Relationship of Ruffed Grouse Home Range Size and Movement to Landscape Characteristics in Southwestern Virginia

by

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RELATIONSHIP OF RUFFED GROUSE HOME RANGE SIZE AND MOVEMENT TO LANDSCAPE CHARACTERISTICS IN SOUTHWESTERN VIRGINIA

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ABSTRACT

I addressed the effects of landscape characteristics on ruffed grouse (*Bonasa umbellus*) home range size and movement, and examined grouse selection for specific landscape characteristics and cover types. Grouse home ranges and movement patterns derived from telemetry data gathered from fall 1996 through fall 1998 were overlaid onto a GIS database of Clinch Mtn. Wildlife Management Area, VA. This database was developed from GPS data and LANDSAT thematic mapping imagery (30m pixel scale) and was composed of 22 cover types. Landscape metrics were calculated using FRAGSTATS/ARC, and multiple regression was used to relate changes in home range size and movement to these metrics. I used Wilcoxon signed-rank tests to compare the values of landscape metrics calculated for each home range to those calculated for the area encompassed by the home range plus a surrounding 300 m buffer. I used Wilcoxon rank-sum tests to compare the values of landscape metrics for the home ranges to the metrics calculated for 50 33 ha random plots. I used compositional analysis to test for preferential use of cover types.

I developed 2 regression models ($P < 0.01$) relating changes in home range size to landscape characteristics, 1 model ($P = 0.09$) relating the distance between seasonal home range centers to landscape characteristics, and 1 model ($P = 0.03$) relating average daily movement to landscape characteristics. Grouse home range size increased as patch shape became more irregular and patch size and the number of different cover types per hectare increased, and decreased as the amount of high contrast edge in the landscape increased. The distance between seasonal home range centers increased as Shannon's diversity index and the average distance between patches of similar cover types increased, and decreased as the amount of high contrast edge increased. Average daily movement increased as the average distance between patches of the same cover type increased and

as the percent cover of a full (~75%) rhododendron and/or laurel understory within a grouse's home range increased, and decreased as the amount of high contrast edge in a bird's home range increased.

Ruffed grouse were selecting areas with high densities of smaller than average patches that were of uniform size and regular shape and contained higher than average amounts of high contrast edge. Areas containing a greater diversity of cover types than what was available in the study area also were preferred. Within these areas, clearcuts and mesic deciduous stands with a rhododendron/laurel understory were the most preferred cover types.

Creating and maintaining a landscape with high densities of small patches that are of uniform size and regular (square) shape would provide the highest quality ruffed grouse habitat in this region. Several of these patches should be early successional cover to provide an abundance of high contrast edge. Rhododendron and/or laurel thickets also may be beneficial as supplemental winter cover, and mesic stands of mature hardwoods should be well interspersed with these cover types to provide supplemental food sources.

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INTRODUCTION

The ruffed grouse (*Bonasa umbellus*) is one of the most popular game birds of North America. With a range including much of Canada and Alaska as well as the western, north central, and eastern portions of the United States, the ruffed grouse occupies a variety of climates, terrain, and ecosystems. In spite of an extensive distribution, approximately 92% of the grouse's native range occurs in areas where aspen (*Populus* spp.) is an important component of the forest (Gullion 1989c). Forest stands containing aspen are important to ruffed grouse for both food and cover (Dorney 1959, Rusch and Keith 1971, Gullion 1972, 1977, Kubisiak et al. 1980, Cade and Sousa 1985, Stauffer and Peterson 1985). Ruffed grouse populations occurring outside the native range of aspen, such as those in the central and southern Appalachian region, must rely on other sources of food and cover. However, little research has been done on the factors limiting these populations.

In recent years, there has been a growing concern that ruffed grouse populations are declining in the Mid-Atlantic region. State hunter surveys have indicated an apparent long-term decline in grouse abundance (Swanson and Stoll 1995), and many grouse biologists in the region believed that current grouse densities were low and were either stable or declining (Norman 1995). Because there was a general lack of knowledge of ruffed grouse ecology in the eastern and southeastern parts of their range, developing successful management plans to counter these declines was difficult at best. For these reasons, the Appalachian Cooperative Grouse Research Project (ACGRP) was initiated in 1996. ACGRP was a 6 state cooperative project encompassing Maryland, Virginia, West Virginia, Kentucky, Pennsylvania, and Ohio designed to collect data over a 7 year period. The overall objectives of this project were to determine the population ecology of ruffed grouse in this region, determine the impacts of predation and hunting mortality on ruffed grouse, and develop population models that integrate demographic and habitat components. Virginia Polytechnic Institute and State University (Virginia Tech) and the Virginia Department of Game and Inland Fisheries (VDGIF) were working jointly to complete the work and research for Virginia's role in the project.

Landscape-level habitat characteristics, such as the size, distribution, spatial arrangement, and availability of different cover type patches in the landscape are important to those species that occupy a variety of habitats during their life (Kareiva 1990, Lamberson et al. 1992, McKelvey et al. 1992). The close proximity of the resources provided by different patch types is critical to the survival and reproduction of such species (McGarigal and Marks 1995). Many studies have documented the effect of habitat configuration at the landscape scale on a variety of bird species. Northern bobwhites (*Colinus virginianus*) are most abundant in landscapes containing a diversity of cover types evenly distributed in small, well-interspersed patches (Roseberry and Sudkamp 1998). Miller et al. (1999) found that the presence of a diversity of mature forest stands in a heavily forested landscape had the most influence on eastern wild turkey (*Meleagris gallopavo silvestris*) habitat use, and they felt that the maintenance of this diversity was critical for turkey management. Merrill et al. (1999) found that the size, location and amount of forest and residential-farmstead patches were important to lek placement and use by greater prairie-chickens (*Tympanuchus cupido pinnatus*). Even birds that are typically associated with a particular cover type often make use of other cover types for feeding or seasonal habitat needs (Whitcomb et al. 1981). In a study comparing forest bird communities between clearcuts and burn areas, Schulte and Niemi (1998) documented several forest-nesting birds foraging in early successional cover types.

Habitat requirements of ruffed grouse change with season and grouse behavior (Bump et al. 1947, Chapman et al. 1952, Dorney 1959, Maxson 1978, Landry 1980, Thompson and Dessecker 1997). Landscape-level habitat use among individuals can reflect the distribution of cover types in a given area (Maxson 1978), and the proper interspersion of necessary cover types is important for the success of a grouse population (Bump et al. 1947, Kubisiak 1978, Landry 1980, Gullion 1989c). Management recommendations for ruffed grouse stress the importance of providing and maintaining the proper mixture of forest age classes and cover types at the landscape scale (Bump et al. 1947, Berner and Gysel 1969, Gullion 1972, Kubisiak et al. 1980, Kubisiak 1985, Gullion 1989c). However, few studies suggest an optimal size, configuration, and relative availability of these cover types in the landscape.

