sites for pine planting and to improve browse in older pine stands. Only a few hectares per year are burned, mostly due to manpower constraints. Commercial thinnings are also performed in pine stands to either promote better pine growth or to encourage hardwood regeneration. These thinnings are limited to a small area, again due to manpower constraints (Karl Kilmer, Tennessee Wildlife Resources Agency, Catoosa Wildlife Management Area, pers. comm. 6/93).

# CHAPTER IV

# MATERIALS AND METHODS

## I. Geographic Information Systems

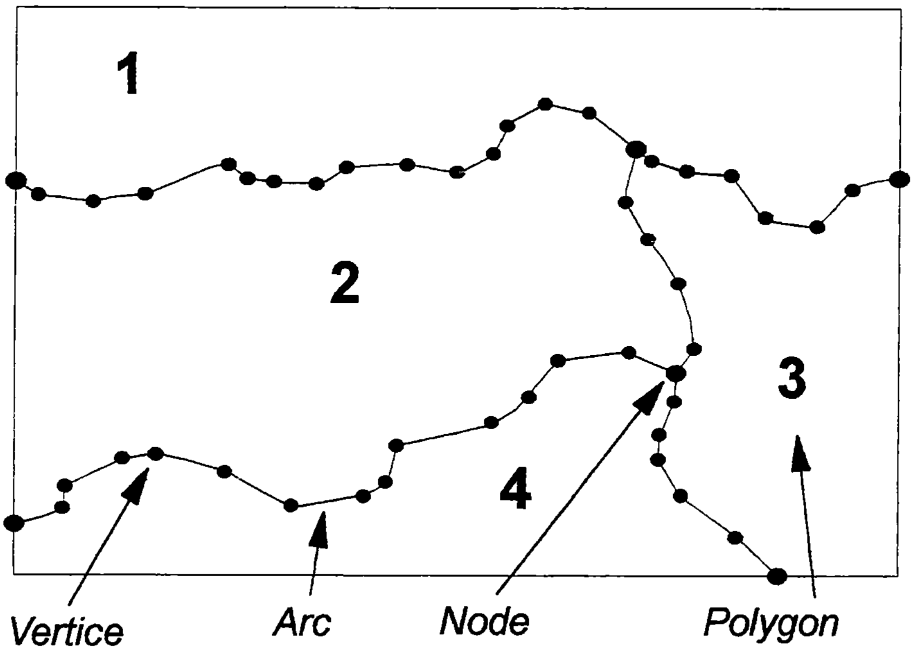
This study used both ARC/INFO and ERDAS geographic information systems for developing models and analyzing data There are two major types of GIS. vector-based systems and raster-based systems. Vector systems associate attributes with a feature such as a point, arc, or polygon (Fig. 2a) ARC/INFO is a vector system. Raster systems (such as ERDAS) associate attributes with a grid cell or pixel (Fig. 2b). Vector-based systems have advantages of high spatial resolution and that points can be located anywhere The main advantage of raster-based systems is that they are simpler than vector systems because all locations are defined by rows and columns (Clark and Van Manen 1993).

The row and column set up of ERDAS was used to create and analyze the habitat diversity component of the model, which was based on polygons of habitat type and could be adequately depicted by pixels ERDAS was used to perform a "filtering" operation to calculate habitat diversity within home range size in a much simpler way than was available through ARC/INFO.

ARC/INFO was used for most of the data analyses because of its high spatial resolution. A vector system like ARC/INFO is better than a raster system

**A**

## VECTOR GIS




**B**

## RASTER GIS

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| 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 3 | 3 | 1 | 1 | 1 | 1 |
| 1 | 1 | 1 | 1 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 3 | 3 | 3 | 1 | 3 | 3 |
| 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 3 | 3 | 3 | 3 | 3 | 3 |
| 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 3 | 3 | 3 | 3 | 3 | 3 |
| 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 3 | 3 | 3 | 3 | 3 |
| 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 3 | 3 | 3 | 3 | 3 |
| 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 4 | 4 | 4 | 3 | 3 | 3 | 3 | 3 |
| 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 4 | 4 | 4 | 4 | 3 | 3 | 3 | 3 | 3 |
| 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 3 | 3 | 3 | 3 | 3 |
| 2 | 4 | 4 | 4 | 4 | 2 | 2 | 2 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 3 | 3 | 3 | 3 | 3 |
| 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 3 | 3 | 3 | 3 |
| 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 3 | 3 | 3 |

*Pixel*

Figure 2 Comparison of vector and raster systems for mapping GIS information for ruffed grouse habitat analysis because grouse use the environment on a finer scale than can be captured with a raster system. ARC/INFO is also the GIS used by both the TWRA and the U S. Forest Service. These agencies will provide most of the future GIS information used to build models for ruffed grouse in other regions in Tennessee.

II Data Acquisition and Analysis

Data analyses were performed using the PC ARC/INFO version 3.4D and ERDAS version 7.5. Data necessary to begin building the database were obtained from the TWRA. The TWRA provided ARC/INFO coverages of roads, water, forest stands, and the Catoosa boundary Additional coverages of forest grouping, stand age, habitat diversity, and buffers were created during this study

Grouse must meet daily and seasonal requirements within a restricted area. Thus, the occurrence of different habitat types and their arrangement within that area is very important In the central part of its range, the appropriate interspersion of habitats can allow a grouse to meet all of its requirements in just 4 ha (Gullion and Svobooda 1972). On the edge of its range grouse will probably need a larger area to meet all life requirements, regardless of interspersion, because overall habitat quality is lower (Woolf et al 1984).

i. Forest Group Coverage

Twenty-four forest types (based on U S. Forest Service classification) are found on the currently mapped area of Catoosa (Fig. 3). These forest types were reclassified into 6 groups, as ruffed grouse probably do not distinguish beyond this level in their habitat choices (Ralph Dimmick, The University of Tennessee, pers. comm. 6/93) (Fig 4). This reclassification groups the forest types primarily on the basis of associated understory components, but also according to topographic location. There are also two non-associated groups, fields and private holdings (Table 1)

ii. Stand Age Coverage

A stand age coverage was created by digitizing areas of cutting from forest sale maps; all cuts from 1967 to 1994 were included Cuts done prior to 1967 were considered mature forest (as far as grouse were concerned). Catoosa forest managers resurvey compartments every ten years Forest stands that were cut in the past decade were assigned the forest type which was managed for after the cut.

Stand age classes were categorized using characteristics described by Hollifield (1992). Class 1 stands were 1-4 years post harvest In the southern Appalachians, the primary flora of this ageclass was blackberry (*Rubus* spp ) and raspberry (*Rubus* spp.), along with the regenerating overstory species (Hollifield 1992)

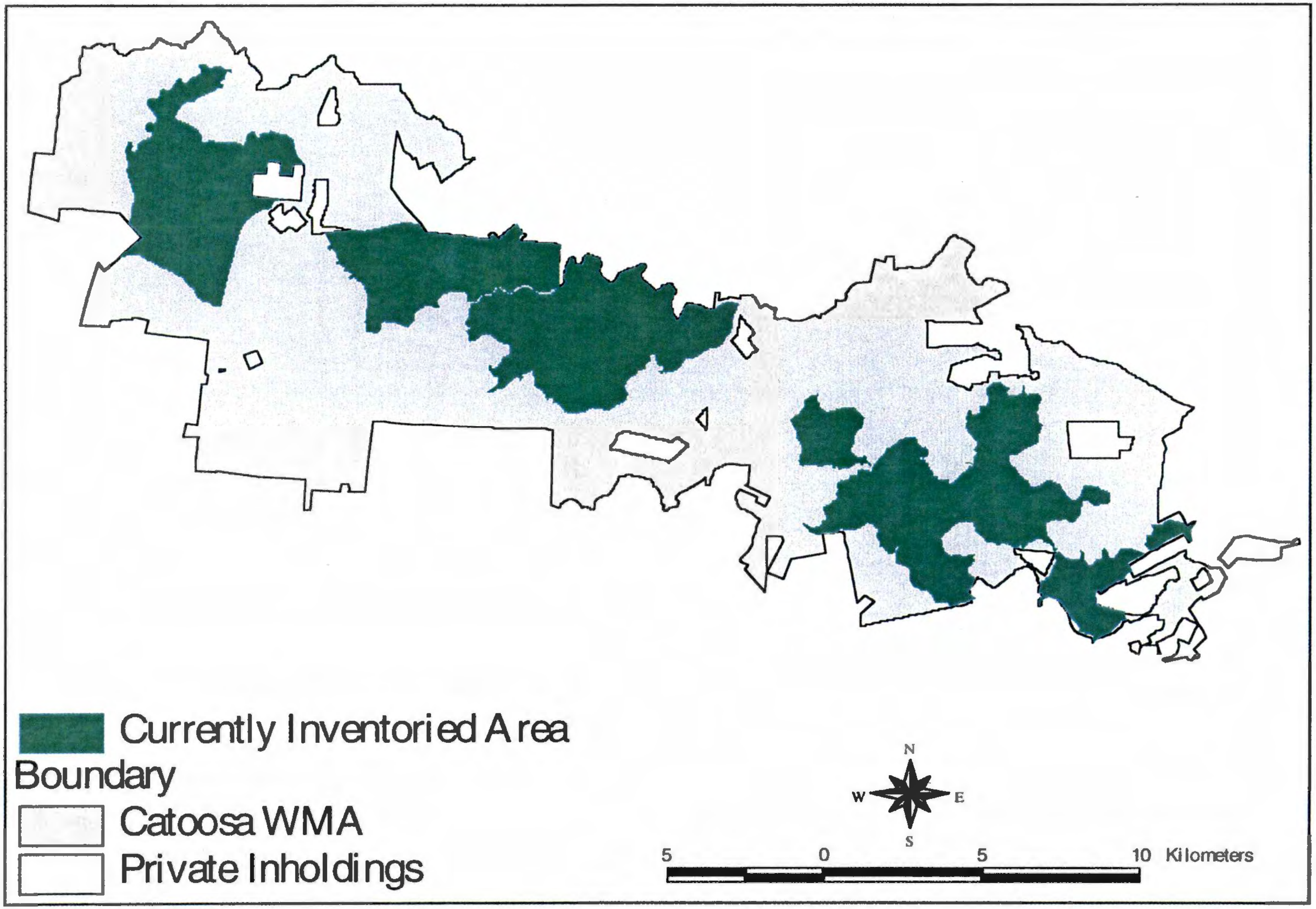


Figure 3. The currently inventoried part of the Catoosa Wildlife Management Area, Tennessee, 1995.

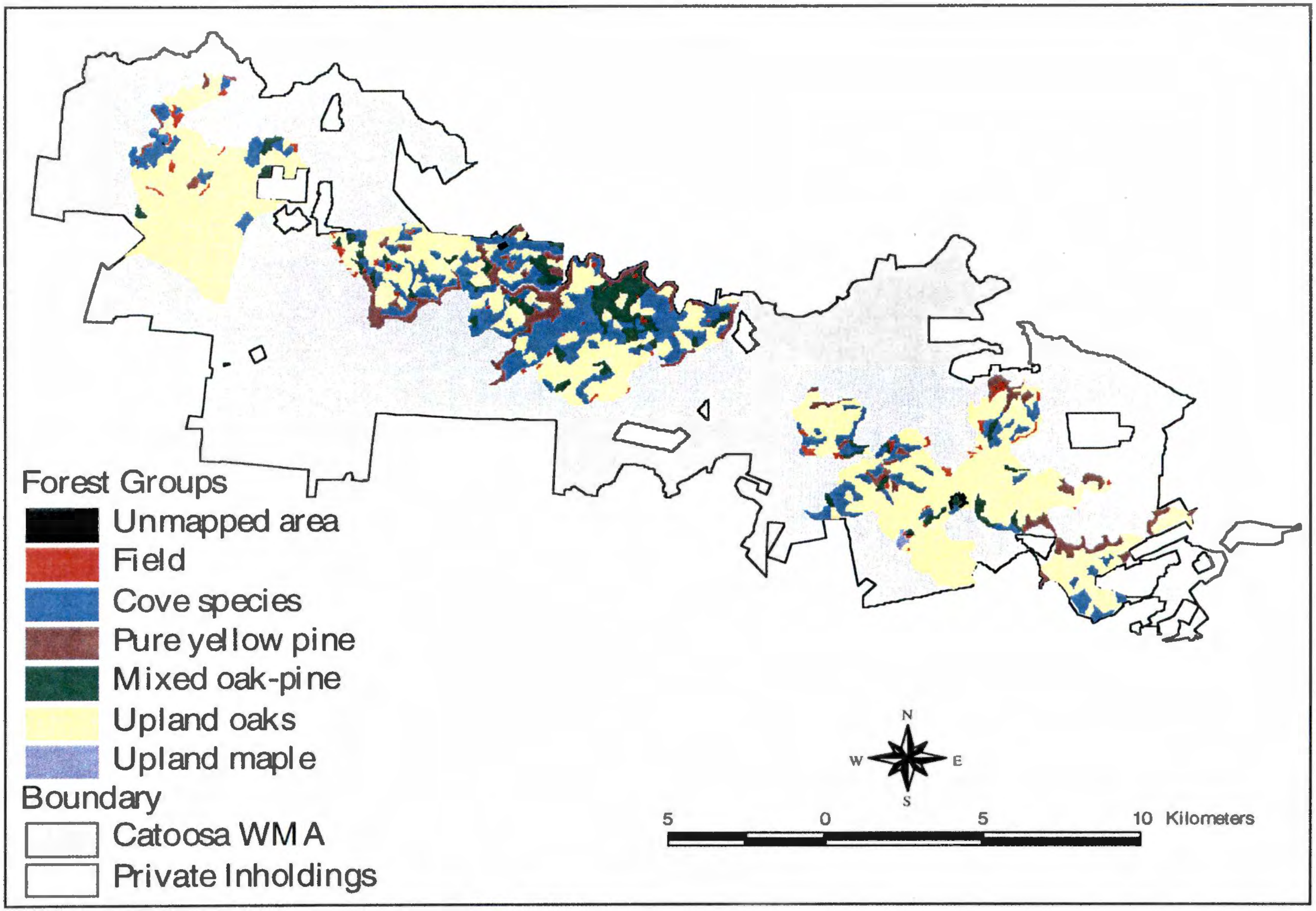


Figure 4. Groups of forest types in the currently inventoried part of the Catoosa Wildlife Management Area, Tennessee, 1995.

Table 1. Model groupıng and percentage of ınventorıed area by forest type

| Model Groupıng | Forest Type | Area (ha) | % of Inventorıed Area |
|---|---|---|---|
| 0 | Unmapped Area | 27 4 | 0 3 |
| 1 | Fıeld | 180 4 | 1 7 |
| 2 | Whıte Pıne | 36.3 | 0 4 |
| | Hemlock-Hardwood | 5 9 | 0 1 |
| | Whıte Pıne-Cove Hardwood | 96 5 | 0 9 |
| | Whıte Pıne-Upland Hardwood | 67 9 | 0 7 |
| | Cove Hardwoods-Whıte Pıne-Hemlock | 311 6 | 5 4 |
| | Upland Hardwoods-Whıte Pıne | 375 6 | 3 4 |
| | Yellow Poplar-Whıte Oak-Northern Red Oak | 117 4 | 1 1 |
| | Subtotal | 1011.2 | 12.0 |
| 3 | Shortleaf Pıne | 311 6 | 3.0 |
| | Vırgınıa Pıne | 343 0 | 3.3 |
| | Subtotal | 654 6 | 6 3 |
| 4 | Shortleaf Pıne-Oak | 555 6 | 3 0 |
| | Vırgınıa Pıne-Oak | 347 4 | 3 7 |
| | Southern Red Oak-Yellow Pıne | 19 2 | 0.2 |
| | Chestnut Oak-Scarlet Oak-Yellow Pıne | 154 5 | 1 5 |
| | Whıte Oak-Black Oak-Yellow Pıne | 667.9 | 6 5 |
| | Northern Red Oak-Hıckory-Yellow Pıne | 4 6 | 0 1 |
| | Black Oak-Scarlet Oak-Yellow Pıne | 240 5 | 2 3 |
| | Post Oak-Black Oak | 48 2 | 0 5 |
| | Subtotal | 2037 9 | 17 8 |
| 5 | Chestnut Oak | 8 2 | 0 1 |
| | Whıte Oak-Red Oak-Hıckory | 6116 4 | 59.6 |
| | Whıte Oak | 48 8 | 0 5 |
| | Scarlet Oak-Black Oak | 134 4 | 1 3 |
| | Scarlet Oak | 8 0 | 0 1 |

Table 1. (cont )

| Model Grouping | Forest Type | Area (ha) | % of Inventoried Area |
|---|---|---|---|
| | Black Oak | 8 2 | 0.1 |
| | Subtotal | 6324 0 | 61.7 |
| 6 | Red Maple-Black Gum | 17 1 | 0 2 |
| | Total | 10252 6 | 100.0 |

Waldrop (1983) found stem densities on Catoosa ranged from 12,214 stems/ha the first year after cutting to 17,731-25,537 stems/ha after the fourth growing season.

Class 2 stands were 5-12 years post harvest Hollifield (1992) described the herbaceous understory as lush, with horsemint (*Monarda* spp.), jewelweed (*Impatiens* spp.), blackberry, and various ferns Grapes (*Vitis* spp.) and greenbrier (*Smilax* spp.) were also common Epperson (1988) noted two clearcuts of this age on Catoosa had a high density of hardwood seedlings and saplings, and the understory was dense with blackberry, pokeweed (*Phytolacca americana*), deerberry (*Vaccinium stamineum*), and blueberry (*Vaccinium* spp.).

Class 3 stands were 13-26 years post harvest, with abundant groundcover similar to class 2 stands, but varying in composition (Hollifield 1992) Epperson (1988) did not delineate age class beyond known regenerating areas (all of which were age class 2) and mature forest This study assumed Hollifield's (1992) understory characterization for class 3 stands held true for the Catoosa area also.

Hollifield (1992) characterized Class 4 stands as mature forest (>26 years post harvest), and noted rich herbaceous ground cover in all his study plots of this age Epperson (1988) reported that mature stands on Catoosa had varying understories Upland areas had scattered shrubby thickets of deerberry, blueberry, and huckleberry (*Gaylussacia baccata*) Lower slope areas near drainages had denser understories, consisting of deerberry, blueberry, and scattered to dense pine seedlings Pure pine stands had sparse understories, with scattered *Vaccinium*, *Rubus*, and pine seedlings Fig 5 shows a map of the currently inventoried part of Catoosa by age class.

iii Habitat Diversity Coverage

Individual codes were assigned to each forest type-age class combination, and also to fields and private inholdings. These codes were used to classify individual pixels after conversion of the coverage to ERDAS Areas with commercial thins and controlled burns were not counted in the habitat diversity layer because of their small area and difficulty in determining their extent and the quality of the habitat for grouse following the treatment.