OBJECTIVES AND RESEARCH HYPOTHESES

My overall objective was to determine the relationship of ruffed grouse behavior to landscape-level habitat characteristics. I intended to identify patterns of landscape characteristics that contained ruffed grouse habitat requirements within small areas. I assumed that landscapes containing grouse habitat requirements in smaller areas would decrease the birds' energy expended searching for food and cover as well as their exposure to predators. Such landscapes also should increase the density of birds and sustainability of the population over a given area, thus maximizing the potential of available habitat and improving hunters' success (Bump et al. 1947). I specifically wanted to address the effects of these landscape characteristics on home range size and movement. I developed 3 main objectives, and addressed specific hypotheses within each objective:

1. Determine the relationship between ruffed grouse home range size and the size and configuration of landscape-level cover types.

    H_{O1}: Total home range size does not vary with the size and configuration of landscape-level cover types.

    H_{O2}: Distance between seasonal home range centers does not vary with the size and configuration of landscape-level cover types.

    H_{O3}: Size of seasonal home ranges does not vary with the size and configuration of landscape-level cover types.

2. Determine the relationship between movement of individual birds and the size and configuration of landscape-level cover types.

    H_{O4}: Daily movement does not vary with the size and configuration of landscape-level cover types.

    H_{O5}: Daily movement between and within seasons does not vary with the size and configuration of landscape-level cover types.

3. Determine ruffed grouse selection for particular landscape characteristics, configuration(s) of cover types in the landscape, and specific cover types.

H_{O6}: The configuration and spatial arrangement of cover types within home ranges is not different than the landscape in general.

H_{O7}: The relative proportion of any cover type within a home range is not different than its availability.

STUDY SITE

My study was conducted in Clinch Mountain Wildlife Management Area (CMWMA) located in Smyth, Washington, Russell, and Tazewell counties in southwestern Virginia. It encompassed 10,343 ha (25,557 acres) and was contained within the Ridge and Valley province (Baker 1996). The topography of the area was rugged and diverse, with a 792m (2,600 ft) vertical elevation change from the base of the area (600 m) to the highest point (1,400 m). Cover types in the management area included mixed oak (*Quercus* spp.) (12,701 acres), mixed hardwood (5,723 acres), yellow poplar (*Liriodendron tulipifera*) (662 acres), pines (*Pinus* spp.) (106 acres), northern hardwoods (461 acres), clearcuts (148 acres), and herbaceous (300-500 acres) (Baker 1996). Other cover types occurring in the area with unknown coverage were wetlands and red spruce (*Picea rubens*). Approximately 11,000 acres of the WMA were inaccessible and were not inventoried (Baker 1996).

METHODS

The field work and data collection for this project were conducted in conjunction with the ACGRP. Some of the data from the ACGRP was used for this project, and the collection of these data followed the protocols established for the ACGRP.

Trapping

Grouse were trapped during fall (September – November) and spring (February – April) using lily-pad style traps with drift fences (Gullion 1965). Birds captured between fall 1996 and spring 1998 were included in my study. All traps were checked at least once per day, usually in the evening. During times of high trapping success, traps were checked twice per day to minimize injuries to trapped birds. Trapping was conducted under VDGIF permit numbers 009451 and 012752, and trapping protocols were approved by the Animal Care Committee at Virginia Tech.

Individual Bird Data and Radio Transmitters

Captured birds were placed in a cloth bag to keep them calm and facilitate handling. Weight, sex, age, and other condition data were collected for each bird. Sex was determined by the number of spots on the rump feathers and the presence or absence of an orange eye stripe (Servello and Kirkpatrick 1986, Gullion 1989b). Age was determined by the molting pattern of the right wing and the amount of sheathing at the base of the primaries (Gullion 1989a). All birds were fitted with 10-11 g necklace-style radio transmitters with a frequency range of 150-151 MHz and battery life of at least 12 months (ATS Inc., Isanti, MN). All transmitters were equipped with an 8-hour delay mortality sensor. The transmitters were fitted to the bird using a bib-style harness consisting of a nylon-over-braid steel cable covered with rubber shrink tubing. The length of the rubber shrink tubing was 83 mm for female birds and 89 mm for males. Birds also were fitted with numbered, aluminum leg bands on their right leg. All birds were released at their capture sites.

Radio Telemetry

Weekly Triangulations. – After birds were released, they had to survive 7 days before they were included in the study. This 7 day conditioning period was part of the ACGRP protocol, and was established to permit the birds to recover from the capture event and become acclimated to the transmitter. Locations of birds were estimated by triangulating on each bird 2 - 3 times per week throughout the year. Triangulations consisted of ≥3 azimuths taken within a 30-minute time interval from telemetry stations with known and differentially corrected universal transverse mercator (UTM) coordinates. UTM coordinates were determined for each telemetry station using Corvallis MicroTechnology, Inc. (Corvalis, OR) March II geographic positioning system (GPS) units. Grouse triangulations were plotted on USGS 1:24,000 topographic maps in the field to gain a preliminary assessment of their accuracy. Data on signal strength and modulation were recorded, and each triangulation was given a confidence factor. Program LOCATE II (Pacer 1990) was used to determine UTM coordinates for each triangulation. When more than 3 azimuths were taken, those that best determined the bird's location were chosen with a Lenth estimator and a goodness-of-fit test (White and

Garrott 1990). When possible, I chose azimuths with a difference of 30° - 120° between each azimuth (Springer 1979).

Telemetry error was determined for all field personnel performing triangulations. This was done by placing 5 beacon transmitters at various locations throughout the study site. The habitats of the beacon locations were comparable to that of grouse habitat, and the UTM coordinates of each beacon were determined using GPS units. Five azimuths were taken from different stations for each beacon, and each beacon was located in January and July to account for any seasonal differences that might affect telemetry accuracy.

Daily Intensive Telemetry. – To obtain data on grouse daily movement patterns, triangulations were done throughout the day as described above on a subset of the radio collared birds. Triangulations began approximately half an hour before sunrise and were taken at 1-hour intervals, ending approximately half an hour after sunset. This was done once per month for each bird in the subset, except during March and April when it was done twice per month for females. Those months tend to be a time of high activity for females as they build their reserves for nesting and look for males and nest sites (Archibald 1975). Intensive telemetry was conducted for 1 year starting January 1998. Grouse that were selected for the intensive telemetry were those that could be reliably located and had an adequate number of triangulations to accurately determine their home range.

Delineation of Home Range and Movement

All home range and movement values presented in the results are reported as mean ± SE. The home range of each grouse was determined using the animal movement program extension (Hooge and Eichenlaub 1997) designed for ArcView (ESRI 1996). UTM coordinates for the locations of each bird were plotted in ArcView and the adaptive kernel method with least squares cross validation for the smoothing factor (Worton 1989) was used to calculate each home range. Home range sizes also were calculated using the minimum convex polygon (MCP) method to compare home range sizes of these birds to those in other studies. I used the increment analysis available in Ranges V (Kenward and Hodder 1996) to assess the cumulative home range size for each bird relative to the number of locations. Only birds whose home range size had become asymptotic given their number of locations were included in my analyses. I calculated seasonal home ranges in the same fashion, with the seasons being spring (April - June), summer (July - September), fall (October - December), and winter (January - March).

Average daily movement (m/hr) on an annual and seasonal basis was calculated for those birds included in the intensive telemetry data collection. Average movement was determined by summing the distances between each successive, hourly location and dividing that sum by the total number of successive locations for that day. Increasing the interval between locations tends to underestimate the true distance traveled (Reynolds and Laundre′ 1990); therefore, only successive locations were used in calculating the average distance moved. If one or more successive locations were missed (e.g. locations were obtained for 7:00 and 9:00, but not 8:00), the distance between the last location prior to those missed and the next location was not used in calculating the average distance.

GIS Database and Habitat Characterization

I acquired the landcover and moisture class data used in the GIS database for this project from the Fish and Wildlife Information Exchange (FWIE) at Virginia Tech. These data were derived from Landsat thematic mapping (TM) imagery at a 30 m pixel scale (McCombs 1997, Morton 1998). ArcView 3.1 and ArcInfo 7.2.1 (ESRI 1994) were used to build the GIS database for the study site.

Twenty-two cover types were developed for the GIS database and landscape analyses (Fig. 1, Table 1). Moisture classes were incorporated to account for differences in species composition and forest structure that result from different forest moisture classes (Whitcomb et al. 1981, Young and Giese 1990). The moisture classifications were based on slope, aspect, and landform index values (S. Klopfer, Virginia Tech FWIE, personal communication). Landform index is a measure of the concavity or convexity of the landscape (McCombs 1997). The evergreen understory and mixed understory cover types were those areas of deciduous forest that had rhododendron (*Rhododendron* spp.) and/or mountain laurel (*Kalmia latifolia*) present in the understory. I developed these 2 cover types in cooperation with the FWIE by comparing differences in the normalized differencing vegetation index (NDVI) between summer and winter Landsat TM images (Justice et al. 1985, Holben 1986, Eidenshink 1992). When rhododendron and/or laurel were present in the understory of a deciduous forest, these areas were often mistakenly classified as conifer forests when winter or leaf-off imagery was used for the classifications. By comparing the magnitude of the NDVI differences between summer and winter images, I was able to approximately classify those areas of deciduous forest with a rhododendron and/or laurel understory from those areas of true conifer cover. The evergreen understory cover types were those areas where the rhododendron and/or laurel shrub canopy cover was approximately 75%, and the mixed understory cover types were those areas where the rhododendron and/or laurel shrub canopy cover was approximately 50%.

To provide general structural information and species compositions for the cover types, I established 201 stratified random habitat plots in the study area. Because of logistical and time constraints, plot locations were limited to the more accessible parts of the study area (Appendix A). Since the habitat plots were established before the GIS database was complete, the cover types used in the database were not the cover types used in the stratification of the plot locations. Instead, I used the following cover types in establishing plot locations: deciduous forest, deciduous forest with a rhododendron/laurel understory, mixed forest, riparian zones, open field, shrub/scrub, and clearcuts. These cover types were established based on known differences that I perceived in the forest structure and their relevance to the objectives of this study. The relative percent coverage of each of these habitat types within each UTM grid was determined using a planimeter, and 10 plots were established in each grid. The plot locations were stratified by cover type and the plot coordinates were generated using a random number generator. Habitat data gathered in the plots were based on the methods described by Noon (1981). I used 20 m radius circular plots (Fig. 2). This plot size was chosen to characterize the data at a large scale and to approximate the size of the pixels used in the GIS database. Four transects in cardinal directions were established within the plot, and using the point intercept method at 4 m intervals along each transect, I recorded canopy cover of deciduous trees, coniferous trees, and shrubs, as well as percent ground cover of dead woody debris. The number of hits for each of the 4 categories was tallied and multiplied by 5 to determine the percent cover of each. The height of shrubs to the nearest 0.5 m also was recorded at each 4 m interval. Stem densities (<8cm dbh) were counted along the transects using a 2 m pole held parallel to ground and perpendicular to the transect while walking the transect and tallying the number of stems touching the pole. The number of stems counted along each transect was summed and multiplied by 64.1 to determine the number of stems per hectare. A 10 m X 10 m nested plot was established in the circular plot to estimate the density of trees (>8 cm dbh). Size categories of 8-20, 20-40, 40-60, and >60 cm dbh were used to match ACGRP protocol; the number of stems in each size category was tallied for each species occurring within the nested plot. Shrub species within the nested plot were tallied in order of dominance based on percent cover. Other data recorded within the plot were basal area using a 5 BAF (in clearcuts) or 10 BAF angle gauge, the height of stand within the circular plot, aspect, slope, and SAF cover type. The plot locations were overlaid onto the GIS database upon its completion, and the habitat data were summarized according to their GIS cover types. I determined the dominant tree and shrub species within each cover type based on the occurrence of each species across all plots within a cover type as well as the abundance within each plot. Dominant trees and shrubs were those that occurred in several plots and were abundant in each of those plots.

Statistical Analyses

The adaptive kernel home range estimates were used in all statistical analyses that included home ranges.

Sex, Age, and Seasonal Differences. – Differences in home range size and daily movement between male and female and adult and juvenile grouse were evaluated using Wilcoxon rank-sum tests, and differences between seasonal home range size and movement were evaluated using Kruskal-Wallis tests (Hollander and Wolfe 1973, Minitab Inc. 1996). Differences in the average distance among seasonal home range centers were evaluated using multi-response permutation procedure (McCune and Mefford 1995).

Landscape Metrics. – FRAGSTATS/ARC (McGarigal and Marks 1995, Berry et al. 1998) was used to calculate all the landscape metrics. After the home ranges were calculated and overlaid onto the GIS database, the cover types within each home range were “clipped” based on the home range’s 95% contour boundary, and each of these clipped coverages was analyzed with FRAGSTATS/ARC. I tested for selection of specific landscape characteristics and preferential use of certain habitat types at 2 scales: the home range scale and study area scale. For the home range scale, I established a 300 m buffer surrounding the 95% contour boundary of each home range to examine what was available to the grouse in their immediate area. I chose 300 m based on the average home range size for all the birds in my study. Assuming a circular shape, a 33 ha home range would have a radius of approximately 300 m. For the study area scale, I established 50 random, circular plots across the study area to examine the average landscape characteristics across the study area. I used the average home range size from the grouse in my study (33 ha) for the size of the plots. The cover types within each home range plus its respective buffer and the random plots were clipped and analyzed with FRAGSTATS/ARC. Available habitat at the study area scale was calculated as the percent coverage of each cover type across the entire study area.

FRAGSTATS calculates a number of edge metrics that consider both the amount and contrast of edge in the landscape. The edge contrast values are based on a predefined weight file that I developed for the FRAGSTATS analyses (Appendix B). I considered each possible edge combination I could have given the 22 cover types, and assigned each edge combination a weight ranging from 0 to 1. High contrast edges, such as those between a clearcut or deciduous stand with a rhododendron/laurel understory and a mature, deciduous stand were given a high weight. Low contrast edges, such as those between a deciduous stand and mixed stand or deciduous stands of different moisture classes, were given a low weight.