This combined forest type-age class coverage was converted to ERDAS using the ERDARC conversion program from ERDAS (ERDAS 1990) Pixel size was set at 20m x 20m (0.04 ha) Although 10m x 10m pixel size was available, ERDAS could not perform the filtering analysis at this scale This small pixel size was chosen to create a best fit of the polygon edges when ERDAS and ARC coverages were later overlaid for analysis The closer edge fitting created fewer "sliver" polygons where edges did not line up. Also, 20m x 20m resolution best delineated the smallest fields and forest stands on Catoosa (Heinen and Cross 1983)

A filtering process was performed in ERDAS to create two habitat diversity coverages (one for each model).

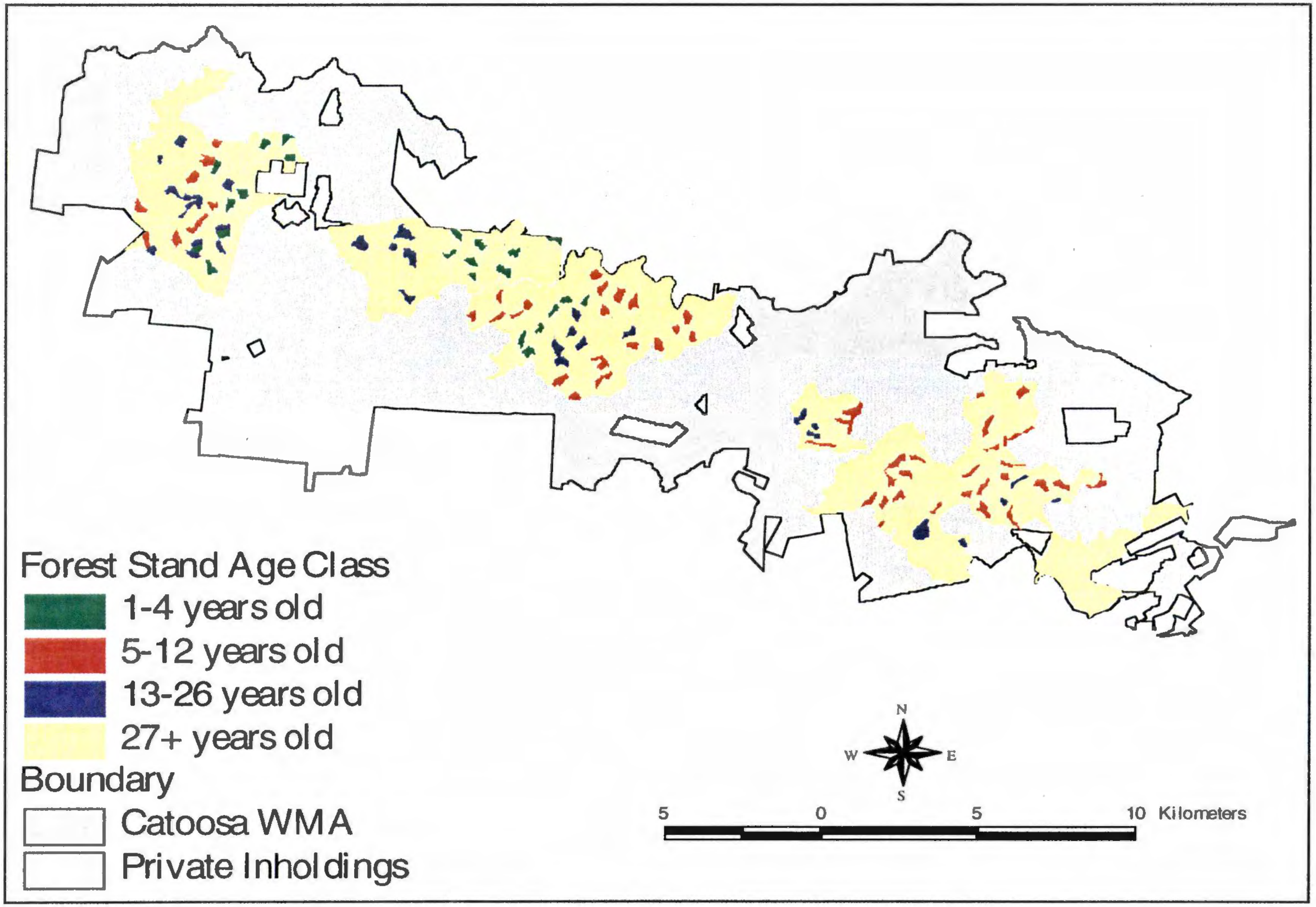


Figure 5. Forest stand age classes on the Catoosa Wildlife Management Area, Tennessee, 1995.

The filtering process looked at the forest type-age class coverage through a "window" which was approximately the size of each model group's average home range size (39.6 ha for the winter model, 43.2 ha for the brood model). A circular window was chosen to best approximate home range shape The window for adult ruffed grouse in the winter had a radius of 17.75 pixels (39.6 ha), the window used for family groups had a radius of 18.54 pixels (43 2 ha).

The number of different cover type-age categories (habitat types) within this window surrounding the center cell was assigned to that center cell as a measure of cover type-age diversity (Fig 6) Pixels near the edges of the original polygons could not be classified by the center cell process These cells were classified the same as the nearest center cell, rather than leaving them out of the end coverage. This process created a habitat diversity coverage for each model group (Figs. 7 and 8)

iv. Buffered Coverages

The road and water coverages were buffered according to road type and stream type. For water features, buffer width varied according to the average width of evergreen shrub thickets measured along each type of feature (rivers, perennial streams, streams flowing more than 6 months per year, streams flowing less than 6 months per year, and ponds). Roads were buffered on each side if they were daylighted (main roads with right-of-way and logging roads). Roads without daylighting were not buffered (state roads and trails).

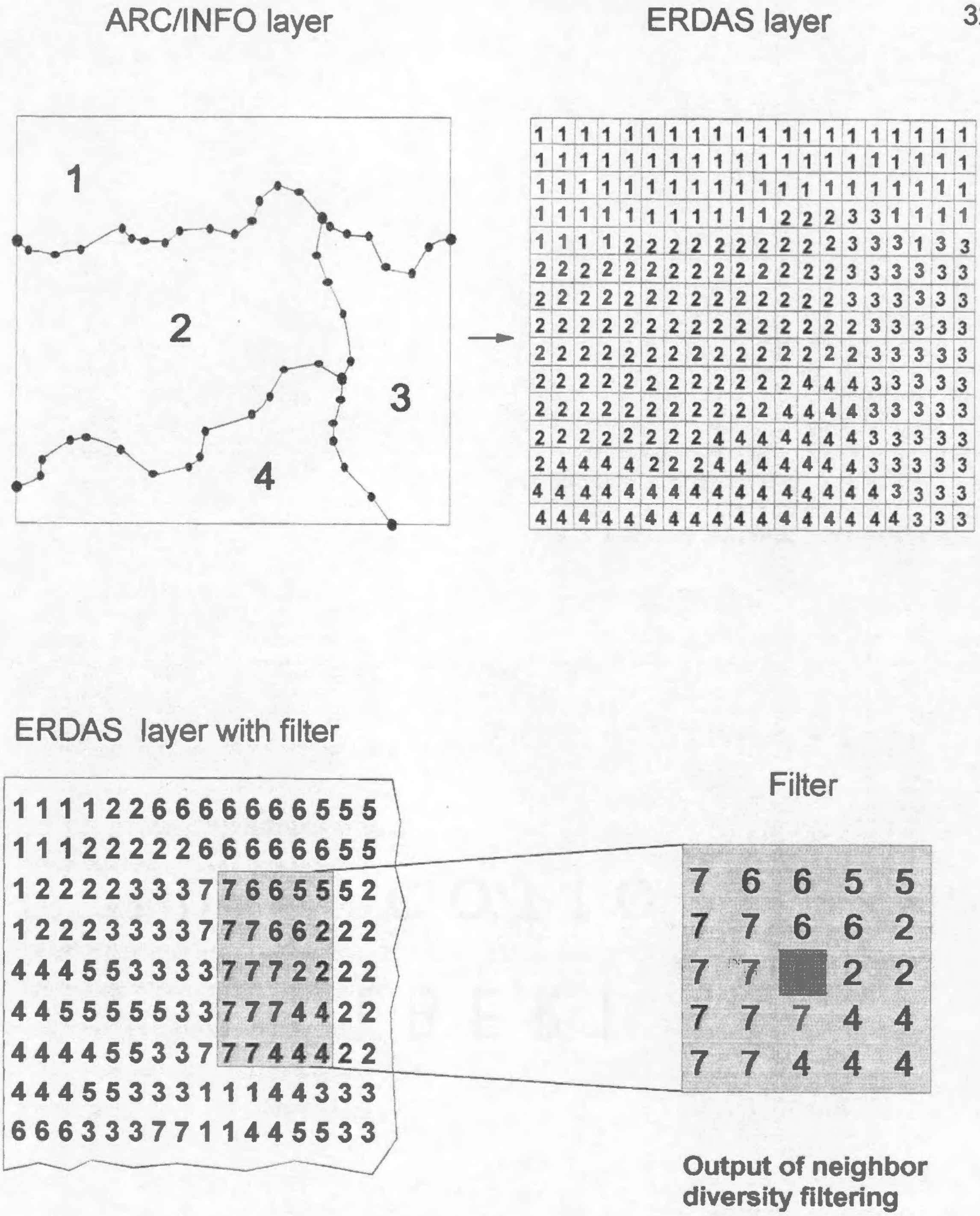


Figure 6. Conversion of ARC/INFO data to ERDAS for the filtering process, and output of neighbor diversity filtering (note darktone box in center of filter). The center pixel of the filter changes to denote the number of habitats surrounding that pixel.

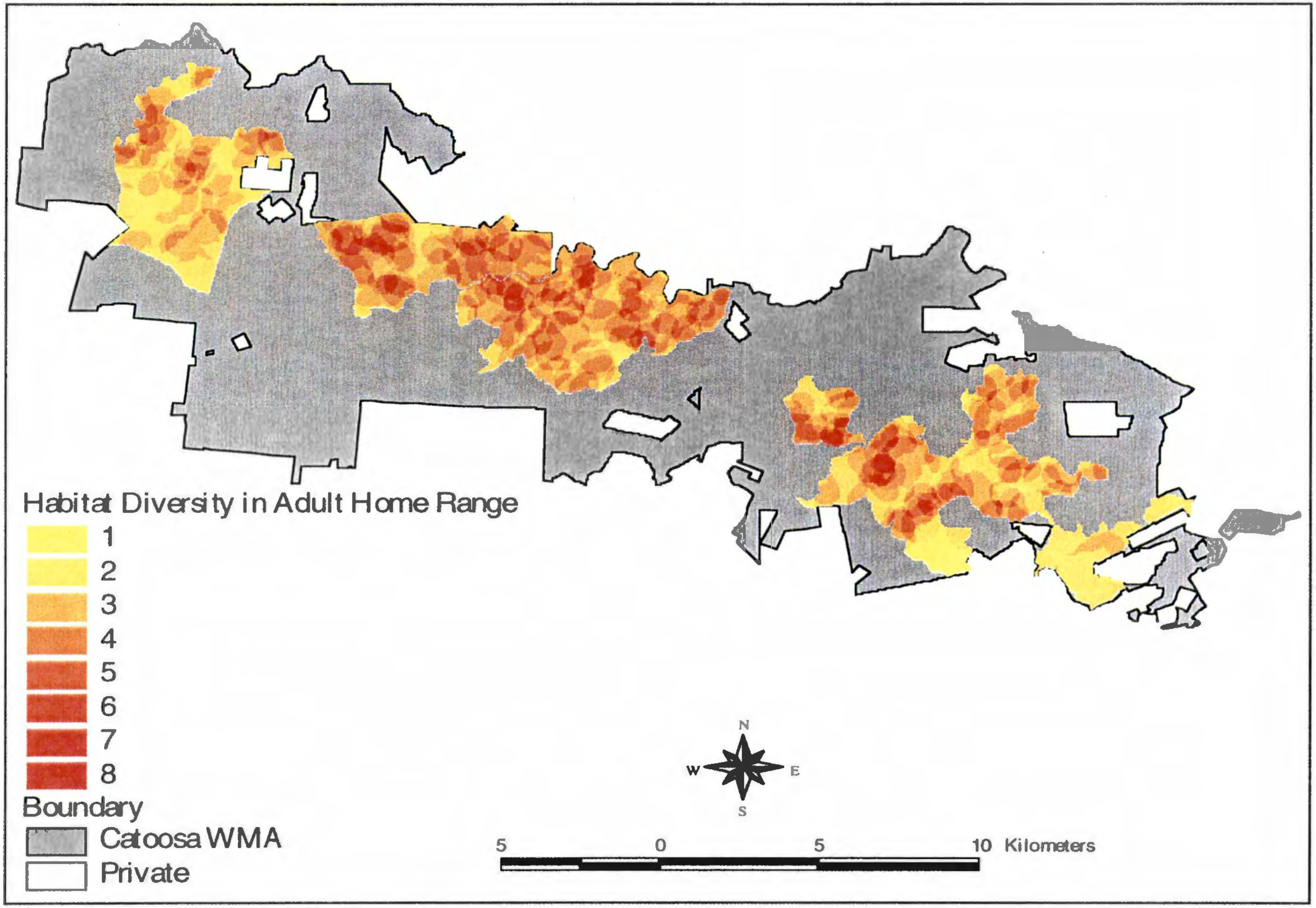


Figure 7. Habitat diversity within home range size for adult ruffed grouse, Catoosa Wildlife Management Area, Tennessee, 1995.

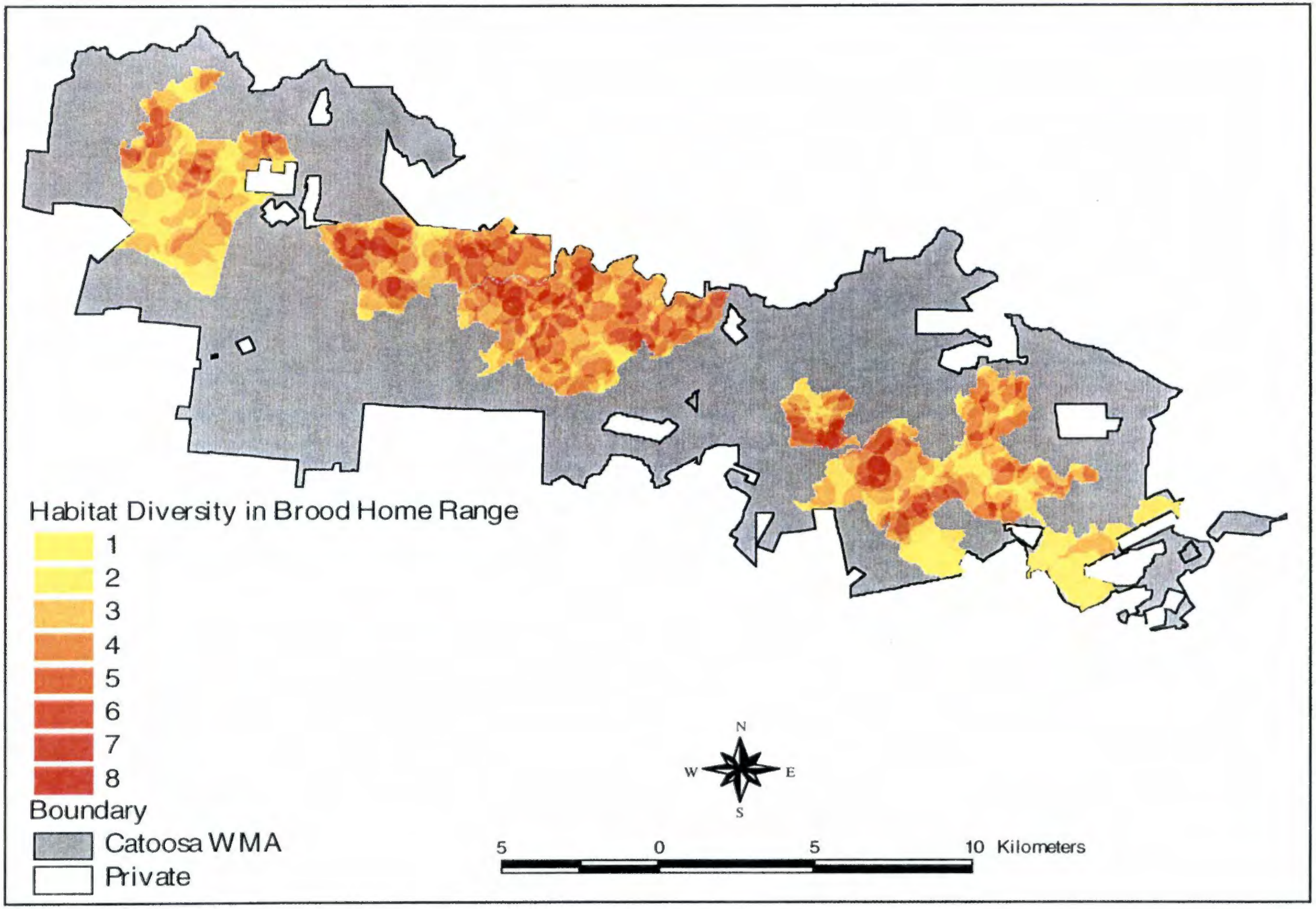


Figure 8. Habitat diversity within home range size for ruffed grouse broods, Catoosa Wildlife Management Area, Tennessee, 1995.