Relating Landscape Metrics to Home Range Size and Movement. – FRAGSTATS generates a number of metrics at the patch, class (or cover type), and landscape scale (McGarigal and Marks 1995). I chose 16 metrics based on their perceived relevance to ruffed grouse habitat requirements (Table 2). However, some of these metrics are redundant or strongly correlated with each other. Pearson's correlations (Milton 1992, Minitab Inc. 1996) were used to judge intercorrelation between landscape metrics as well as initially evaluate the relation of each landscape metric with home range size and movement (Appendix C). Values of each landscape metric for each bird as well as the average values for each metric across the study area are given in Appendix D. Landscape metrics that appeared to influence home range size or movement were plotted to further judge the magnitude and type of relationship. Best subsets regression (Neter et al. 1990, Minitab Inc. 1996) was used to determine which landscape metrics best predicted variations in home range size and movement. Regression equations that contained strongly intercorrelated metrics (>0.50) were discarded.

Selection and Preferential Use. – To determine ruffed grouse selection for certain landscape characteristics at the home range scale, landscape metrics for the home ranges were compared to the metrics calculated for the home ranges plus their buffers. These were treated as paired samples, and the median values of each metric within the home ranges were compared to the median values of each metric within the home ranges plus their buffers using the Wilcoxon signed-rank test (Hollander and Wolfe 1973, Minitab Inc. 1996). To determine selection at the study area scale, landscape metrics for the home ranges were compared to the metrics calculated for the 50 random plots. These were treated as 2 independent samples and the median values of each metric within the home ranges were compared to the median values of each metric within the random plots using the Wilcoxon rank-sum test (Hollander and Wolfe 1973, Minitab Inc. 1996).

Compositional analysis (Aebischer et al. 1993) was used for the use-availability analyses. Use-availability ratios were determined at the home range and study area scale. At the home range scale, used habitat was that located within each bird's home range, and available habitat was that located in the home range plus its surrounding 300 m buffer. At the study site scale, used habitat was that located within each bird's home range, and available habitat was averaged across the entire study area. The percent coverage of each cover type was determined in the FRAGSTATS analyses, and I used a SAS algorithm for the compositional analysis calculations (SAS Institute 1989, Ott and Hovey 1997).

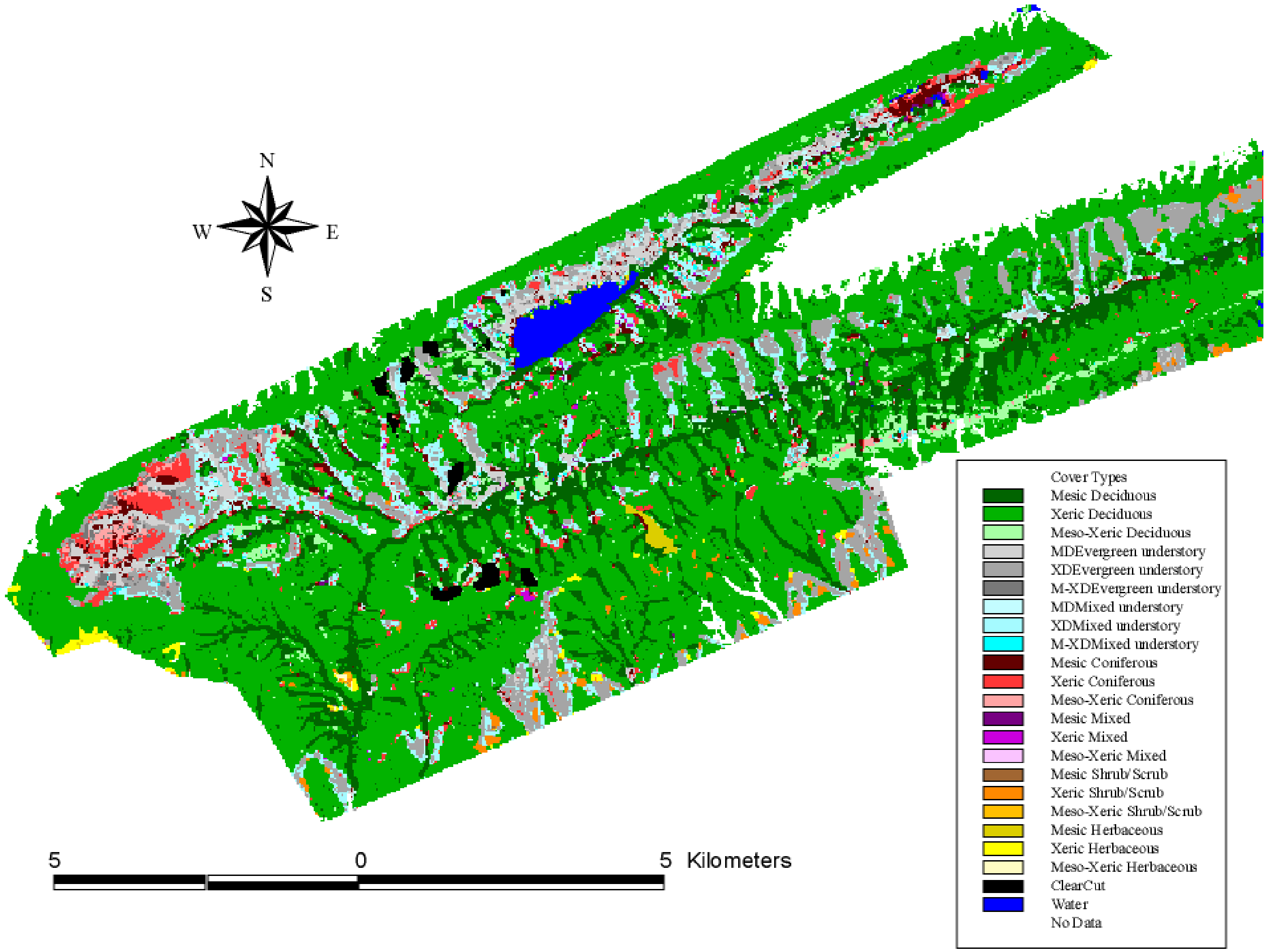

Figure 1. GIS map of Clinch Mtn. Wildlife Management Area, VA, and the cover types used in the landscape analyses, 1996-1998.

Table 1. Cover types developed for the CMWMA GIS database to be used in the landscape-level habitat analyses, CMWMA, VA, 1996-1998.