Forest age, forest group, habitat diversity within home range and buffered coverages were sequentially overlaid to include all four variables for each model The final coverage was created by calculating the HSI model function for all polygons, and then dissolving the boundaries between all polygons with the same value The HSI values were split into four even groups for each model (quartiles), and categorized as poor (0-.24), fair (.25-.49), good (.50-.74), and excellent habitat (.75-1.0) A map showing these four suitability classes for each model was produced To identify the best habitat according to both models, areas having HSI values in the highest quartile (0.75-1.00) in both models were overlaid in a single coverage to compare the proximity of the best habitat determined by the two models

## III. Model Creation

Models are simplified versions of real-world systems They can never completely emulate the real world, and they require numerous simplifying assumptions (Hall and Day 1977) However, with proper simplification, most system operations and relationships are preserved (Smith 1974). The U S Fish and Wildlife Service (1981) established a standardized process for modeling wildlife habitats. These models utilize basic life requirements (e.g , food, water, protective cover), and assign relative values to habitats based on how well the habitats fulfill these requirements These values are combined to obtain a obtain a Habitat Suitability Index (HSI) for a specified area (Donovan et al 1987)

An existing HSI model for ruffed grouse is applicable for grouse that live in the range of aspen (*Populus* spp.) (Cade and Sousa 1985) The southernmost populations may have different limiting factors than their northern counterparts because ruffed grouse at the southern periphery of their range use different types of habitat because aspen is absent (Cole and Dimmick 1991) Cade and Sousa's (1985) model assumes winter food and fall to spring cover are limiting requirements In the Southeast, winter habitat and/or brood habitat may be important factors (Ralph Dimmick, The University of Tennessee, pers. comm 2/92).

## IV Model Variables

Schamberger and O'Neil (1985) and Cooperrider (1986) noted that acceptable model variables are limited to those: 1) to which the species responds; 2) which can be measured or estimated readily, 3) whose values can be predicted for future conditions; 4) that are vulnerable to change during the course of the project; and 5) that can be influenced by planning and management decisions Variables which meet these requirements have been chosen to approximate the limiting factors for each group Approximation was necessary because ruffed grouse in the southern aspect of their range utilize a wide array of habitats and foods to meet their life requisites. These habitats and foods are most often associated with the understory of the forest, and are difficult to analyze using remote sensing methodologies. The model variables were also chosen to be based on data that are easily and consistently collected over time among agencies and surveying personnel These types of data usually involve the forest overstory, but overstory components can be used to approximate understory conditions (Williams 1986)

HSI models were created for winter habitat and for brood habitat Assumptions differ between these models according to the different limiting factor for each group These models are based on literature reviews, expert opinion, and telemetry data gathered from 17 March - 27 October 1983, 19 March - 13 September 1984 (Longwitz 1985), and 24 April 1985 - 1 May 1986 (Epperson 1988).

Many HSI models use a combination of arithmetic and geometric averaging to compute HSI values from suitability curves (Allen 1984, Cade 1985, Cade and Sousa 1985, Schroeder 1985a, Schroeder 1985b) Variables that do not compensate for each other are usually averaged geometrically (multiplied together and then divided by their total number). Geometric averaging causes an HSI value to be 0 if one variable measures 0 This study assumed grouse would use an area even if one of the variables was 0, rather than avoiding the area. Variables that do compensate for one another are added and then divided by total weights of variables (arithmetic averaging). The variables used in this study's models were considered compensatory. That is, a low value of one variable could be made up for by a high value of another variable. Thus, the models used arithmetic averaging to calculate HSI values. Davis and DeLain (1984) found their HSI model for spotted owls improved when arithmetic averaging was used instead of geometric averaging.

Cade and Sousa (1985) determined final habitat suitability for ruffed grouse in their model by weighting individual habitat scores by their area and then summing these together, the result was then divided by the total area of all cover types available to ruffed grouse Barrett (1970) pointed out that assuming all habitat types were equally available no matter where the grouse was is problematic This study attempted to circumvent this problem by using habitat diversity *within home range size* as a variable in the models for winter and brood habitat. Cade and Sousa (1985) also felt that none of the variables in their calculations of fall to spring cover were able to compensate for any of the others, and multiplied all variables together to determine fall to spring cover habitat suitability. Because each variable in that equation could directly modify each of the others, suboptimal suitabilities for two or more variables would result in a final suitability lower than the lowest suitability of any individual variable I felt that the variables in my models could compensate for each other, especially because they only approximate the finer-scale conditions (e g , temperature, humidity, vegetation density and height) to which ruffed grouse respond

## The Winter Habitat Model

The winter period used in this study extended from December 16 to March

15 (Boyd 1990). Ideal winter habitat provides both shelter from predators and the weather, and provides food (Barber et al 1989). For ruffed grouse in the northern part of their range (where aspen is present), the best winter habitat and survival occurs in sapling aspen and alder stands (14,000-20,000 stems/ha) and upland brush habitat, with some evergreen trees present. Snow also provides important winter cover, both from predators and the cold Snow burrows break the wind and reduce radiant heat loss, as well as completely conceal the grouse from a predator's view (Gullion and Svoboda 1972, Gullion 1977, Crawford 1986, Barber et al 1989). In the southern part of their range, aspen is absent and snow rarely accumulates in depths adequate for roosting burrows White and Dimmick (1978) found ruffed grouse typically use mountain laurel (*Kalmia latifolia*) and rhododendron (*Rhododendron* spp ) thickets for winter cover in Tennessee. Grouse in the Appalachians used evergreen shrub thickets in proportion to their availability in the winter, this was probably because of the ubiquitous presence of the shrubs (Boyd 1990, Pelren 1991) Evergreen tress are also selected for winter cover (Backs 1984, Thompson 1987). Authors disagree on ruffed grouse use of clearcuts for winter habitat in the Southeast Boyd (1990) found southern Appalachian ruffed grouse avoided clearcuts during winter months, but Pelren (1991) found just the opposite in the same area. Clearcut ages ranged from 2-9 years in both these studies. Barber et al (1989) support the contention that ruffed grouse use clearcuts for winter cover. Thompson (1987) showed grouse winter roosts occurred in areas with

significantly higher stem densities than random plots.

On the Cumberland Plateau, laurel-rhododendron thickets occur in a patchy distribution following certain streams and rivers Ten measurements of the width of the evergreen shrub thickets around each type of water feature were made Based on these measurements, buffers of uniform width were assumed around streams equal to the average measured width of the laurel-rhododendron thickets along each type of stream Uniform buffers were used because the forest overstory obscures these thickets on aerial photographs, making digitizing of the actual boundaries of the thickets impossible. Rivers were assigned a 20 m buffer, permanent streams a 33 m buffer, and intermittent streams flowing for more than half the year were given a 20 m buffer. Intermittent streams flowing less than half the year and ponds were given no buffer, because they did not support dense enough laurel-rhododendron vegetation for ruffed grouse to use

Habitat diversity is based on both temporal (stand age) and physical/biological (understory and overstory species composition and density) characteristics. The importance of habitat diversity is shown in several studies on ruffed grouse in the northern US (Polderboer 1942, Bump et al 1947, Gullion and Svoboda 1972, Little and Sheets 1982, Kubisiak 1989) where grouse densities were highest in areas with several age classes of trees, especially aspen Ruffed grouse can fill all life requisites within aspen forests alone if a mosaic of age classes (3-4) is available within foraging range (4 ha) (Gullion and Svoboda 1972). Ruffed grouse in the south depend more on shrubs, vines, and herbs for food and cover requirements than do grouse in the north (Barber et al 1989, Stafford 1989) A habitat diversity coverage was developed that determined the number of habitat types available to adult ruffed grouse within their average home range area This coverage incorporated stand age and forest type to approximate the understory conditions to which ruffed grouse respond

Epperson's (1988) and Longwitz's (1985) telemetry studies on the Cumberland Plateau included seven adult grouse, six males and one female Their home ranges contained 2-5 habitat types, defined by both stand age and forest type. All of these home ranges included laurel/rhododendron thickets. Boyd (1990) and Pelren (1991) found adult ruffed grouse home ranges in eastern Tennessee contained 2-6 habitat types These ranges also all included laurel/rhododendron thickets. A northern Georgia study (Harris 1981) showed adult ruffed grouse used 3-6 habitats in their home range, including evergreen thickets Hale et al (1982) found all vegetation layers contributed to a site's suitability for drumming in Georgia, and that rhododendron and azalea were important at all occupied sites.

Home range size was used in both models to assess habitat interspersion, with the assumption that home range was a good measurement of how far a grouse would travel (on average) to get to a particular habitat. The home range size used for the winter habitat model analysis was the average of all seven adult birds in Epperson's (1988) study, which combined both his and

Longwitz's (1985) telemetry data. Epperson (1988) did not delineate home ranges by season, and monitored only one adult male through the winter. The home range of this male for two seasons, fall and winter, was 20.9 hectares as measured by the minimum convex polygon method. A juvenile male monitored during the same period had a home range of 26.5 hectares. All other birds were monitored during spring-summer or summer-fall The home ranges were averaged to increase sample size and decrease variability This average home range then, is only comparable with other studies covering two or more seasons Comparisons of the average home range of grouse on Catoosa with other studies (Table 2) shows this range is comparable to some southern studies (Boyd 1990, Harris 1991, Pelren 1991), but larger than studies in Missouri (Thompson 1987, Thompson and Fritzell 1989, Neher 1993). Catoosa home ranges were larger than studies done in more northern areas (Archibald 1975, Bakke 1980).

Home range size is a function of habitat quality Smaller ranges will be found in good quality habitat and large ranges in poorer quality habitat where resources are widely dispersed (Woolf et al 1984, Thompson and Fritzell 1989) Species at the periphery of their range are not considered to be in the best habitat (Woolf et al. 1984), although patches of high quality habitat may exist

Table 2 Comparison of home range sizes of adult ruffed grouse.

| Researcher | Location | Time Studied[a] | No of Birds | Mean Home Range [range] | Comments |
|---|---|---|---|---|---|
| Epperson 1988 | Middle Tennessee | Two+ seasons | 5 | 46 6 ha [12 6-96 4] | Used minimum convex polygons |
| | | Fall | 2 | 22 2 ha [15 8-28 6] | |
| | | | 7 | 39 6 ha [12 6-96 4] | Overall average Modified minimum area values are 20 3 ha [4 5-52 7] |
| Boyd 1990 | Eastern Tennessee | Two+ seasons | 6 | 33 1 ha [12 6-51 7] | Used minimum convex polygons |
| | | Fall | 7 | 34 2 ha, 17 5 ha[b] | |
| | | Winter | 4 | 11 8 ha [5 2-20 4] | |
| Pelren 1991 | Eastern Tennessee | Two+ seasons | 3 | 50 ha [37 3-56 5] | Used minimum convex polygons, birds made excursions which greatly increased HR size Only studied males |
| | | Summer | 1 | 56 3 ha | |
| Gudlin and Dimmick 1984 | Western Tennessee | Fall | 2 | 51 5 ha [31 0-72 0] | Used minimum convex polygons Studied reintroduced birds |
| Hewitt 1994 | Southwestern Virginia | Winter | 9 | 14 0±2 2 ha | Used minimum convex polygons |
| Harris 1991 | North Georgia | Two+ seasons | 3 | 31 7 ha [30 9-32 4] | Used an approximation of the modified minimum area method Studied only females during the summer |
| | | Summer | 5 | 25 0 ha [13 9-40 8] | |
| Neher 1993 | Central Missouri | Fall-winter | 14 | 83 ha [36-186] | Used minimum convex polygons Only studied males Adults and juveniles mixed |
| Thompson 1987 | Central Missouri | Spring-summer | 11 | 45±8 5 ha | Used minimum convex polygons Adults and juveniles mixed |
| | | Fall-winter | 12 | 61±15 1 ha | |
| Thompson and Fritzell 1989 | Central Missouri | Spring-summer | 20 | 45±4 4 ha | Used minimum convex polygons Adults and juveniles mixed |
| | | Fall-winter | 12 | 84±12 2 ha | |

Table 2. (cont.)

| Researcher | Location | Time Studied | No of Birds | Mean Home Range [range] | Comments |
|---|---|---|---|---|---|
| Woolf et al 1984 | Southern Illinois | Two+ seasons | 8 | 77 ha [26 9-153 5] | Used minimum convex polygons Studied reintroduced birds |
| Cerretani 1976 | Central New York | Spring | 3 | 7 0 ha [1 6-12 6] | Used minimum convex polygons Monitoring periods were 9-21 days Studied males only |
| Vadas 1984 | Pennsylvania | Two+ seasons<br>summer | 3<br>1 | 16 3 ha [9 3-20 4]<br>12 9 ha | Only females studied during summer |
| Archibald 1975 | East-central Minnesota | Spring | 9<br>3 | 8 9±1 18 ha<br>16 5 [NA][c] | Males Juvenile male included<br>Females Used a modified computer-fill method |
| Bakke 1980 | Northern North Dakota | Two+ seasons | 2 | 14 3 ha [6 4-22 2] | Used the minimum area method |

[a]Seasons are defined as: spring - March 16 to June 15, summer - June 16 to September 15, fall - September 16 to December 15, winter - December 16 to March 15, after Boyd (1990).
[b]Male average, female average
[c]Not Available

Based upon the preceding information, the grouse winter habitat model was developed with the following assumptions:

1) Winter habitat is the factor limiting overwinter survival.

2) Winter habitat can best be approximated by proximity to stream type, habitat diversity within home range size, forest group, and forest age class

3) Home range size averages 39.6 ha (Epperson 1988).

## Habitat Suitability Curve Values

The habitat suitability curves used in the winter habitat model are illustrated in Fig 9. Categories within each variable were subjectively assigned habitat suitability values based on the available literature and expert opinion from Dr. Ralph Dimmick, The University of Tennessee, Knoxville.

The suitability curve for the groups of forest types is illustrated in Fig. 9a Forest groups 0 and 1 (private inholdings and fields) (see Table 1) were given values of 1 Grouse were found to use fields significantly less than their availability on Catoosa (Longwitz 1985, Epperson 1988). Private inholdings consist of privately owned land in agricultural and residential use, because of human and agricultural activity, these areas were expected to provide little habitat for grouse Forest group 2 contains cove associated species Coves are generally more mesic in nature, and support more herbaceous species such as Christmas fern (*Polystichum acrostichoides*), which is a staple for grouse during the winter (Stafford and Dimmick 1979). Coves also support more evergreen

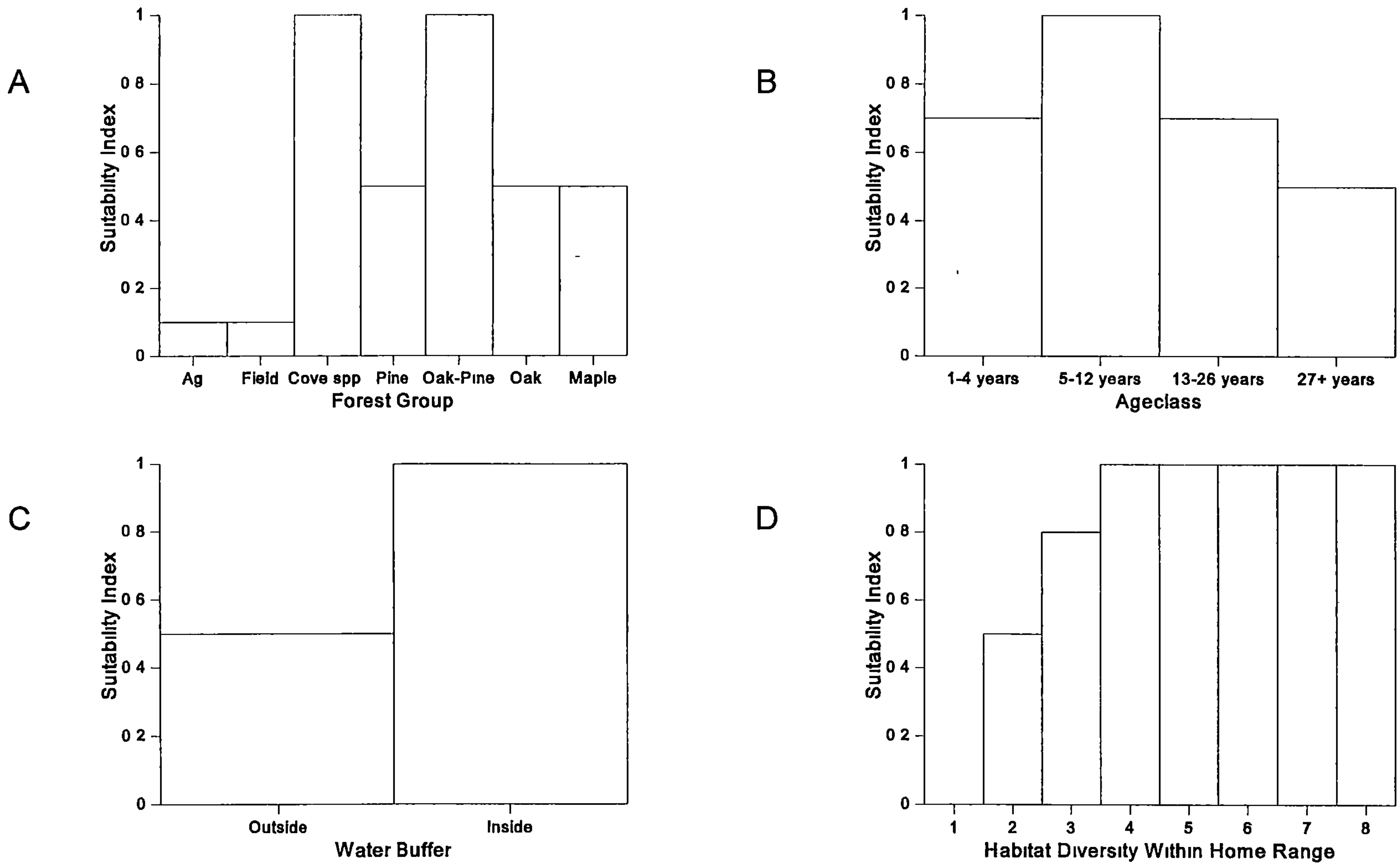


Figure 9 Habitat suitability curves for the four variables in the winter habitat model

species that provide winter cover (Stafford 1989) Thus, this group was assigned a suitability of 1 Forest group 3 consists of pure yellow pine stands. Such stands generally have an open understory which grouse avoid (Longwitz 1985, Epperson 1988) However, pines are also used by grouse for winter roosting in the South (Barber 1989, Brenner 1989) As a trade-off, this group was assigned a suitability of .5 Forest group 4 was used by grouse significantly more than expected in Epperson's (1988) study. The overstory trees in this group (oaks and pines, see Table 1) provide some mast, but the importance of this group is its association with laurel and rhododendron thickets which grouse use as preferred cover during the winter (White and Dimmick 1978) This group was also assigned a suitability of 1. Forest group 5 consists of upland species, primarily oaks, which grouse used less than expected (Epperson 1988) Longwitz (1985) also noted grouse avoided certain forest types in this classification. During winter, the uplands probably do not support much of a herbaceous layer for food, unless there is early successional growth Upland areas also tend to have a sparser understory, providing less cover (Epperson 1988) Because the uplands provide little winter food and cover, forest group 5 was given a suitability of 5 Forest group 6 includes only one forest classification, red maple-blackgum While there may be some food available to grouse from these trees during the winter, the location of this classification is upland in nature. This group was given a suitability of 5.

The habitat suitability of different age classes of trees is illustrated in Fig

9b (see Fig 5 also) Age class 1 trees range from 1-4 years old This age class was given a suitability value of .7 because of the vine and herbaceous vegetation [e.g., grapes (*Vitis* spp ), greenbrier (*Smilax* spp.), alumroot (*Heucheria villosa*), cinquefoil (*Potentilla canadensis*)] that would be available to grouse during the winter (Stafford 1989). However, grouse travel might be impeded by the dense growth and slash left over from harvest. Vertical cover is also low in such young stands (Kubisiak 1989). Age class 2 (5-12 years old) would also provide a good herbaceous layer as well as more vertical cover Travel through the stand would be easier for grouse because there would be some shade-out of the grasses, and slash left from harvest would have mostly decomposed. This age class was given a suitability of 1 In age class 3 (13-26 years old), the trees are approaching maturity as far as grouse are concerned In such places, the herbaceous layer for winter food is decreasing because of the closed canopy, and the stand is opening up, decreasing cover. Therefore, this age class was given a suitability value of 7 Mature trees (27+ years) make up age class 4. This age class was given a suitability of .5 because both winter cover and food are lowest in these stands if evergreen shrubs are absent (Kubisiak 1989, Hewitt et al 1994) Harlow et al (1975) estimated mature oak-pine stands contained 0 1 kg/ha of forbs, whereas 7 year old clearcuts contained 0 5 kg/ha of forbs

The suitability values for proximity to water (and thus to laurel and rhododendron thickets) could range from 0 0 to 1 0, but only values of 0.5 and

1.0 were used for locations outside and inside the water buffer, respectively (Fig. 9c) The available telemetry data did not allow better delineation of habitat suitability versus proximity to water supporting laurel-rhododendron thickets. Both Epperson (1988) and Longwitz (1985) demonstrated grouse select areas with evergreen shrubs. Thus, areas inside the buffer where shrubs were assumed to be present were considered optimal. A value of 0 5 was chosen for areas outside the buffer because this habitat is not unsuitable for grouse, just less suitable

Habitat diversity was established by combining forest type and age class Many researchers have found ruffed grouse thrive in areas with a mosaic of vegetation types and ages (Bump et al. 1947, Gullion and Svoboda 1972, Gullion 1977, Kubisiak 1989, Brenner 1989, Wiggers et al 1992). The suitability curve for habitat diversity within home range is shown in Fig. 9d No adult grouse in any of the southern studies used only one habitat type, this was considered unsuitable More grouse used 3+ habitat types than used 2, and there were no grouse using more than 7 habitat types (Harris 1981, Longwitz 1985, Epperson 1988, Boyd 1990, Pelren 1991) Because a mosaic of habitat types is better for ruffed grouse, but it is seldom that more than 4 types would be available in a home range (see Fig 7), areas with more than 4 habitat types in a home range were assumed to also have a suitability of 1.0

## The HSI Model For Winter Habitat

I set up my HSI calculations for the winter habitat model according to the equation below, using a multiplier of 2 for the proximity to evergreen shrub variable to make it twice as important as the other variables.

$$\frac{2V_1+V_2+V_3+V_4}{5}$$

where: $V_1$ = proximity to evergreen shrub thickets
$V_2$ = habitat diversity within home range size
$V_3$ = forest age class
$V_4$ = forest group

## Variable Weighting

The winter habitat model assumed proximity to streams supporting laurel and rhododendron thickets was twice as important as other variables in the model, and weighted this variable accordingly. Many of the southern studies of ruffed grouse have noted the preferred use of evergreen thickets during the winter (when such thickets were available) and at other times (White and Dimmick 1978, Harris 1981, Hale et al. 1982, Longwitz 1985, Thompson 1987, Epperson 1988, Pelren 1991), with some exceptions (Gudlin and Dimmick 1984, Boyd 1990) Both Longwitz (1985) and Epperson (1988) noted preferential use of evergreen thickets on Catoosa Evergreen thickets provide both cover and food if mountain laurel is present. Stafford and Dimmick (1979) showed mountain laurel leaves were the second most important food for southern

Appalachian grouse over the winter On the Plateau, Stafford (1975) found mountain laurel ranked third in importance as a winter food. The dense, tortuous growth habit of both of these shrubs provides excellent cover from avian and ground predators Grouse probably use these thickets as corridors for traveling from one area to another

ii The Brood Habitat Model

The brood period for this study was assumed to begin in late May when broods first start hatching, and to last until fall dispersal, ending in late October One of the necessary components of ruffed grouse brood habitat is the availability of insects For the first three weeks after hatching, grouse chick's diets are comprised of greater than 90% invertebrates Invertebrates continue to predominate for five to six weeks after hatching (Kimmel and Samuel 1984) Godfrey (1975) found broods will exchange areas of good cover for areas with poorer cover where insects are abundant if both are not closely situated. Hens have been known to move their chicks 0.8 km to get to good insect habitat (Bump et al 1947)

Preferred habitat for ruffed grouse broods in the northern part of their range consists of aspen stands with stem densities of 19,000-25,000 stems/ha (Gullion 1977). Overall, small forest openings which provide a diverse mixture of herbaceous plants and host an abundance of insects provide good brood habitat (Barber et al. 1989) In the southern part of their range, these stem densities are provided somewhat by regenerating clearcuts, but slash from timber removal in recently harvested sites (0-4 years old) can impede travel by grouse chicks (Barber et al 1989) Other areas providing these stem densities in the Southeast include borders of logging roads, overgrown fields, and regenerating forest stands. Insect abundance and biomass were highest on managed logging roads (those planted with clover and orchard grass) in eastern Tennessee (Hollifield 1992)

The daylighted strips along the main and logging roads in Catoosa are managed to provide both plant and insect food for grouse and other species (Dwayne Robinson, Tennessee Wildlife Resources Agency, Catoosa Wildlife Management Area, pers comm 5/93). Daylighted roads were given a 10 m buffer, equal to the daylighted strip width (John Hamby, Catoosa Wildlife Management Area manager, Tennessee Wildlife Management Agency, pers comm. 5/94) Roads without daylighting, such as trails and state routes, were not considered to be influential and were not buffered.

Studies on the effect of habitat diversity on brood habitat quality conflict. In Minnesota, Maxson (1978) found hens used 7-10 habitat types (based on forest type), and hens with broods used more habitat types than hens without. Porath and Vohs (1972) noted broods were seen in all cover types (8) except agricultural areas Broods stayed in small areas of good habitat, and made unidirectional movements in lesser quality cover. Hungerford (1951) and Sharp (1963) both reported ruffed grouse broods used many types of cover, and noted conditions were optimal when age classes and understory were interspersed Broods on Catoosa used 2-4 habitat types (Epperson 1988). Other southeastern studies also report less habitat types used by broods compared to adults (Hein 1970, Harris 1981, Boyd 1990). Detailed habitat use by hens with broods has not been quantified in the Catoosa area.

Epperson (1988) determined brood home range size from late summer data, which did not cover the crucial insect foraging time of young broods Bump et al (1947) and Porath and Vohs (1972) reported little change in preferred cover as broods matured Other authors disagree. Stewart (1956) noted an abrupt change in brood habitat use in the first week in July, when blueberries became ripe. Maxson (1978) and Vadas (1984) found brood home range size increased after June, perhaps because the older chicks needed more food and increased their range to get it. However, Godfrey (1975) observed broods cover the majority of the range they will occupy for the summer in the first 10 days, and that three-week old broods may travel as far as 11-week old birds as they move throughout a home range. Broods on Catoosa had home ranges that were similar to other studies (Epperson 1988) (Table 3).

Table 3 Comparison of home range sizes of female ruffed grouse with broods.

| Researcher | Location | Time Studied | No of Broods | Home Range Size [range] | Comments |
|---|---|---|---|---|---|
| Epperson 1988 | Middle Tennessee | August-September<br>August-September<br>August-September | 1<br>1<br>1 | 99 0 ha<br>15 5 ha<br>15 3 ha | Used minimum convex polygons Modified minimum area values are 54 5 ha, 2 4 ha, 9 9 ha, overall mean 22 3 ha |
| | | | | 43 2 ha | Average of all brood ranges |
| Boyd 1990 | Eastern Tennessee | August | 2 | 22 3 ha [13 6-31 0] | Used minimum convex polygons |
| Harris 1991 | North Georgia | May-July | 2 | 71 3 ha [29 5-113 1] | Used an approximation of the modified minimum area method |
| Vadas, 1984 | Southwestern Pennsylvania | June-September | 3 | 22 48 ha [5 2-64 8] | Used the Jennrich and Turner (1969) estimate, which created elliptical shaped home ranges |
| Bump 1947 | Central New York | Season long | many | ~16 2 ha [4–40+] | Estimates based on observations and repeated flushes |
| Polderboer 1942 | Northeast Iowa | June | 6 | ~17 6 ha [NA][a] | Estimate of maximum range, based on multiple observations |
| Fisher, 1939 | South-central Michigan | Season long | 9 | ~16 2 ha [NA] | Estimate based on multiple observations |
| Godfrey 1975 | East-central Minnesota | June-September | 6 | 12 9 ha [6 3-18 9] | Connected peripheral locations, then used compensating polar planimeter All broods >3 weeks old |
| Schladweiler 1965 | East-central Minnesota | June | 1<br>1 | 16 2 ha<br>161 9 ha | Broods tracked for 2 and 3 weeks |

Table 3. (cont )

| Researcher | Location | Time Studied | No of Broods | Home Range Size [range] | Comments |
|---|---|---|---|---|---|
| Maxson 1978 | East-central Minnesota | April-July | 5 | 14 7 ha [9 0-22 6] | Used grid square determination Tracked for 4 weeks after hatching |
| Hungerford 1957 | Northern Idaho | June-November | 30 | NA [4 1-8 1 ha] | Estimate based on multiple observations and marking of ranges |
| Bakke 1980 | Northern North Dakota | June-July | 2 | 7 8 ha [7 2-8 4] | Used the modified minimum area method |

[a]Not Available

In accordance with the previous information, the following assumptions apply to the brood habitat model.

1) Brood habitat is the factor limiting survival of juveniles to autumn.

2) Brood habitat can best be delineated by proximity to road type and habitat diversity within home range size.

3) Home range size averages 43 2 ha (Epperson 1988).

## Habitat Suitability Curve Values

Forest group habitat suitability values changed in some cases from the winter habitat model (Fig. 10a) Forest groups 0 and 1 remained the same at 1 Forest group 2 was assigned a suitability value of .8 This reflects the insect production in cove areas due to the mesic conditions which support an abundant herbaceous layer (Stewart 1956, Barber et al. 1989) This herbaceous layer is also easy for chicks to move through and provides overhead concealment from predators Forest group 3, with its open understory produces few insects and provides less cover, but is easy for chicks to travel through Epperson (1988) noted broods used this group in proportion to its availability, thus, this group was given a value of .5. Broods utilized forest group 4 less than expected (Epperson 1988). Epperson (1988) reported the understory in this category was more dense than in the uplands, and contained many of the same species. It is unclear why this area was avoided by the monitored broods, although brood age

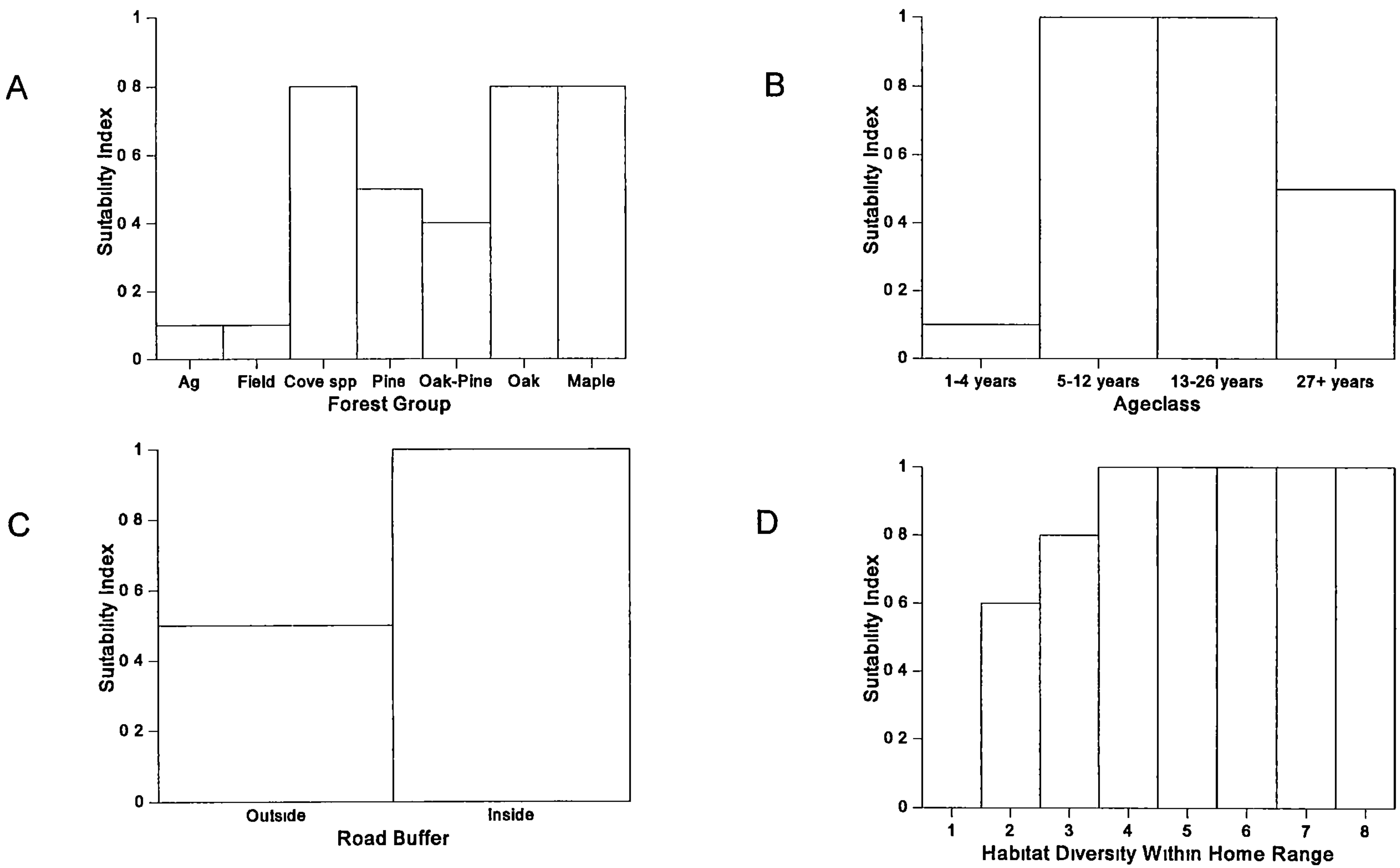


Figure 10 Habitat suitability curves for the four variables in the brood habitat model

may be a factor. Both Hein (1970) and Stewart (1956) noted broods moved from lowlands to uplands as they got older. Forest group 4 was assigned a value of .4 Uplands (forest group 5) were favored by the broods monitored by Epperson (1988); Hein (1970) also noted this preferred use in North Carolina However, because Epperson (1988) monitored older broods, it is questionable if this forest group would be as useful to younger broods and their need for insects Uplands have a more sparse understory which may be easier for chicks to move through. Uplands are drier and warmer than lowlands, and may be used for thermal properties because young grouse do not thermoregulate well until three weeks of age (Hungerford 1951, Johnsgard et al 1989) Thus, forest group 5 was given a suitability value of 8 The tree species in forest group 6 were listed as upland associates in Epperson's (1988) study The one stand of this type is located in an upland area, and so was assigned a value of .8 also

Ruffed grouse broods respond most strongly to age class of trees, probably because of the abundance and variety of insects found among different age classes of trees (Fig 10b) However, slash left after harvest can severely impede chick travel (Barber 1989) Hollifield (1992) noted this age class was the least productive insect habitat In light of this, the youngest age class (age class 1) was given a suitability value of 1. Although age classes 2 and 3 produce less arthropods than mature forest (Hollifield 1992), they provide good protective cover and ease of travel following slash breakdown (Barber et al 1989). These age classes were both assigned values of 1 Mature trees (age class 4) can provide abundant insects, but often do not provide sufficient cover for broods (Thompson et al 1987, Hollifield 1992) This class received a suitability value of .5.

The suitability values inside and outside of the road buffer also relate to insect abundance. The linear food plots planted along daylighted roads contain plant species which attract arthropods Hollifield (1992) found logging roads which had been planted to clover contained the highest arthropod abundance and biomass as well as more of the insect species preferred by grouse chicks Logging roads that were planted to orchard grass had lower arthropod abundance and biomass than roads planted to clover, but more than other habitats (Hollifield 1992) Clover foliage is also readily eaten by grouse (Gullion 1989) These linear food plots will help provide food as plant material becomes a brood's principal diet. The suitability value inside the buffer was set to 1, areas outside the buffer were set to 5 (Fig 10c) Again, the .5 value indicates less suitability for grouse chicks instead of unsuitability. The extent to which daylighting provides greater herbaceous growth in forest stands along roads, and perhaps greater brood use, is unknown.