Cover Type	% Coverage in study area	Acronym	Description
Mesic deciduous	14.38	MD	Moist, sheltered, mature deciduous stands
Meso-xeric deciduous	2.55	MXD	Mature deciduous stands on flat, minimal aspect areas
Xeric deciduous	59.33	XD	Dry, exposed, mature deciduous stands
Mesic deciduous w/ evergreen understory	2.53	MDEU	Moist, sheltered, mature deciduous stands w/ ~75% rhododendron and/or laurel understory
Meso-xeric deciduous w/ evergreen understory	0.38	MXDEU	Mature deciduous stands on flat, minimal aspect areas w/ ~75% rhododendron and/or laurel understory
Xeric deciduous w/ evergreen understory	7.85	XDEU	Dry, exposed, mature deciduous stands w/ ~75% rhododendron and/or laurel understory
Mesic deciduous w/ mixed understory	1.40	MDMU	Moist, sheltered, mature deciduous stands w/ ~50% rhododendron and/or laurel understory
Meso-xeric deciduous w/ mixed understory	0.23	MXDMU	Mature deciduous stands w/ ~50% rhododendron and/or laurel understory on flat, low aspect areas
Xeric deciduous w/ mixed understory	4.42	XDMU	Dry, exposed, mature deciduous stands w/ ~50% rhododendron and/or laurel understory
Mesic mixed	0.15	MM	Moist, sheltered, mature mixed coniferous and deciduous stands
Meso-xeric mixed	0.01	MXM	Mature mixed deciduous and coniferous stands on flat, minimal aspect areas
Xeric mixed	0.15	XM	Dry, exposed, mature mixed deciduous and coniferous stands
Mesic coniferous	1.47	MC	Moist, sheltered, mature coniferous stands
Meso-xeric coniferous	0.52	MXC	Mature coniferous stands on flat, minimal aspect areas
Xeric coniferous	2.47	XC	Dry, exposed, mature coniferous stands
Mesic shrub/scrub	0.05	MSS	Moist, sheltered, shrub/scrub habitats
Meso-xeric shrub/scrub	0.02	MXSS	Shrub/scrub habitats on flat, minimal aspect areas
Xeric shrub/scrub	0.77	XSS	Dry, exposed, shrub/scrub habitats
Mesic herbaceous	0.24	MH	Moist, sheltered, herbaceous habitats
Meso-xeric herbaceous	0.02	MXH	Herbaceous habitats on flat, minimal aspect areas
Xeric herbaceous	0.75	XH	Dry, exposed herbaceous habitats
Clearcut	0.51	CC	Clearcuts between 7-20 years of age
Water	0.92	Water	Water bodies

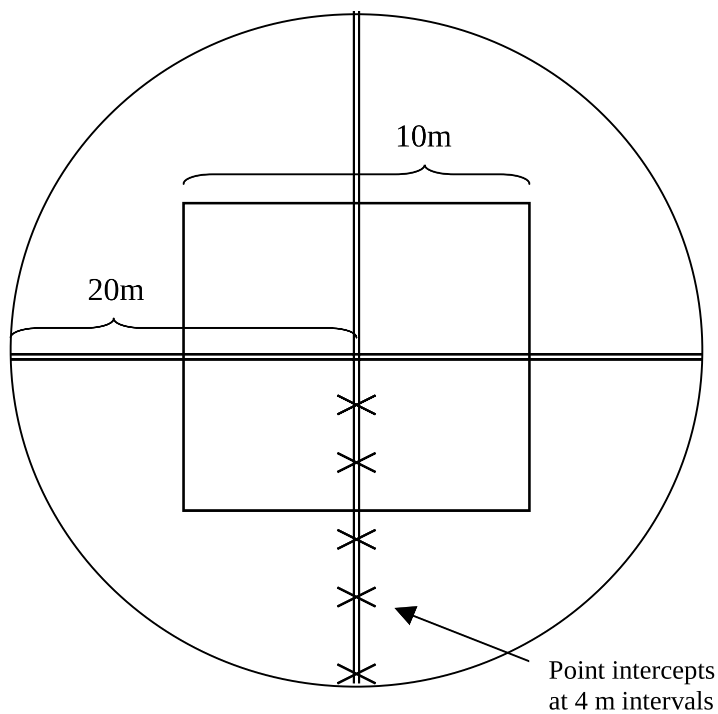

Figure 2. Schematic of the 20 m radius circular habitat plot used to gather structural information and species composition for the cover types used in the GIS database, CMWMA, VA, 1996-1998.

Table 2. Landscape metrics* used as independent predictors in the development of the regression models for home range size and movement and in the landscape characteristic selection by ruffed grouse at CMWMA, VA, 1996-1998.

Acronym	Units	Description
NP/ha	#/ha	Number of patches per hectare
LPI	%	Largest patch index: percentage of the home range the largest patch comprises
MPS	ha	Mean patch size
MSI	none	Mean shape index: quantifies patch shape, increases with irregularity in patch shape
AWMSI	none	Area weighted mean shape index: same as MSI, but weighted by patch size
TCAI	%	Total core area index: percentage of the home range that is core area. Core area is the interior area of a patch greater than 50 m from the patch's edge
MCAI	%	Mean core area index: mean percentage of core area within patches
PSSD	ha	Patch size standard deviation: variation of patch size in the landscape
MNN	m	Mean nearest neighbor distance: distance from one patch to another of the same type, averaged across all patches in the landscape
HRCPR/HA	#/ha	Number of cover types per hectare: number of different cover types within a 22 ha circle centered on the kernel center of the home range
SHDI	none	Shannon's diversity index
CWED	m/ha	Contrast weighted edge density: Length (m) of all edge in the landscape, scaled to a per hectare basis, and weighted by each edge weight value.
TECI	%	Total edge contrast index: Measure of edge contrast in the landscape, approaches 100% when all edge is maximum contrast (based on preset edge weightings)
Total%EU	%	Percent of the landscape in the 2 evergreen understory cover types
Total%MU	%	Percent of the landscape in the 2 mixed understory cover types
%CC	%	Percent of the landscape in clear cuts

*See McGargal and Marks (1995) for more detailed descriptions and computational formulas.

CHAPTER 1

RELATIONSHIP OF HOME RANGE SIZE TO LANDSCAPE CHARACTERISTICS

RESULTS

Home Range Estimates

The overall bearing error for my telemetry data was ±7.2°. Given this error, an azimuth could be 12.5 m off of a bird's true location if it was 100 m away, 25.1 m off at 200 m, 37.6 m off at 300 m, 50.1 m off at 400 m, and 62.7 m off at 500 m. A total of 111 grouse was captured between September 1996 and April 1998. Of these birds, 78 survived the 7-day conditioning period. However, only 23 of these birds had home ranges that were asymptotic given their number of locations, and these were the birds I included in my analyses (Table 3). For the purposes of these comparisons, birds that were aged as juveniles at capture remained juveniles throughout the duration of my study. The average home range size for all birds (pooled across sexes and ages) was 33.3 ± 4.4 ha (adaptive kernel) or 38.4 ± 4.3 ha (MCP). The average home range size for adult males (n = 7, 22.2 ± 4.3 ha – adaptive kernel, 29.2 ± 5.9 ha – MCP) was significantly less (Z = 49.0, P = 0.09) than that of juvenile males (n = 10, 33.7 ± 6.4 ha – adaptive kernel, 37.8 ± 7.9 ha – MCP). Only 1 juvenile female was included in my sample, so adults and juveniles were pooled for the home range analyses. The average home range size for females (n = 6, 45.5 ± 10.7 ha – adaptive kernel, 50.7 ± 5.5 ha – MCP) was significantly larger (Z = 181.0, P = 0.06) than males (pooled across ages; n = 17, 29.0 ± 4.3 ha – adaptive kernel, 34.3 ± 5.2 ha – MCP).