Southern studies indicate family groups use fewer habitats than adults. The two broods in Epperson's (1988) study used two and four habitat types, respectively These broods were monitored during summer and fall. Boyd (1990) monitored two broods, one utilized two habitat types, and the other three habitat types. The brood using three habitat types was monitored from hatching to the end of the summer Hein (1970) also noted broods used fewer sites and habitats than adult grouse in North Carolina. However, two broods monitored in Georgia (Harris 1981) from hatching through summer used 6 and 7 habitat types; this was less than adults used in Harris' study. Research in northern areas has shown family groups use more habitat types than adults during the first weeks of life. Maxson (1978) reported family groups used at least seven habitats, and hens with broods used more habitats than hens without broods. Because Epperson's (1988) brood monitoring did not include the critical insect foraging time, and because other monitoring studies that did have noted both low and high habitat diversity, habitat diversity suitability values were set according to figure 4d. Areas with only one habitat type were considered unsuitable Areas with two or three habitat types were given suitability values of 0 6 and 0 8, respectively Areas with four or more habitat types were assumed to be optimal (suitability = 1.0)

## The HSI Model For Brood Habitat

The model for brood habitat weights proximity to daylighted roads and forest age class twice as much as habitat diversity within home range and forest type

Accordingly, the equation for the brood habitat model calculations was set up as.

$$\frac{2V_1 + V_2 + 2V_3 + V_4}{6}$$

where $V_1$ = proximity to daylighted roads
$V_2$ = habitat diversity within home range size
$V_3$ = forest age class
$V_4$ = forest group

Variable Weighting

This study weighted road and forest age class variables twice as much as other variables because of the importance of insects to brood habitat Several studies have noted the importance of good insect habitat for broods, and that females will travel to areas with lesser quality cover to get insects (Bump et al 1947, Berner and Geysel 1969, Godfrey 1975) Hollifield (1992) discovered that managed logging roads and mature hardwood stands with a dense groundstory produced the most insects in the southern Appalachians. Epperson (1988) monitored older broods that no longer were dependent on insects. However, other southern studies have monitored young broods, and noted habitats with lush groundstory vegetation were selected (Hein 1970, Harris 1981) Proximity to daylighted roads (and thus to linear food plots) and forest age class are the most indicative of insect availability in this model

# CHAPTER IV.

# RESULTS

Both models were run using the data from approximately 30% of the total area of the Catoosa WMA. Some resulting individual areas were quite small (<1 ha). These areas were included because of their potential for grouse use (or avoidance) despite their size Gullion (1976) found ruffed grouse responded to clearcuts and wildlife openings .4 ha in size

## I Suitability Values For The Winter Habitat Model

The raw data habitat suitability index values ranged from 0.32 to 1 0 for the winter habitat model (Table 4). The lowest possible HSI value in this model was 0 32, and the highest possible value was 1.0 To compare the results of this study to others, the data needed to be adjusted to fit a scale from 0-1 0 This was accomplished by first subtracting the lowest possible score from all values. Then, the resulting value was multiplied by the reciprocal of the highest possible score minus the lowest possible score. For this model then, 0.32 was subtracted from all values, setting the range of values to 0.0-0.68 These were multiplied by 1 / 0 68 (the reciprocal) The adjusted HSI values are shown in Table 5

The adjusted data shows most of the inventoried area of Catoosa (63 23%) had a suitability between 0.25 and 0.49 Almost 69% of the area falls

Table 4. Raw data Habitat Suitabilıty Indices and percentage of the total inventoried area for the winter habitat model.

| HSI | Area (ha) | % of ınventoried area | % of inventorıed area by quartile |
|---|---|---|---|
| 32 | 0 66 | < 0 01 | |
| 40 | 481 31 | 4 90 | |
| 42 | 14 97 | 0 15 | 5 52 |
| 44 | <0 01 | <0 01 | |
| 48 | 46 43 | 47 | |
| 50 | 1671 97 | 17 02 | |
| 52 | 144 29 | 1 47 | |
| 54 | 63 60 | 0 65 | |
| 56 | 1652 77 | 16 82 | |
| 60 | 2503 85 | 25 47 | |
| 64 | 176 77 | 1 8 | 90 58 |
| 66 | 697 28 | 7 10 | |
| 68 | 0 01 | <0 01 | |
| 70 | 1873 48 | 19 07 | |
| 72 | 1 70 | 0 02 | |
| 74 | 113 65 | 1 16 | |
| 76 | 91 58 | 0 93 | |
| 80 | 187 96 | 1 91 | |
| 84 | 2 67 | 0.03 | |
| 86 | 28 19 | 0 29 | |
| 90 | 64 91 | 0 67 | 3 90 |
| .94 | 1 35 | 0 01 | |
| 96 | 0 68 | <0 01 | |
| 1 00 | 5 64 | 0 06 | |

Table 5. Adjusted Habitat Suitability Indices and percentage of the total inventoried area for the winter habitat model.

| HSI | Area (ha) | % of inventoried area | % of inventoried area by quartile |
|---|---|---|---|
| 0 00 | 0.66 | < 0 01 | |
| 11 | 481.31 | 4 90 | |
| 14 | 14 97 | 0 15 | 5 52 |
| 17 | <0 01 | <0 01 | |
| 23 | 46 43 | 47 | |
| 26 | 1671 97 | 17 02 | |
| 29 | 144 29 | 1.47 | |
| 32 | 63 60 | 0 65 | 63 23 |
| 35 | 1652.77 | 16 82 | |
| 41 | 2503 85 | 25 47 | |
| 47 | 176 77 | 1 8 | |
| 50 | 697 28 | 7 10 | |
| 52 | 0 01 | <0 01 | |
| .55 | 1873 48 | 19.07 | |
| 58 | 1 70 | 0 02 | 30 19 |
| 61 | 113 65 | 1 16 | |
| 64 | 91 58 | 0 93 | |
| 70 | 187 96 | 1 91 | |
| 76 | 2 67 | 0 03 | |
| 79 | 28 19 | 0.29 | |
| 85 | 64.91 | 0 67 | 1 06 |
| 91 | 1 35 | 0 01 | |
| 94 | 0 68 | <0 01 | |
| 1 00 | 5 64 | 0 06 | |

below 50 (ı e., below average) Only 1 06% of the inventoried area had HSI values greater than 0.75, less than 1% of the inventoried area was optimal habıtat (HSI = 1 0)

Figure 11 shows a map of these values for the portıon of Catoosa for whıch data were avaılable Higher HSI values occur along streams and draınages Thıs ıs evıdenced by linear patches of red, and by dıagonal bandıng of oranges Other patches exhıbiting hıgh HSI values occur where there are a varıety of forest age classes (see Fıg 5). Low HSI values are prımarıly seen along the edges of the currently ınventorıed area These may not reflect true values because there is certain to be ınfluence from adjacent areas for whıch data were not avaılable Interıor low HSI values ındıcate large expanses (greater than home range sıze) of mature forest composed of lesser valued overstory.

## II Suıtabılity Values For The Brood Habıtat Model

Raw data habıtat suitability ındex values ranged from 0 35 to 0.97 for the brood habıtat model (Table 6) The range of possıble values was 0 22 - 0 97 The adjusted score subtracted 0.35 from all values, then multıplıed the results by 1 / 0 62 (the reciprocal of 0.97 mınus 0.35)

The adjusted brood habitat model had slightly more area in the 0 0 - 0.24 quartıle (7.23%) than the winter habıtat model (5 52%) (Table 7) The majorıty (82 65%) of the inventoried area ranged from 0 25-0.49 ın habıtat suıtabılity for broods Only a small percentage (10 12%) of the ınventorıed area was above

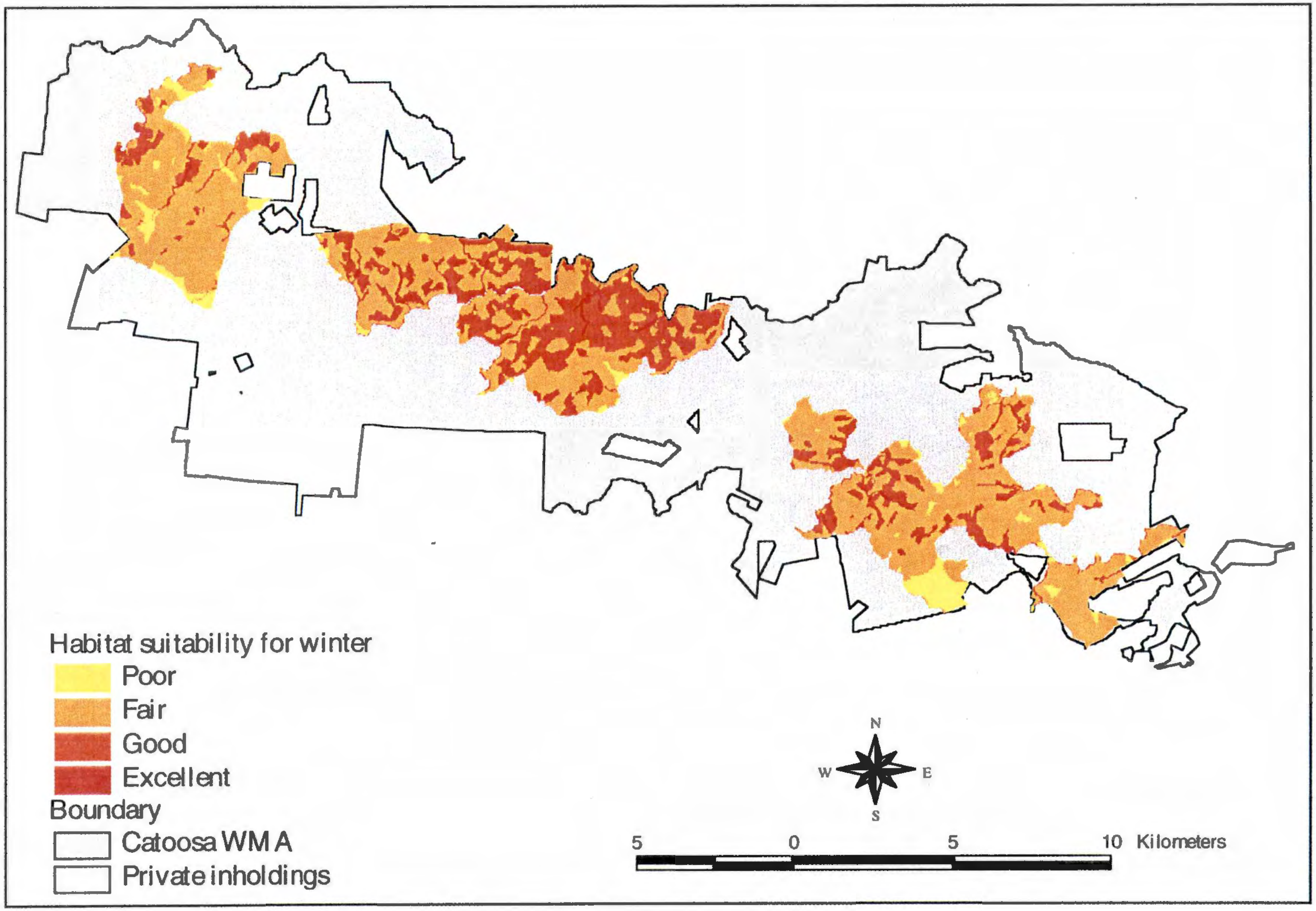


Figure 11. Habitat suitability for winter from the winter habitat model, Catoosa Wildlife Management Area, Tennessee, 1995.

Table 6. Raw data Habitat Suitability Indices and percentage of the total inventoried area for the brood habitat model

| HSI | Area (ha) | % of inventoried area | % of inventoried area by quartile |
|---|---|---|---|
| 35 | 0.32 | < 0 01 | |
| 40 | 8 42 | 0 09 | |
| 42 | 26.66 | 0 27 | |
| 43 | 32 56 | 0 33 | 6 25 |
| 45 | 25 93 | 0 26 | |
| 47 | 478 54 | 4 87 | |
| 48 | 41 95 | 0 43 | |
| 50 | 96 16 | 0 98 | |
| 52 | 348 60 | 3 55 | |
| .53 | 114 71 | 1 17 | |
| 55 | 185 82 | 1 89 | |
| 57 | 1966 60 | 20 01 | |
| 58 | 417 96 | 4 25 | |
| 60 | 1902 55 | 19.36 | |
| 62 | 1 83 | 0.02 | 86 57 |
| 63 | 3182 66 | 32.39 | |
| 65 | 1 37 | 0.01 | |
| 67 | 22 36 | 0 23 | |
| 68 | 6 17 | 0 06 | |
| 70 | 21 37 | 0 22 | |
| 72 | 10 62 | 0.11 | |
| 73 | 226 56 | 2 32 | |

Table 6. (cont.)

| HSI | Area (ha) | % of inventoried area | % of inventoried area by quartile |
|---|---|---|---|
| 75 | 33 47 | 0 34 | |
| 77 | 220 78 | 2.25 | |
| .80 | 421 67 | 4 29 | |
| 83 | 0 47 | < 0 01 | |
| 85 | 0 18 | <0 01 | |
| 87 | 1 52 | 0.02 | 7 18 |
| 88 | 0 05 | <0.01 | |
| 90 | 5 59 | 0 06 | |
| 92 | 0 16 | <0 01 | |
| .93 | 7 80 | 0 08 | |
| 97 | 13 70 | 0 14 | |

Table 7 Adjusted Habıtat Suitabılity Indices and percentage of the total inventoried area for the brood habitat model.

| HSI | Area (ha) | % of inventorıed area | % of ınventoried area by quartile |
|---|---|---|---|
| 0 00 | 0 32 | < 0 01 | |
| 08 | 8 42 | 0 09 | |
| .11 | 26 66 | 0 27 | |
| 12 | 32 56 | 0 33 | |
| .16 | 25 93 | 0 26 | 7 23 |
| 19 | 478 54 | 4 87 | |
| 20 | 41 95 | 0.43 | |
| 24 | 96 16 | 0 98 | |
| 27 | 348 60 | 3 55 | |
| 29 | 114 71 | 1 17 | |
| 32 | 185 82 | 1 89 | |
| 35 | 1966 60 | 20.01 | |
| 37 | 417 96 | 4 25 | 82.65 |
| 40 | 1902 55 | 19 36 | |
| 43 | 1 83 | 0 02 | |
| 45 | 3182 66 | 32 39 | |
| 48 | 1 37 | 0 01 | |
| 51 | 22 36 | 0 23 | |
| 53 | 6 17 | 0 06 | |
| 56 | 21 37 | 0.22 | |
| 59 | 10 62 | 0 11 | |
| 61 | 226 56 | 2 32 | 9 82 |
| 64 | 33 47 | 0 34 | |
| 67 | 220.78 | 2 25 | |
| 72 | 421 67 | 4.29 | |

Table 7. (cont.)

| HSI | Area (ha) | % of inventoried area | % of inventoried area by quartile |
|---|---|---|---|
| 77 | 0 47 | < 0 01 | |
| 80 | 0 18 | <0 01 | |
| 83 | 1 52 | 0 02 | |
| 85 | 0 05 | <0 01 | |
| 88 | 5 59 | 0 06 | 0 30 |
| 91 | 0 16 | <0 01 | |
| 93 | 7 80 | 0 08 | |
| 1 00 | 13 70 | 0 14 | |

average (HSI = .5) for broods Less than 1% of the inventoried area had HSI values in the highest quartile (0 75-1 00) for broods, compared to 1.06% in the winter habitat model Optimal habitat (HSI = 1.0) for both models was less than 1% Overall, the brood habitat model displayed a lesser amount of higher quality habitat than the winter habitat model.

A map of HSI values for the brood habitat model is depicted in Fig. 12 Again, linear patches of high HSI values are found, this time along daylighted roads There are also more high HSI value patches than in the winter habitat model because of the brood habitat model's weighting of forest age class (see Fig. 5) The brood habitat model also shows lower HSI values along the edges of the inventoried area for the same reason as the winter habitat model. Additional low HSI patches reflect forest that is younger than 6 years

III. Best Habitat Proximity

Only 1.06% of the winter habitat model and 0 30% of the brood habitat model had HSI values in the 75-1 00 range Fig 13 shows the proximity of the best habitats for both models The linearity of the best habitat as it follows roads or water is clear Most notably, this linear habitat is what often connects the larger patches of good habitat between the two models The best habitats as delineated by these models are often within the home ranges described in this study However, there are areas where connectivity could be improved Overall, Fig. 13 demonstrates the paucity of excellent grouse habitat on Catoosa, which helps explain the low grouse density in the area.

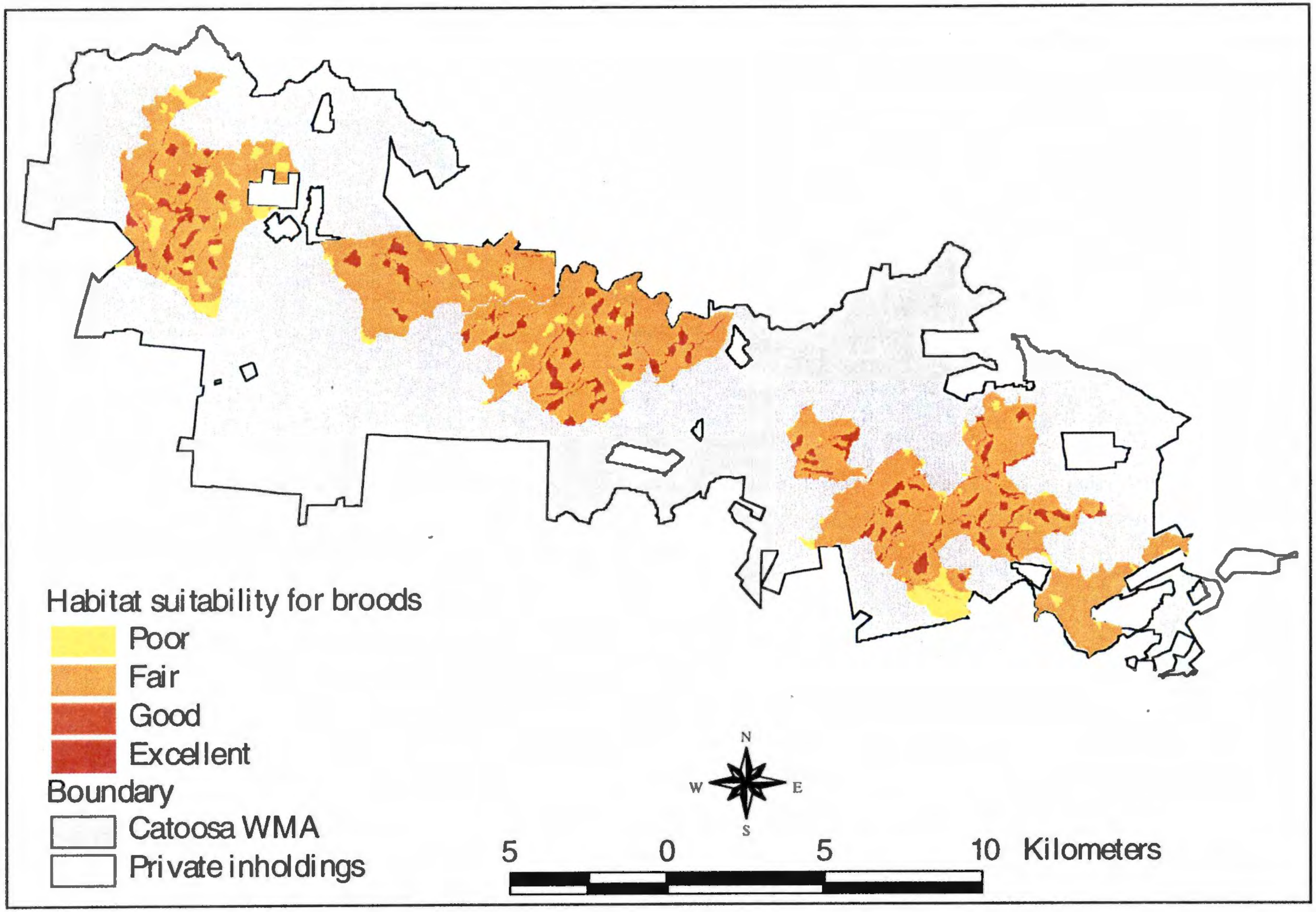


Figure 12. Habitat suitability for broods from the brood habitat model, Catoosa Wildlife Management Area, Tennessee, 1995.

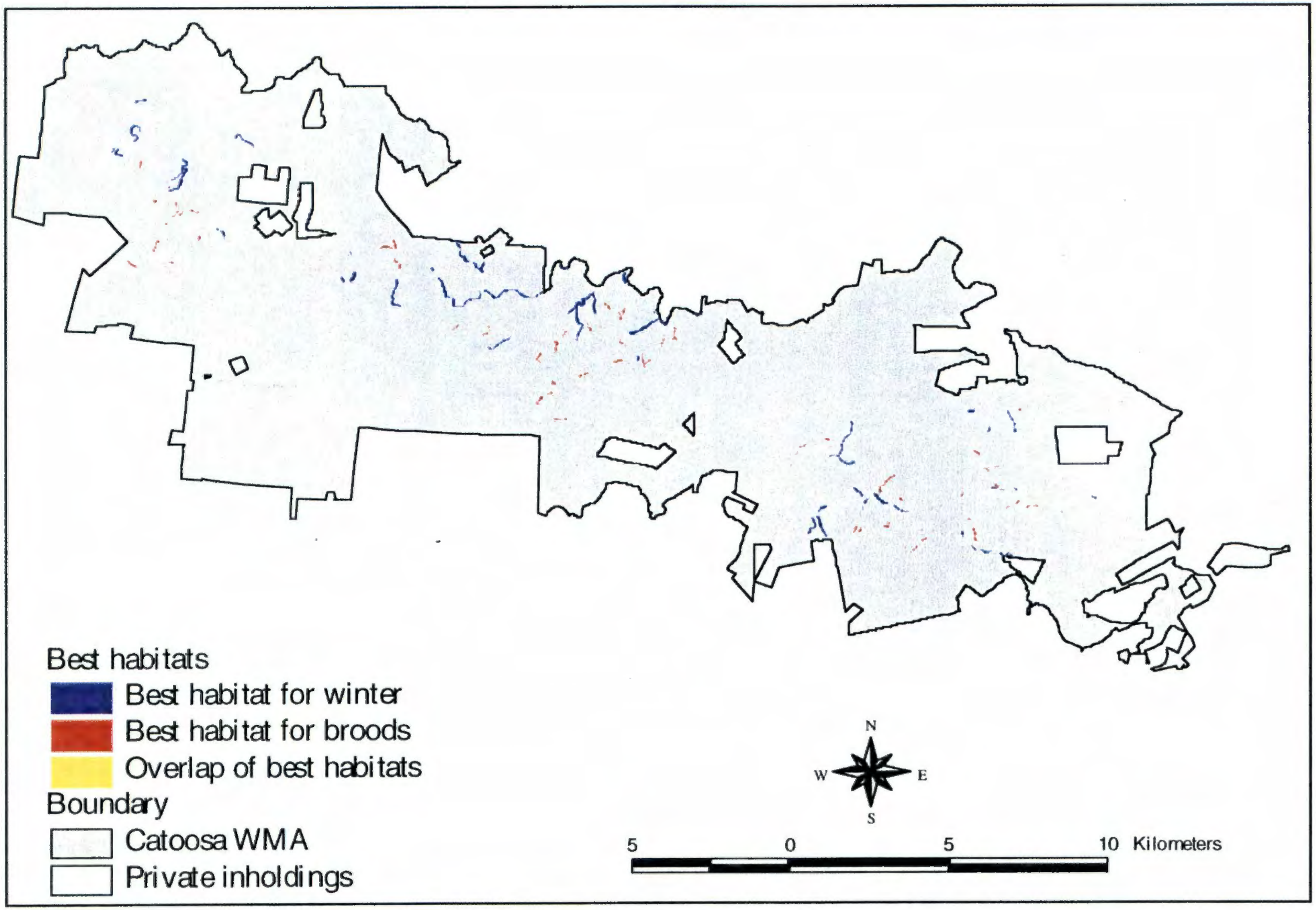


Figure 13. Proximity of the best habitats delineated by both models, Catoosa Wildlife Management Area, Tennessee, 1995.

# CHAPTER V

# DISCUSSION

## I Modelling Implications

### i The Winter Habitat Model

This model shows limited amounts of good winter habitat, and the location of this habitat follows streams that support evergreen shrub thickets The linear arrangement of the best winter habitat was expected because of the model's weighting of stream proximity. The HSI values along the edge of the currently inventoried area are suspect because ERDAS determined their initial vegetation diversity from the closest interior point surrounded by a complete home range. Even when all of Catoosa is inventoried, HSI values along the edges may be inaccurate because land use outside the Catoosa boundary will affect grouse habitat use inside the boundary.

The overall distribution of HSI values for adult winter habitat will change as more of Catoosa is inventoried. The currently inventoried area contains all of the forest cutting done over the last 13 years because these compartments received priority during the surveying process. The uninventoried area of Catoosa has had little or no harvest or other cultural treatments over the last 20 years that would benefit grouse When this untreated area is inventoried and added into the model, a higher percentage of the inventoried area will have lower

HSI values for adult winter habitat than the results shown here However, additional good winter habitat may appear as more areas with streams supporting laurel/rhododendron thickets are inventoried

The limited amount of good winter habitat may contribute to the low grouse populations on Catoosa. Winter habitat has been cited as the limiting factor for northern grouse (Cade and Sousa 1985), and has been hypothesized to limit southern grouse populations as well (Servello and Kirkpatrick 1987)

ii The Brood Habitat Model

This model indicates Catoosa has less area in good to excellent habitat for broods than for adults during the winter. Much of the brood habitat with HSI >.5 is linearly arranged, following roads that have been daylighted and planted to wildlife food mixtures Some additional patches of good habitat occur in areas with 5-26 year-old forest stands These results are predictable given the model's weighting of the road and age class variables.

The distribution of HSI values for the brood habitat model will also change with an increase in inventoried area Values for brood habitat suitability along the edge of any inventoried area will have to be carefully considered because they are influenced by adjacent areas that are not inventoried. The lack of harvest in the uninventoried area will depress HSI values over large areas. However, as more roads are daylighted and planted to wildlife food mixtures, linear brood habitat will increase. Also, any forest management similar to clearcutting should provide brood habitat after a few years.

Low juvenile:adult ratios in the fall have led some researchers to propose brood habitat as a factor limiting southern grouse populations (Pyle 1975, 1976, Coggin 1977, Pack 1977, Kimmel and Samuel 1984) The limited amount of good brood habitat on Catoosa probably contributes to the low grouse population in the area. Overlap of the best habitat between the models showed good brood habitat is also often located at a distance from good wintering habitat Grouse don't usually move far from winter coverts, but Catoosa family groups will need to do so to find good areas for foraging for insects Broods that move around more expose themselves to increased predation and environmental stress. Over the long term, this could lead to lower autumn population levels because of lowered brood survival

iii Model Adjustment and Testing

HSI models are practical models for operational planning Planning studies use habitat modelling as their basis because habitat integrates the concepts of population size and carrying capacity (Schamberger and O'Neil 1985) HSI models provide a bridge between science and planning, where science improves model performance for planning projects Habitat modelling can provide a consistent basis for many types of studies (e.g., baseline, mitigation, impact assessment, and monitoring) (Schamberger and O'Neil 1985)

The advantages of HSI models are that they are fairly simple, can be applied in a timely manner at low cost, and the outputs are easily understood. This is because HSI models contain only basic habitat variables considered important to both the wildlife species and to management needs (Schamberger and O'Neil 1985) Variables that are not readily measured, predicted, or controlled (e g., predation, competition, and weather) are not used. Another reason for using fewer variables is because averaging functions (which are typically used in these models) diminish the sensitivity of the overall index as more variables are added (Morrison et al 1992). Although habitat models are based on the concepts of habitat and carrying capacity, carrying capacity is a function of all factors limiting population size. Habitat models may include only a few of the factors determining population size, consequently, habitat models cannot model carrying capacity (Schamberger and O'Neil 1985) The output of an HSI model is best viewed as a hypothesis of a species-habitat relationship, rather than as a causal function (Morrison et al. 1992) The HSI value determined for an area does not predict population levels, but a value of .9 indicates better habitat than a value of .5, and should represent greater potential carrying capacity (Schamberger and O'Neil 1985).

HSI models are used in situations where habitat change is planned. They assess resulting changes in habitat quality and availability for selected wildlife species Their reliability is not as high as is desirable, but managers are usually comfortable with accuracy levels between 75% and 80% (i e., percent accuracy of model predictions as compared to field observations) for total model output (Hurley 1985, Schamberger and O'Neil 1985)

An HSI model's reliability depends upon whether or not the model's assumptions were taken into consideration before its application Models require numerous assumptions, and are therefore applicable only where the assumptions are met (Cade and Sousa 1985, Palmeirim 1985, Morrison et al 1992) The models used in this study will require modification or reclassification of their variables for other areas of the Plateau region. The models used here employ stream and road variables that may not approximate ruffed grouse habitat in other areas on the Plateau, either because streams supporting laurel and rhododendron do not exist, or daylighted strips along roads are not planted with wildlife food species. A possible alternative would be emphasis on openings in general (e.g , powerline rights-of-way, clearcuts, roads, and fields) and their edges. Broods have been observed using openings or their adjacent edges in several studies (Polderboer 1942, Bump et al. 1947, Hungerford 1951, Sharp 1963, Porath and Vohs 1972) Edge use by adults has been documented also (Hein 1970, Archibald 1975, Longwitz 1985 ). Grouse feed in strip fields adjacent to roads on Catoosa (Epperson 1988), and Jones (1979) reported extensive use of a field plowed and planted to grass and clover. Other forest data such as stand condition class, stocking rates, basal area, and percent crown cover could be used to approximate the understory (O'Brien 1990) Several researchers have used these kinds of data to describe grouse habitat utilization (Kubisiak 1978, Harris 1981, Hale et al 1982, Gudlin and Dimmick 1984, Longwitz 1985, Thompson and Fritzell 1987). The TWRA has data on landtypes within Catoosa; these landtypes include descriptions of physiography, soils, moisture, and overstory and understory vegetation. Landtype variables could also be useful in a regionally applied model

The basic format of these two models may be made pertinent to other physiographic regions in Tennessee by substituting or adding other appropriate macro-habitat variables For example, a model for the Blue Ridge region may include elevation, slope and aspect (which are not significant factors in the Plateau region), as well as evergreen thicket and other understory variables when modelling habitat for ruffed grouse. Digital elevation models and satellite imagery can provide these kinds of data, and both are easily incorporated into GIS databases. Satellite imagery expands the application range of a model due to its regional data collection, allowing broad scale analysis of habitat variables Another advantage of satellite imagery is that it can be easily updated periodically (Shih 1988) Integrating satellite imagery into this model in the future will allow rapid delineation of habitats across a range of land ownerships for the entire Plateau region With satellite imagery of a large area, management could be coordinated among different landowners (Homer et al 1993). Using routinely and consistently collected data from a region for modelling species-habitat relationships could allow models for several species to be considered simultaneously. For example, forest type, basal area, stand age and condition class data collected during forest inventories on Catoosa could be used to approximate the conditions that are important in determining suitable turkey habitat (e.g , percent herbaceous canopy cover, mean height of herbaceous canopy, and percent shrub crown cover) (Schroeder 1985b)

The models used in this study could be improved by additional field research. Cade and Sousa (1985) developed a proximity method for estimating the winter food component in their HSI model, using the average radius of a circle containing 20 mature male aspen trees. This idea would improve the predictive ability of both models in this study if applied to the road and water variables. A gradual increase in suitability as roads or water are approached rather than the sharp demarcation used in this study would better approximate true conditions. More telemetry data are needed to determine appropriate suitability curves for these variables

Testing HSI models is difficult HSI models are developed around concepts (habitat suitability and carrying capacity) that have several definitions and are hard to quantify Each habitat model uses restricted definitions of habitat and carrying capacity; these definitions must be considered when designing model tests (Schamberger and O'Neil 1985).

The most sensible test would be to evaluate the model within the conditions for which it was developed This would best be done by applying these models to an area where change is planned, and then predicting ruffed grouse response (Schamberger and O'Neil 1985) After the land-use change is implemented, grouse response over time could be compared to the model's predictions. Long term data sets covering several sites would be necessary to determine if changes in population densities occur that are unrelated to habitat factors (Cole and Smith 1983, O'Neil et al. 1988) Model performance, however, improves when multiple year data sets are used (Hurley 1985).

Both telemetry and abundance data will be needed to determine if these models make accurate predictions Factors other than habitat can affect an animal's habitat use, such as hunting pressure or competition Telemetry is needed to demonstrate that a measure of use and habitat quality are related. Ruffed grouse abundance is usually determined by spring drumming counts This does not address brood success or overwinter mortality directly. However, these abundance data do provide a means of preliminary verification of the winter habitat model.

Three seasons of pre-management population data exist for the experimental area of Longwitz's (1985) and Epperson's (1988) projects Drumming male censuses from 1983 - 1986 showed the adult male grouse population fluctuated between 0 and 0.45 grouse per 100 ha; assuming a 1:1 sex ratio (Gullion 1966a), total adult population fluctuated between 0 and 0 9 grouse per 100 ha. The experimental area had three clearcut harvests made during 1986 From 1987 to 1993, grouse populations grew steadily to 5.4 adult grouse per 100 ha in 1993 (Dimmick and Harris, unpublished progress report, 1993). In comparison, the grouse population in the control area over this time (1983-1993) rose slowly with fluctuations from 1 8 adult birds per 100 ha in 1983 to 2 3 grouse per 100 ha in 1993. Both areas had about the same amount of laurel/rhododendron thickets This implies winter habitat for adult grouse improved on the experimental area compared to the control area due to clearcutting. A closer view of the experimental area (Fig. 14) shows the HSI values for the winter habitat model are in the upper quartile in the center of the area where cutting has been performed near streams supporting evergreen shrub thickets

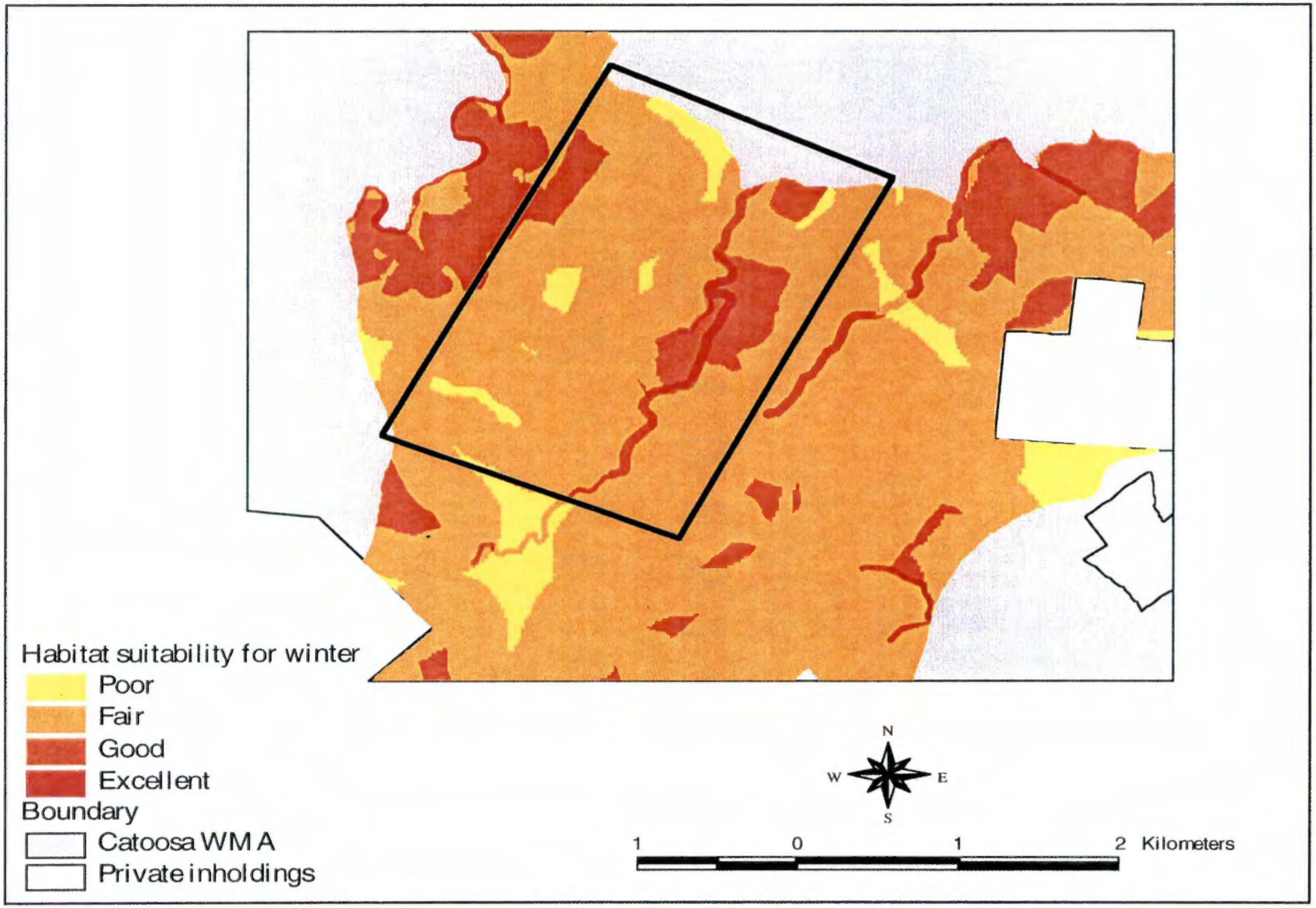


Figure 14. Habitat suitability for winter in the experimental area (box), Catoosa Wildlife Management Area, Tennessee, 1995.