I also calculated seasonal home ranges for the same birds (Table 4). The average summer and fall home ranges for all birds were similar (19.0 ± 3.3 ha and 19.9 ± 3.0 ha, respectively – adaptive kernel method; 14.6 ± 2.2 ha and 13.0 ± 2.0 ha, respectively – MCP; Table 5). The average winter home range for all birds was the largest relative to the other 3 seasons (32.0 ± 5.2 ha – adaptive kernel; 18.2 ± 3.4 ha – MCP), and average spring home range size was 29.0 ± 5.8 ha (adaptive kernel) or 20.5 ± 3.6 ha (MCP; Table 5). No significant differences were detected among seasonal home range sizes (pooled across sexes and ages; $H_3 = 4.82$, $P = 0.19$). Females had a larger average spring home range size (50.0 ± 15.5 ha – adaptive kernel; 31.4 ± 9.6 ha – MCP) relative to the other seasons, while winter home ranges were the largest for adult and juvenile males (21.7 ± 5.3 ha and 45.8 ± 8.6 ha, respectively – adaptive kernel; 12.1 ± 3.7 ha and 24.6 ± 6.5 ha, respectively – MCP). Spring home range size of females was significantly larger (Z = 65.0, P = 0.05) than male spring home range size (pooled ages; Table 5). No other significant differences were detected between sexes (all $P > 0.1$). The winter and spring home ranges of juvenile males were significantly larger (winter: Z = 28.0, P = 0.05; spring: Z = 23.0, P = 0.05) than those of adult males, while no significant differences were detected between adult and juvenile male fall or summer home ranges (all $P > 0.1$; Table 5).

The distance between the centers of seasonal home ranges was calculated for those birds with ≥2 consecutive seasonal home ranges (Table 6). The average distance among seasonal home range centers was significantly greater than what would be expected by chance for sixteen birds ($P \leq 0.06$; Table 6) indicating that these birds were shifting their home ranges among seasons. The average distance between female seasonal home range centers (n = 4, 245 ± 114 m) was greater than that of males (n = 14, 159 ± 27 m), but this difference was not significant (Z = 42.0, P = 0.35). The average distance between the seasonal home range centers was significantly less (Z = 31, P = 0.04) for adult males (n = 6, 104 ± 20 m) than for juvenile males (n = 8, 199 ± 39 m).

Home Range – Landscape Analyses

Total Home Range. – All grouse were pooled for this regression analysis to maintain an adequate sample size. Since I had a relatively large sample of male birds (n = 17), and male home range size was smaller than that of females (see above), I also performed a regression analysis on the male birds.

Four landscape metrics were significant predictors of ruffed grouse home range size (Table 7). The adjusted R^2 value for the model was 0.642, and the model was significant (n = 23, $F_{4,18}$ = 10.84, $P < 0.01$). Home range size was positively related to mean shape index (MSI), total core area index (TCAI), and number of cover types per hectare (HRCPR/ha). Home range size was negatively related to total edge contrast index (TECI).

Two landscape metrics were significant predictors of male ruffed grouse home range size (Table 8). The adjusted R^2 for this model was 0.617, and the equation was significant ($n = 17$, $F_{3,13} = 9.58$, $P < 0.01$). Male home range size exhibited a positive, curvilinear relationship with Shannon's diversity index (SHDI) and a positive, linear relationship with MSI.

Seasonal Home Ranges. – Since no significant differences were detected between seasonal home range sizes across all birds, and small sample sizes made tests within sexes or ages impractical, I performed no further analyses on seasonal home range size variation. To maintain an adequate sample size, all birds were pooled for the analyses relating distance between seasonal home range centers to landscape characteristics. The regression model that yielded the best R^2 contained 3 landscape metrics (Table 9). Though the model was significant ($n = 18$, $F_{2,15} = 2.83$, $P = 0.09$), it only explained a small amount of the variation (adjusted $R^2 = 0.177$), and only 1 of the predictors was significant (Table 9). The average distance between seasonal home range centers was positively related to SHDI and mean nearest neighbor distance (MNN) and negatively related to contrast weighted edge density (CWED).

DISCUSSION

Home Range Estimates

I selected the 23 birds in my analyses based on the Ranges V incremental analysis. Only birds whose home range size had become asymptotic given their number of locations were included in my analyses. Several birds had relatively few locations because they moved into remote areas where telemetry was difficult or impossible, or were taken by predators or hunters shortly after their capture. As a result, I did not have enough locations for these birds to accurately estimate their total home range size. Several of the seasonal home ranges reported here did not become asymptotic with the number of locations obtained within a season. With few exceptions, at least 30 locations were needed for accurate home range estimation, and it was difficult to obtain this many locations within a season. Therefore, the seasonal home ranges should be considered with this limitation in mind.

Total and seasonal home range estimates for the ruffed grouse in my study were similar or often smaller compared to those reported from other studies. However, most studies only report seasonal home range sizes. The methods and computer programs used to calculate home range sizes in these studies were different from the program and method I used, and this can contribute to differences in home range estimates among studies (Lawson and Rodgers 1997). The oak mast crops varied over the 3 years that I was collecting these data. The fall 1996 and 1998 mast crops were very good, while the fall 1997 mast crop was a failure (G. Norman, S. Whitcomb, VDGIF, personal communication). The home range estimates for those birds that had a year or less of data may not reflect the effects of these mast crop variations. Also, only 1 of the hens (1891) for which I have spring and summer home range data carried a brood completely through this period. All other hens lost their broods within 1 to 4 weeks of hatching, and their spring and summer home range sizes should be considered accordingly. In Tennessee, Epperson (1988) reported a mean home range size (mean ± SE, minimum convex polygon) for male grouse of 38.1 ± 13.2 ha. In Missouri, Neher (1993) reported mean fall-winter home ranges (mean ± SE, minimum convex polygon) of 83 ± 11 ha for male grouse, with home range sizes ranging from 36 – 186 ha, while Thompson (1987) reported a mean fall-winter size (mean ± SE, minimum convex polygon) of 78.0 ± 9.3 ha and a mean spring-summer size of 45 ± 8.5 ha, both for males and females combined. Landry (1980) reported spring home range sizes (no method reported) between 8.9 ha and 16 ha for breeding males in Utah. The mean home range size (modified computer-fill method) of territorial male ruffed grouse in Minnesota was 8.9 ha for 12 March - 10 June, and during the drumming season (9 April - 10 June) it was 6.7 ha (Archibald 1975). The mean home range (mean ± SE, minimum convex polygon) for hens with broods in Tennessee was 43.2 ± 27.9 ha (Epperson 1988), and in Utah, Landry (1980) reported average home range sizes (no method reported) of 12.9 ha to 16.0 ha for hens with broods. In Michigan, Clark (1996) reported average home range sizes (mean ± SE, minimum convex polygon) ranging from 39.4 ± 8.3 ha to 163.9 ± 24.5 ha. The increase in the spring home range size of the female birds in my study was not unexpected, as hens build their energy reserves for nesting and look for males and suitable nesting sites during this time (Archibald 1975).