Verification of the brood habitat model was not possible because there were no telemetry data on broods both before and after cutting in the experimental area Greater numbers of broods or brood success can only be inferred from greater numbers of drumming grouse in the spring The control area from Longwitz's (1985) and Epperson's (1988) studies was not available for further model verification because it had not yet been inventoried

A need for habitat assessment and forest management planning for ruffed grouse exists now While the information behind these models was incomplete, models offer the most comprehensive approach to habitat assessment (Cole and Smith 1983). In practice most decisions have to be made with incomplete information (Cooperrider 1986).

## II. Management Implications

### i. GIS and Modelling

Managers require a tool that will predict the effects of habitat change resulting from management activities (Hurley 1985) While the initial setup of a geographic information system can be expensive in terms of time and money, this is recouped later by continued use of the database (Williams 1986). Perras et al. (1988) noted their GIS inventory of habitat was much more economical than traditional (aerial photography, ground surveys) inventories HSI models utilizing GIS offer natural resource managers the opportunity to predict the results of management, compare alternative management plans, and to target areas in need of certain management activities (Morrison et al. 1992) These kinds of models provide contributions to wildlife resource management more quickly and easily than conventional field studies (Williams 1986).

Hurley (1985) and Morrison et al (1992) stated that useful modelling systems need the following characteristics. 1) a modelling system must be based on habitat identification that is useful to managers (i.e., commonly used, easily gathered), 2) this system should also be integrated with classification systems used for other resources, such as timber or range, and 3) managers should have access to the information, along with guidelines for its use and interpretation. This study incorporated these characteristics by using forest data that are regularly collected by Catoosa foresters and integrating it with other site data (road and water features). Catoosa managers will have access to this model and its information because this study used the same GIS used by the TWRA (ARC/INFO)

### ii Silvicultural Practices

The models used in this study indicate that good habitat for ruffed grouse either in winter or during the brood season is limited. Most grouse do not move far from their winter coverts (Gullion 1989). While family groups may move large distances (0 8 km) soon after hatching to locate good brood habitat (Bump et al 1947), greater movement affects survival by exposing broods to greater environmental stress and predation (Kimmel and Samuel 1984)

Lack of suitable winter habitat will also depress grouse numbers. Habitats without sufficient thermal shelter or food will decrease survivorship because grouse will forage longer, increasing their exposure to predation, and increased metabolic rates to raise body temperatures will decrease body reserves (weight loss) Thompson (1987) found evidence for this, in that grouse with greater winter movements had lower survival, particularly juveniles

Focusing on improving only one of these necessary habitats may not increase grouse numbers Gullion (1989) reported that Sharp's efforts to improve brood habitat in Pennsylvania failed to increase grouse abundance This failure was attributed to lack of suitable winter habitat. Both habitat types may be crucial because overwinter losses must be made up by annual recruitment. Gullion (1970) demonstrated that grouse populations in Minnesota have a normal attrition rate of 55% per year It is possible that southern grouse have even higher rates, due to lower habitat quality (Boag and Summanik 1969, Rusch and Keith 1971, Gullion and Alm 1983) The key to managing for ruffed grouse in the north is providing the necessary interspersion of forest types and age classes (Gullion 1989) For southern grouse, managing habitat containing laurel/rhododendron thickets or creating linear food plots along roads may be important.

Grouse habitat structure is critical to their survival Throughout their range, ruffed grouse prefer areas with high stem densities and vegetation diversity (Bump et al 1947, Korschgen 1966, Gullion and Svoboda 1972, Hale et al. 1982, Gullion 1984a, Gudlin and Dimmick 1984, Thompson 1987, Epperson

1988, Thompson and Fritzell 1987, Wiggers et al. 1992) Many studies have demonstrated that grouse responded positively to clearcutting when it is used as a tool to improve vegetation interspersion. Gullion (1989) reported a consistent positive response of grouse to clearcutting 4 ha units in a Michigan forest. Kubisiak (1985) found grouse numbers increased after clearcutting 5 7 ha units in Wisconsin. Yahner (1986) in Pennsylvania and Schultz (1984) in North Dakota also reported numbers of grouse increased after clearcutting 1 ha blocks Researchers in Cloquet, Minnesota have noted grouse population increases in response to early successional vegetation from logging or burning since 1927 (Gullion 1989)

Commercial clearcutting is the most cost-effective method of management, but smaller cuts (such as those done for fuelwood) are the most beneficial to grouse (Gullion 1989) Benefits from clearcutting diminish as the cuts exceed 1 ha (Gullion 1989). Large cuts (>16 ha) make large areas unsuitable for grouse during the lag time between cutting and when the area becomes suitable Also, the distance from acceptable cover to necessary foods becomes excessive with large cuts, hence good habitat can go unused (Gullion 1989). Gullion (1989) advocated clearcutting strips of blocks about 4 ha in size every 16 ha in areas of mature forest. Larger cuts benefit fewer grouse, such that cuts of more than 16 ha benefit only 30% as many grouse as 4 ha cuts Commercially harvested areas on Catoosa generally range from 5-10 ha (TWRA 1992) Catoosa is fortunate to have had a history of both commercial and fuelwood cuts. In the future these harvest types could be more closely integrated in specific areas to provide the vegetation diversity grouse need

Forest harvests could be used to better connect areas of good habitat that are separated by large expanses (greater than home range size) of mature forest. Selecting stands close to both appropriate streams and daylighted roads for clearcut harvest would also improve the connectivity of ruffed grouse habitat on Catoosa However, it is possible that placing cuts near roads will increase hunting mortality, because hunters usually hunt within 400 m of driveable roads (Kubisiak 1989). Leaving evergreen shrub thickets intact during harvest would give grouse corridors for movement until the cut area had sufficiently grown up again Fig. 5 shows different aged stands are not close to one another, but occur in groups. This indicates areas without further cutting will improve habitat for grouse for only a short period of time as the stands mature. More cutting will be necessary to maintain habitat quality

The amount of laurel and rhododendron thickets cannot be improved by traditional forest management techniques However, in areas where the thickets extend beyond the low-intensity buffer (no cutting allowed) around streams, leaving such thickets intact when a stand is harvested would at least maintain this winter habitat. Cutting near areas with evergreen shrub thickets would place foraging areas close to protective cover, helping decrease predation and energy expenditure (Harlow and Guthrie 1972).

Since there is conflicting evidence concerning grouse use of clearcuts for winter cover in the southern part of their range (Boyd 1990, Pelren 1991), placing cuts near mixed pine-hardwood stands in areas where evergreen shrub thickets are not available would at least ensure winter cover (the pines) is close to winter food (the cut stand). Forest management practices that increase fruit and herbaceous leaf availability (thereby decreasing dependence on evergreen leaves) can improve diet quality and over-winter survival (Norman and Kirkpatrick 1984, Servello and Kirkpatrick 1987) Practices such as pre-commercial thins, prescribed burns, and overstory stocking reduction all have potential in this area The understory and groundstory would be enhanced in stands with lower overstory stocking levels (e g., <16 $m^2$/ha) because more sunlight would get through (Norman and Kirkpatrick 1984).

Continuing to create linear food plots along the sides of daylighted and timber roads should help increase and improve brood habitat for grouse as long as these plots are maintained (mowed and replanted periodically) Hollifield (1992) suggested creating soft edges near such roads to provide easily accessible escape cover. Areas selected for cutting to improve brood habitat must be chosen carefully Not all areas will produce a good herbaceous layer when the overstory is reduced Sharp (1963) discovered that sites lacking desired groundstory plants prior to cutting generally did not produce the desired plants after cutting Sharp (1963) proposed that poor plant distribution was more of a problem than getting plants to grow. Thus, there may be merit in selecting stands that have a sparse, but desirable groundstory for harvest

The role of prescribed burns for grouse brood habitat improvement needs more investigation. Sharp (1963) determined mulch and leaf litter removal stimulated understory growth, indicating there may be a role for prescribed burning along with overstory reduction Burning returns nutrients to the soil in a form readily available for plant uptake. The ensuing vegetation has higher nutrient quality (Gullion 1970) Burning may also reduce bulky litter on the ground that might hide predators (Gullion 1970)

To make significant changes in ruffed grouse abundance, large tracts of land must be managed (Gullion 1989) However, not all areas on Catoosa can be targeted for ruffed grouse management because the needs of species which require large tracts of mature forest must also be taken into account (e.g., squirrel, woodpecker). Therefore, it is further suggested that these additional harvests be targeted toward those areas which have had cutting performed already. For example, compartments 34, 36, 37, 40, 41, and 42 are adjacent to each other and have had several stands harvested in each compartment over the last 20 years. The combined area of these compartments is 2,509 ha; their combined harvested area totals 273 ha for the 31 stands that were harvested (TWRA 1992) Other areas on Catoosa that could be suitable are compartments 56, 60, 65, and 69 These compartments total 1,859 ha, with a combined harvest of 201 ha in 26 stands (TWRA 1992) Wiggers et al. (1992) suggested maintaining more than 14% of a forest in 7-15 year-old regeneration to enhance grouse habitat Further cutting in these compartments would increase forest age class interspersion, and replace habitat which becomes unfavorable because of aging. The forest management techniques mentioned above will also improve habitat for other wildlife species of interest on Catoosa, such as turkey, some neotropical migrant birds, and deer.

iii Model Simulation

A simulation of these models was run to demonstrate the effects of forest management on the HSI values for an area, and to show the utility of these models for prediction The area chosen for the simulation includes compartments 34, 36, 37, 40, 41, and 42 mentioned above. This area is located in the central part of the currently inventoried area (see Fig. 3).

The simulation predicted HSI values for the year 2003, following two harvests Harvests took place in 1996 and 2001. Each harvest included five full-stand cuts and two smaller fuelwood cuts Four logging roads were added to access stands for harvest (Fig. 15) The number and types of cuts in each harvest year were based on current trends of cuts per compartment (TWRA 1992) The harvest locations were selected to improve vegetation interspersion and to place foraging habitat close to winter cover.

Fig 16 shows the adjusted HSI values for winter habitat for the simulation area in 1995 Almost 60% of this area in 1995 fell below HSI = 0.5 (Table 8) Fig 17 shows the predicted adjusted HSI values for 2003. Connectivity has improved, as has overall habitat quality for winter. Most of the improvement took place in the middle ranges of values (Table 9) Area in the second quartile (0.25 - 0.499) dropped almost 10%, and area in the third quartile (0 50 - 0 749) increased almost 10% Optimal habitat (HSI = 1) decreased, probably in response to an age class 2 stand inside the water buffer changing to age class 3 in this eight year interval.

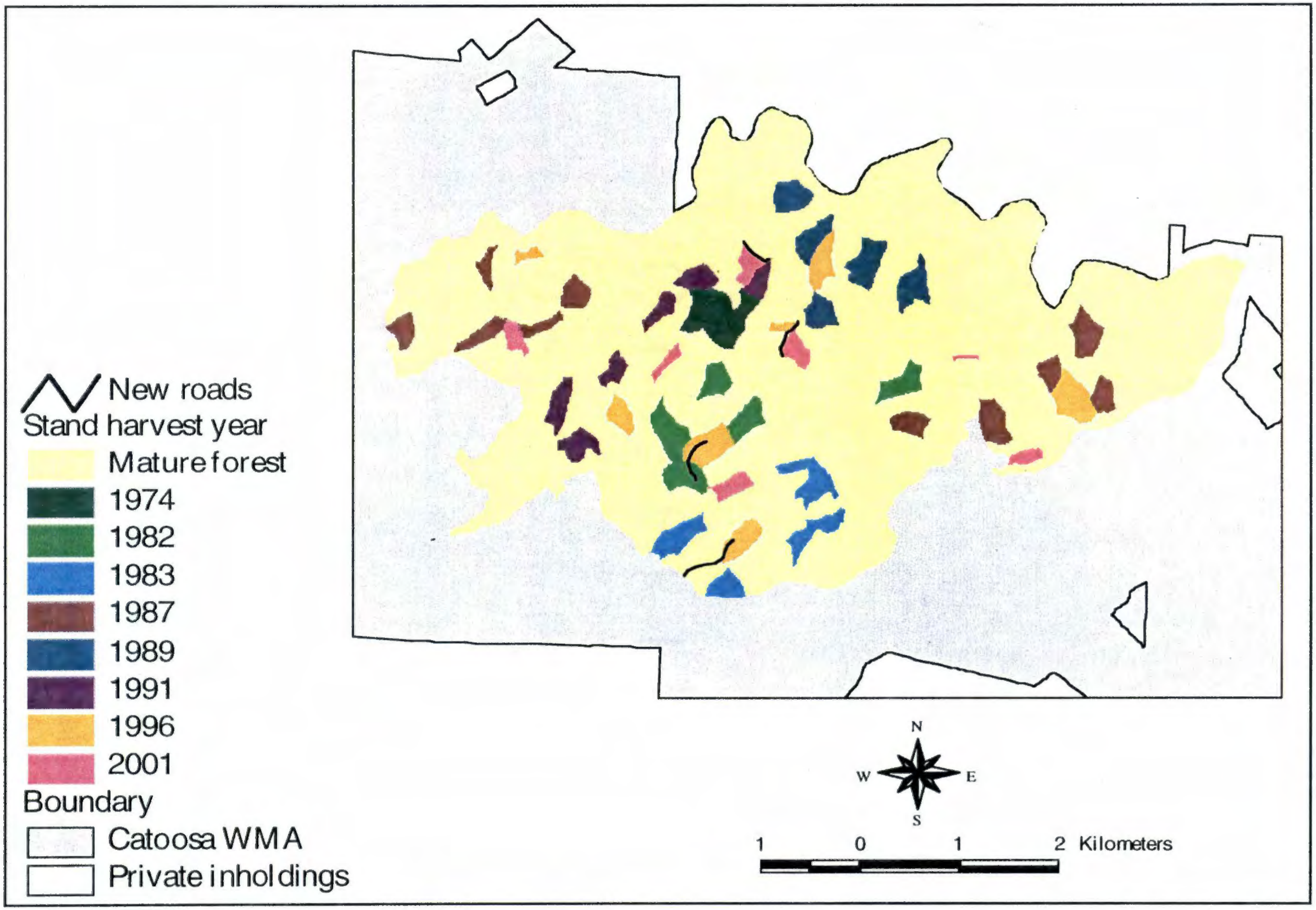


Figure 15. The model simulation area and forest stand harvest years, Catoosa Wildlife Management Area, Tennessee, 1995.

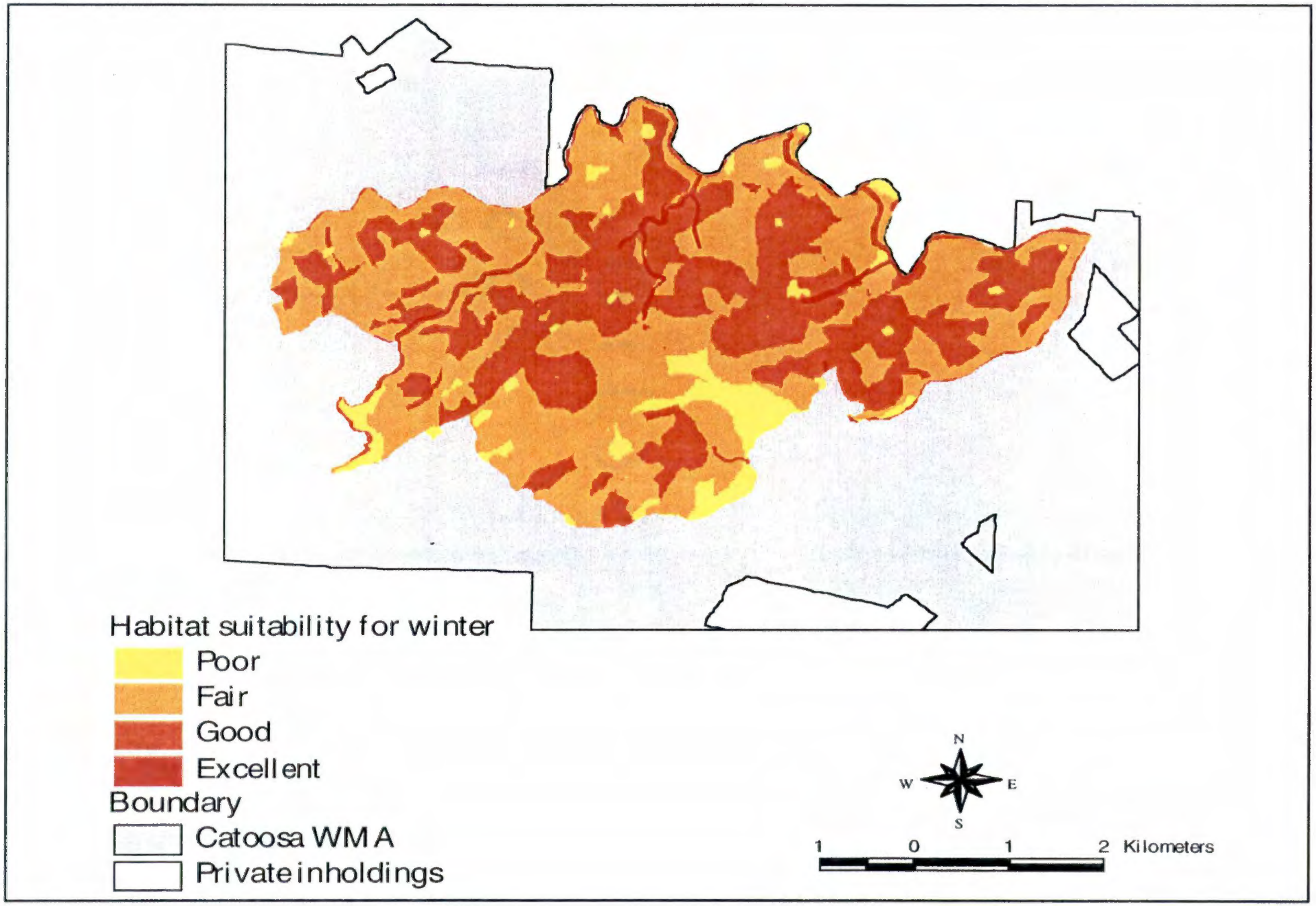


Figure 16. Habitat suitability for winter in the model simulation area, Catoosa Wildlife Management Area, Tennessee, 1995.

Table 8. Adjusted Habitat Suitability Indices and percentage of the simulation area for the winter habitat model, 1995

| HSI | Area (ha) | % of simulation area | % of simulation area by quartile |
|---|---|---|---|
| 0 00 | 25 88 | 1 05 | |
| .03 | 2 14 | 0.09 | |
| 13 | 3 63 | 0.15 | |
| 17 | 106 38 | 4 32 | 6 35 |
| 20 | 18 91 | 0 77 | |
| 23 | 1 47 | 0 04 | |
| 27 | 260 72 | 10.58 | |
| 33 | 672 59 | 27 30 | |
| 40 | 46 76 | 1.90 | 52 24 |
| 43 | 306 94 | 12 46 | |
| 50 | 836 58 | 33 96 | |
| 56 | 36 38 | 1 48 | |
| 60 | 37 93 | 1 54 | 40 14 |
| 67 | 77 88 | 3 16 | |
| 77 | 9 99 | 0 41 | |
| 83 | 15 94 | 0.65 | |
| 90 | 43 | 0 02 | 1 19 |
| 1 00 | 2 78 | 0 11 | |

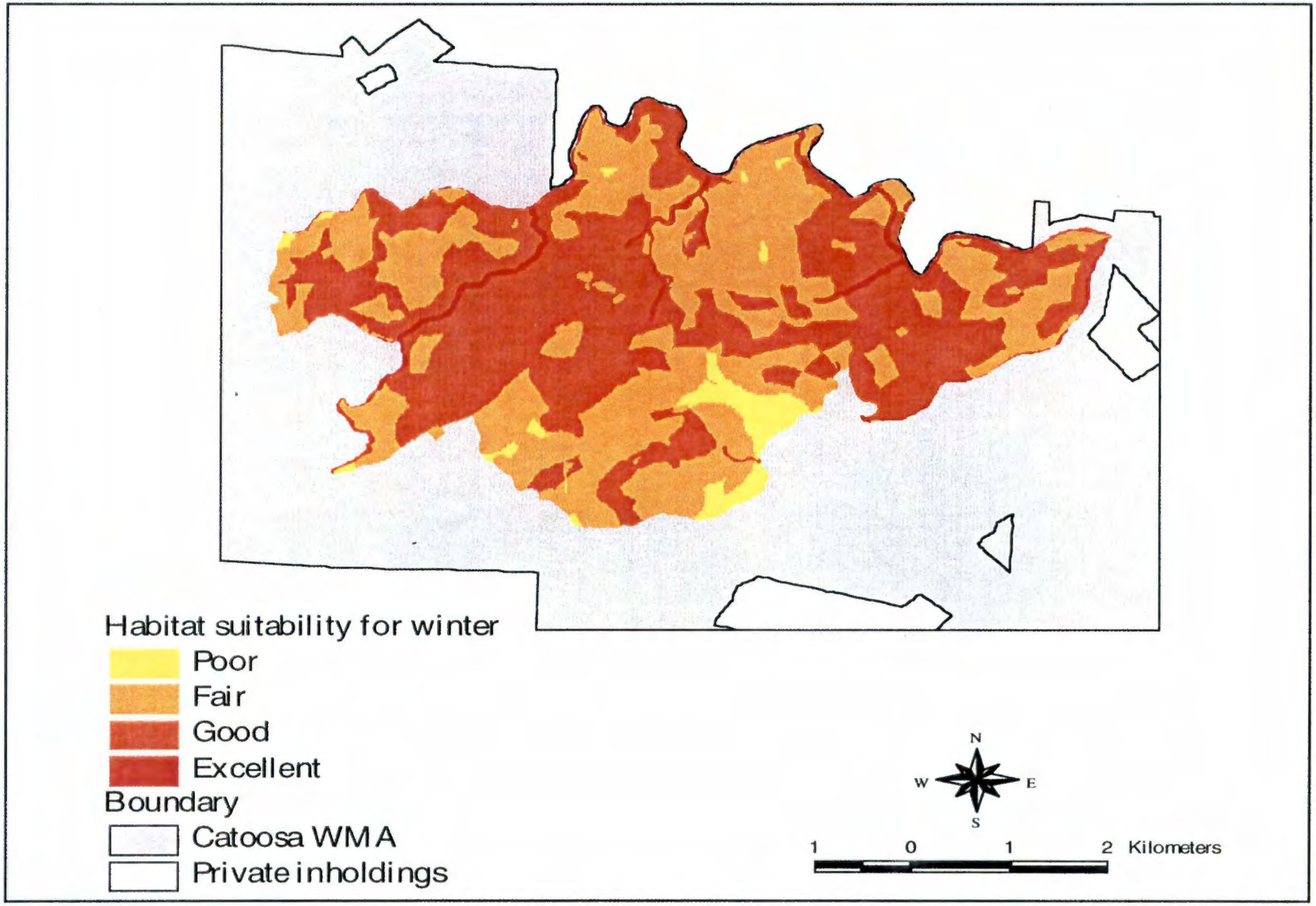


Figure 17. Predicted habitat suitability for winter in the model simulation area, Catoosa Wildlife Management Area, Tennessee, 2003.

Table 9 Adjusted Habitat Suitability Indices and percentage of the simulation area for the winter habitat model, 2003

| HSI | Area (ha) | % of simulation area | % of simulation area by quartile |
|---|---|---|---|
| 0 00 | <0 01 | <0 01 | |
| 09 | 25 85 | 1 05 | |
| 12 | 1 48 | 0 06 | 3 66 |
| 21 | 1 11 | 0 04 | |
| 24 | 61 83 | 2 51 | |
| 27 | 22 97 | 0 93 | |
| 30 | 0 21 | <0 01 | |
| 33 | 129 08 | 5 24 | |
| 39 | 768 62 | 31 20 | 43 45 |
| 45 | 78 79 | 3 20 | |
| 48 | 70 93 | 2.88 | |
| 55 | 974 55 | 39 56 | |
| 61 | 162 01 | 6 58 | |
| 64 | 6 78 | 0.28 | 50 05 |
| 70 | 89 33 | 3 63 | |
| 76 | 2 78 | 0 12 | |
| 79 | 10 39 | 0 42 | |
| 85 | 55 73 | 2 26 | 2 84 |
| 91 | 0 46 | 0 02 | |
| 1 00 | 0 48 | 0 02 | |

The adjusted HSI values for brood habitat in the simulation area in 1995 are shown in Fig 18. Again, the majority of the values fall below HSI = 0.5, and less than 1% of the simulation area is in the excellent category (Table 10) The predicted adjusted HSI values show a marked improvement (Fig 19). The middle quartiles changed the most, with area in the second quartile dropping about 26% and the third quartile gaining almost 32% (Table 11) Larger changes were seen in the lowest and highest quartiles as compared to the winter habitat simulation. Optimal habitat increased, probably in response to the added roads

These simulation pictures also indicate places where harvests should be focused next Areas with large contiguous yellow and light orange patches (poor and fair habitat) would probably benefit from harvest Linear high quality habitat surrounded by low quality areas could be better connected to other higher quality areas by placing cuts parallel to the linear habitat

## IV. Conclusions

Wildlife resource strategic plans often call for increases in hunter numbers and trips to meet public demands (TWRA 1990a). A common problem, however, is a lack of both basic biological and management information for the species under consideration This information is necessary for improving management strategies and techniques (TWRA 1990a). Despite the lack of testing for the models in this study, their application could help managers on Catoosa make better informed decisions about ruffed grouse management.

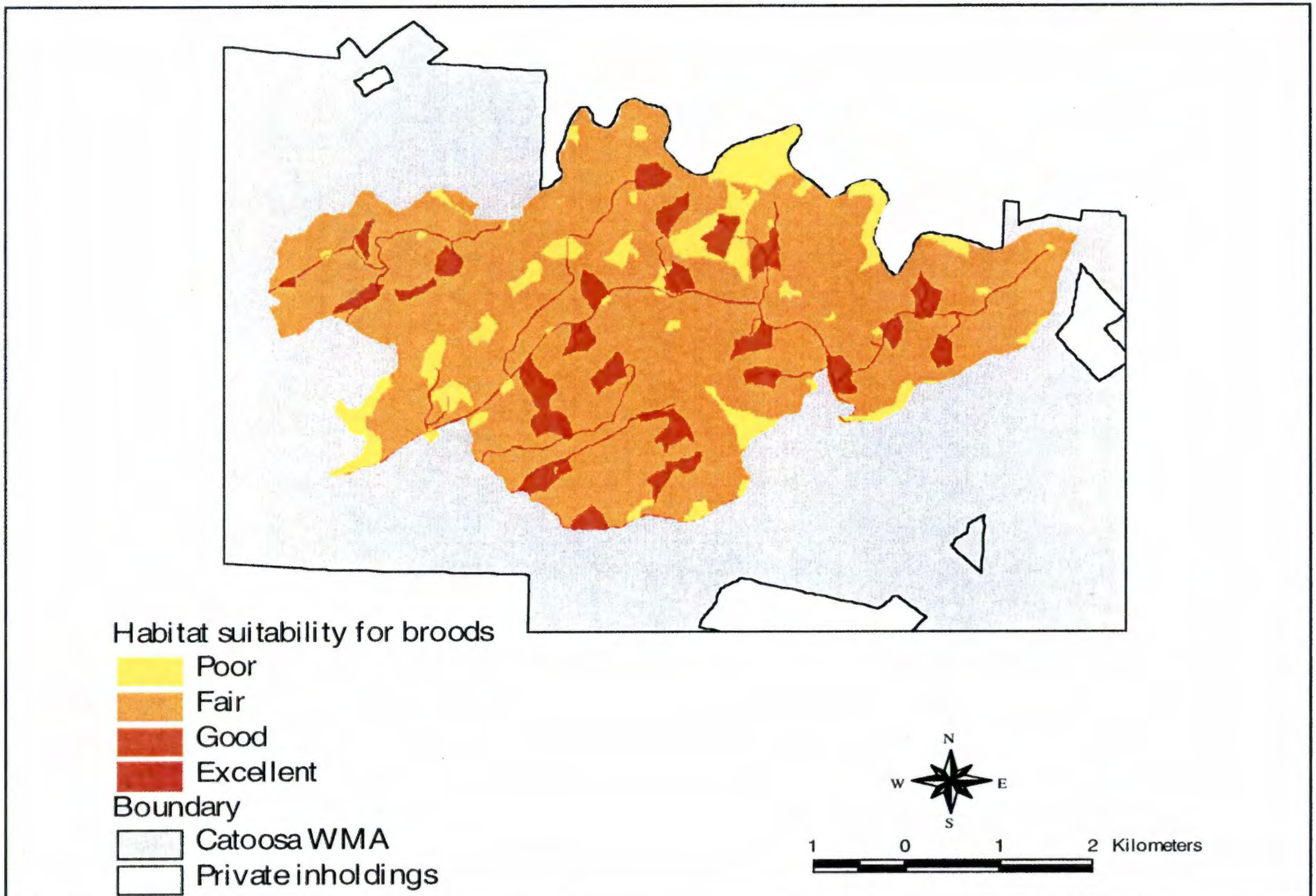


Figure 18. Habitat suitability for broods in the model simulation area, Catoosa Wildlife Management Area, Tennessee, 1995.

Table 10. Adjusted Habitat Suitability Indices and percentage of the simulation area for the brood habitat model, 1995

| HSI | Area (ha) | % of inventoried area | % of inventoried area by quartile |
|---|---|---|---|
| 0.00 | 4 01 | 0 16 | |
| 01 | 1 79 | 0 07 | |
| 05 | 6 36 | 0 26 | |
| 09 | 27 38 | 1 11 | |
| 10 | 2 82 | 0 11 | 9 73 |
| 14 | 37 25 | 1 52 | |
| 18 | 53 37 | 2 17 | |
| 20 | 53 79 | 2 19 | |
| 23 | 52 60 | 2 14 | |
| .27 | 309 23 | 12 59 | |
| .29 | 189 54 | 7 72 | |
| .32 | 394 61 | 16 07 | |
| 36 | 0 08 | <0 01 | |
| 38 | 1028 09 | 41 85 | 78 60 |
| 41 | 35 | 0 01 | |
| 45 | 7 72 | 0 31 | |
| 47 | 1.17 | 0 05 | |
| 50 | 18 48 | 0 75 | |
| 54 | 0 41 | 0 02 | |
| 56 | 76 49 | 3 11 | |
| .60 | 0 62 | 0 03 | 11.19 |
| 63 | 43 15 | 1 76 | |
| 69 | 134.94 | 5 50 | |
| 74 | 0 39 | 0 02 | |

Table 10. (cont.)

| HSI | Area (ha) | % of inventoried area | % of inventoried area by quartile |
|---|---|---|---|
| .81 | 1 41 | 0.06 | |
| 87 | 1 82 | 0 07 | |
| .92 | 1 61 | 0 07 | 0 48 |
| 1 00 | 6 87 | 0 28 | |

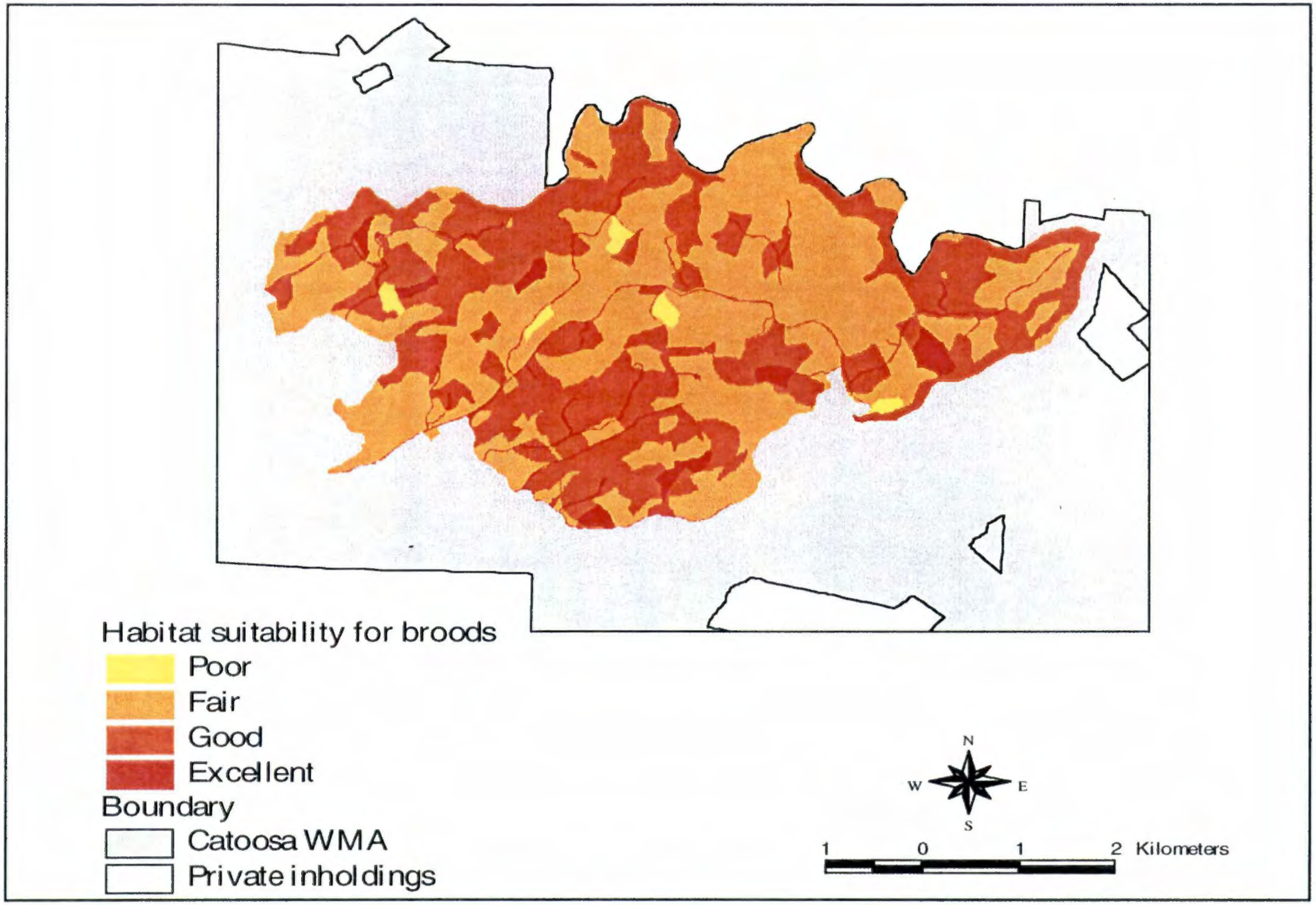


Figure 19. Predicted habitat suitability for broods in the model simulation area, Catoosa Wildlife Management Area, Tennessee, 2003.

Table 11 Adjusted Habitat Suitability Indices and percentage of the simulation area for the brood habitat model, 2003

| HSI | Area (ha) | % of inventoried area | % of inventoried area by quartile |
|---|---|---|---|
| 0 00 | <0 01 | <0 01 | |
| 11 | <0 01 | <0 01 | |
| 19 | 0 49 | 0 02 | 1 14 |
| .23 | 27 58 | 1 12 | |
| 26 | 2 80 | 0 11 | |
| 28 | 23 74 | 0 96 | |
| 30 | 0 81 | 0 03 | |
| 33 | 21.73 | 0 88 | |
| .36 | 22 57 | 0 92 | 52 11 |
| .37 | 28 72 | 1 17 | |
| .40 | 15 55 | 0 63 | |
| .43 | 788 80 | 32 02 | |
| .44 | 231 77 | 9.41 | |
| 47 | 147 31 | 5 98 | |
| .51 | 756 23 | 30 70 | |
| .56 | 4 88 | 0 21 | |
| 59 | 1 51 | 0 06 | |
| 61 | 23 45 | 0 95 | |
| 64 | 3 41 | 0.14 | 43 17 |
| 66 | 207 71 | 8 43 | |
| 69 | 63 32 | 2.57 | |
| 71 | 2 62 | 0 11 | |

Table 11. (cont.)

| HSI | Area (ha) | % of inventoried area | % of inventoried area by quartile |
|---|---|---|---|
| 76 | 73.23 | 2.97 | |
| 80 | 0 36 | 0 01 | |
| 86 | 0 94 | 0 05 | |
| 87 | 0 37 | 0 01 | |
| 90 | 9 96 | 0 40 | 3 58 |
| 93 | 2 39 | 0 10 | |
| 94 | 0 19 | <0 01 | |
| 1 00 | 0 91 | 0 04 | |

Researchers and managers must work together in order for modelling to reach its greatest potential. Researchers must understand management's needs to develop appropriate models Managers must make efforts to understand models and the modelling process to supply researchers with the contexts for model building Successful model development and forest management requires continuing communication and cooperation between researchers and managers.

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