Home Range – Landscape Analyses

Total Home Range. – The 4 landscape metrics included in the regression for all birds were all significant ($P < 0.01$) predictors of home range size. The mean shape index (MSI) quantifies the average shape of the habitat patches in the landscape (McGarigal and Marks 1995). The MSI value increases as the average shape of the patches becomes more irregular. The positive relation of home range size to MSI indicates that grouse home range size increased as the patches within their home ranges were more irregularly shaped.

The total core area index (TCAI) is the percentage of the home range in core area (McGarigal and Marks 1995). Core area is the interior area of a habitat patch >50 m from the patch's edge. As more core area was present in the home range, the home range size increased.

I determined the values for the number of different cover types per hectare (HRCPR/ha) by placing a 22 ha circle on the center of each bird's home range (calculated using the adaptive kernel estimator) and tallying the number of different cover types within that circle. I arbitrarily chose 22 ha for the circle because I had 22 cover types. I used these circles to avoid any artificial relation between the number of cover types per hectare and a given bird's home range size. Larger home ranges tended to have more cover types simply because the home range covered a larger area. Using the home range size to the scale the value to a per hectare basis created an artificial relationship, making it appear that large home ranges had low number of cover types per hectare when in fact this was not the case. As more cover types were present in a grouse's home range, home range size increased.

The total edge contrast index (TECI) quantifies the overall edge contrast in the landscape, and approaches 100% when all edge is maximum contrast (McGarigal and Marks 1995). As the TECI within a grouse's home range increased, the home range size decreased.

The 2 landscape metrics included in the regression model for males also were significant, but not as strongly as those in the regression for all birds. Shannon's diversity index (SHDI) increases as the cover types/ha and/or the proportional distribution of area among cover types becomes more equitable (McGarigal and Marks 1995). As SHDI increased, male grouse home range size increased. However, it has marginal significance as a predictor of male grouse home range size (Table 8). Mean shape index also was a significant predictor in this equation, with male grouse home range size increasing as the patches in their home ranges became more irregularly shaped.

From a theoretical perspective, the optimal size, configuration, and spatial arrangement of habitat patches in the landscape should minimize ruffed grouse home range size. Such landscapes would contain ruffed grouse habitat requirements within smaller areas, thereby decreasing energy expended searching for food and cover as well as exposure to predators and increasing the density of birds and sustainability of the population over a given area (Bump et al. 1947, Thompson and Dessecker 1997). For example, Gullion (1989c) stated that ideal cover for grouse should be no further than 100 m from nesting habitat and an adequate winter-long food supply. The regression models for all birds and males both indicate that landscapes with regularly shaped patches of cover will decrease ruffed grouse home range size. Elongated, irregularly shaped patches have decreased plant species richness compared to compact, regularly shaped patches, thus potentially decreasing food supplies and available cover (Forman 1995). Narrow, elongated patches also seldom provide the proper interspersion of different cover types preferred by grouse (Bump et al. 1947). Therefore creating and maintaining square or circular patches of cover would be most beneficial for grouse.

The first equation also indicated that landscapes containing a high amount of high contrast edge, such as that between clearcuts and adjacent mature forest stands, and a small amount of core area within patches decreased home range size. These variables compliment each other since several smaller patches of cover, versus a few large patches containing lots of core area, will result in more edge in the landscape. Also, the presence of high contrast edge, versus any edge, was what decreased home range size. Several of the home ranges of the birds in my study were centered on the edges of clearcuts or other high contrast edges (Fig. 3a,b). Several studies document the importance of these edge habitats for grouse, and especially male birds, as this tends to be where they establish their drumming areas (Bump et al. 1947, Kubisiak et al. 1980, DeStefano and Rusch 1984, Schulz et al. 1989).

The SHDI and HRCPR/ha variables in the 2 equations compliment each other since they are both a measure of the cover type diversity in the landscape. However, increased values of these variables resulted in increased home range sizes. These results were unexpected, especially given the number of management recommendations for ruffed grouse stressing the importance of providing and maintaining the proper mixture of forest age classes and cover (Bump et al. 1947, Berner and Gysel 1969, Gullion 1972, Kubisiak et al. 1980, Kubisiak 1985, Gullion 1989c,). This result contradicts the results from my analyses examining grouse selection for specific landscape characteristics, and I discuss this contradiction in the summary and conclusions.

Seasonal Home Ranges. – Habitat requirements of ruffed grouse change with season and grouse behavior (Bump et al. 1947, Chapman et al. 1952, Dorney 1959, Maxson 1978, Landry 1980, Thompson and Dessecker 1997), and birds will shift their home ranges accordingly to meet these requirements. For example, food sources can vary seasonally (Bump et al. 1947, Barber et al. 1989, Hewitt et al. 1992), and grouse may shift their home ranges to areas of seasonal food abundances. Behavioral patterns also may influence seasonal home range location. Nesting, brood rearing, and winter habitats of female grouse can all vary, and females may shift their home ranges to meet these differing requirements (Bump et al 1947, Kubisiak 1978, Maxson 1978).

Of the 3 predictors included in the regression model relating the average distance between seasonal home range centers to landscape characteristics, SDHI was the only one that was significant (Table 9). The average distance between seasonal home range centers increased as SHDI increased.

Contrast weighted edge density (CWED) is a measure of the amount of edge in the landscape (m/ha) relative to weight of each edge specified in the weight file (McGarigal and Marks 1995). For example, 100 m/ha of edge with a weight of 1 is reported as 100 m/ha of edge, while 100 m/ha of edge with a weight of 0.2 is reported as

20 m/ha of edge. Therefore, both the total amount of edge in the landscape as well as its contrast are reflected in the measure. As the CWED value increased, the distance between seasonal home range centers decreased.

Mean nearest neighbor distance (MNN) is the distance from one patch to the nearest other patch of the same cover type, averaged across all cover types for which there are 2 or more patches present in the landscape (McGarigal and Marks 1995). As the MNN value increased, so did the distance between seasonal home range centers.

In addition to reducing the overall size of a grouse's home range, the optimal size, configuration, and spatial arrangement of habitat patches in the landscape also should minimize the distance between seasonal home range centers (Bump et al. 1947). Ideally, a grouse would not have to shift its home range between seasons. While this regression model explained a relatively small amount of the variation seen in the data, and not all the predictors were significant, it exhibited the same trends as the previous models. The CWED metric in this equation is comparable to the TECI in the first model, and grouse were shifting their home ranges less with an increasing presence of high contrast edge in their home range. The relationship of less core area or smaller patches in decreasing home range size seen in the first model is reinforced by the increase in distance between seasonal home range centers with an increase in MNN seen in this model. Increasing patch size will increase the distance between patches and decrease interspersion of cover types (Forman 1995). This will force birds to move greater distances in search of seasonal food and cover requirements, thus increasing the distance between seasonal home ranges (Bump et al. 1947).

As in the previous equations, as SHDI, and thus the diversity of cover types in the landscape increased, so did the average distance between seasonal home range centers. Again, this contradicts results presented later in my thesis and is discussed in the summary and conclusions.

All 3 regression models displayed similar trends. As patch shape became more irregular, and patch size and the number of different cover types per hectare increased, grouse home range size increased. As the amount of high contrast edge in the landscape increased, home range size decreased. As Shannon's diversity index and the average distance between patches of similar cover types increased, the distance between seasonal home range centers increased. As the amount of high contrast edge increased, distance between seasonal home range centers decreased. Creating and maintaining landscapes containing several small patches, including several patches of early successional habitat, that are square or circular in shape would be most beneficial for grouse. Such a landscape would minimize the amount of core area within patches, as well as increase the interspersion of cover types and maximize the amount of high contrast edge in the landscape. These characteristics should provide several of the grouse's habitat requirements in a small area, decreasing their home range size and minimizing the energy they expend searching for food and cover as well as their exposure to predators.

Table 3. Sex, age, total home range size based on the adaptive kernel and minimum convex polygon methods, number of locations, and air time for ruffed grouse at CMWMA, VA, 1996-1998.

Bird ID	Sex	Age at capture	Adaptive Kernel 95% home range (ha)	Minimum Convex Polygon home range (ha)	Number of locations	Air time
924	F	A	91.2	60.3	28	Oct'97-Apr'98
1252	F	A	46.0	39.3	61	Mar'97-Aug'97
1283	F	A	56.7	41.2	23	Mar'98-May'98
1513	F	A	17.8	72.8	65	Apr'97-Oct'97
1891	F	A	35.0	41.3	87	Mar'97-Mar'98
903	F	J	26.2	45.5	134	Oct'97-Dec'98
92	M	A	31.2	57.9	109	Sep'96-Mar'98
333	M	A	18.9	25.1	99	Oct'96-Mar'98
612	M	A	34.0	20.8	22	Oct'97-Jan'98
1063	M	A	35.6	26.0	45	Sep'97-Mar'98
1103	M	A	10.1	13.3	193	Mar'97-Oct'98
1793	M	A	17.3	42.5	114	Sep'96-Apr'98
1832	M	A	8.3	18.9	114	Nov'96-Oct'98
703	M	J	77.3	94.0	133	Oct'97-Dec'98
870	M	J	22.0	52.1	140	Oct'97-Dec'98
1232	M	J	37.4	44.8	116	Mar'97-Aug'98
1313	M	J	21.8	20.4	64	Apr'97-Oct'97
1333	M	J	53.8	49.7	28	Oct'96-Apr'97
1452	M	J	17.2	21.8	78	Oct'96-Sep'97
1533	M	J	41.0	46.1	86	Apr'97-Feb'98
1633	M	J	12.5	10.3	106	Feb'97-Jan'98
1871	M	J	38.2	17.7	15	Nov'96-Apr'97
1971	M	J	16.2	21.0	93	Mar'97-Dec'97

Table 4. Seasonal home range sizes based on the adaptive kernel and minimum convex polygon methods for ruffed grouse in CMWMA, VA, 1996-1998.

			Seasonal Home Range (ha)*											
			Fall			Winter			Spring			Summer		
Bird ID	Sex	Age at capture	*n*	Adaptive Kernel	MCP	*n*	Adaptive Kernel	MCP	*n*	Adaptive Kernel	MCP	*n*	Adaptive Kernel	MCP
924	F	A	-	-	-	19	37.8	26.5	-	-	-	-	-	-
1252	F	A	-	-	-	-	-	-	37	49.2	24.0	18	*24.6*	*19.4*
1283	F	A	-	-	-	-	-	-	18	*8.2*	*12.6*	-	-	-
1513	F	A	-	-	-	-	-	-	27	*99.9*	*68.0*	35	6.2	7.4
1891	F	A	17	12.5	7.9	13	*4.4*	*5.5*	21	62.7	30.5	33	20.4	15.1
903	F	J	26	30.2	15.1	16	32.2	20.5	37	29.8	22.1	36	22.3	9.8
92	M	A	20	14.4	8.7	17	37.2	28.5	29	26.1	26.1	26	12.8	9.1
333	M	A	19	13.7	8.5	12	20.4	10.2	28	9.8	8.2	30	12.5	12.6
612	M	A	15	*35.8*	*19.9*	-	-	-	-	-	-	-	-	-
1063	M	A	23	41.0	23.7	16	*30.5*	*13.4*	-	-	-	-	-	-
1103	M	A	25	10.2	5.3	19	*4.2*	*2.5*	36	8.0	7.5	38	6.1	7.6
1793	M	A	20	18.8	23.0	18	28.6	12.1	24	14.9	11.1	30	17.8	10.5
1832	M	A	19	10.8	5.8	21	9.1	5.9	25	5.9	3.1	23	13.8	7.1
703	M	J	34	28.6	23.7	11	*50.1*	*19.2*	31	49.6	34.8	37	46.6	35.7
870	M	J	32	21.6	13.1	20	57.9	41.2	32	25.6	15.2	38	18.9	16.7
1232	M	J	14	9.2	5.9	11	*14.0*	*6.6*	24	49.5	34.2	31	49.0	29.9
1313	M	J	-	-	-	-	-	-	27	*20.4*	*17.2*	35	15.8	17.3
1333	M	J	-	-	-	22	69.4	47.4	-	-	-	-	-	-
1452	M	J	-	-	-	18	26.7	15.3	33	14.2	10.4	27	*4.1*	*8.3*
1533	M	J	14	35.9	23.8	-	-	-	31	18.0	17.6	30	35.6	29.4
1633	M	J	28	6.8	4.4	-	-	-	32	11.8	8.3	36	8.7	6.8
1871	M	J	-	-	-	13	56.7	17.8	-	-	-	-	-	
1971	M	J	24	*9.1*	*6.1*	-	-	-	31	17.5	17.9	37	7.2	6.3

*Italics imply locations do not span the full 3-month season.

Table 5. Seasonal home range sizes based on the adaptive kernel and minimum convex polygon methods averaged by sex and age for ruffed grouse in CMWMA, VA, 1996-1998.

	Seasonal Home Range (ha)															
	Fall				Winter				Spring				Summer			
	Adaptive Kernel		MCP		Adaptive Kernel		MCP		Adaptive Kernel		MCP		Adaptive Kernel		MCP	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Female (pooled sexes)	21.4	8.9	11.5	3.6	24.8	10.3	17.5	6.2	50.0	15.5	31.4	9.6	18.4	4.2	12.9	2.7
Adult Male	20.7	4.7	13.6	3.1	21.7	5.3	12.1	3.7	12.9	3.6	11.2	3.9	12.6	1.9	9.4	1
Juvenile Male	18.5	4.9	12.8	3.7	45.8	8.6	24.6	6.5	25.8	5.4	19.4	3.5	23.2	6.4	18.8	4.1
Male (pooled sexes)	19.7	3.3	13.2	2.3	33.7	6.0	18.3	4.0	20.9	3.9	16.3	2.8	19.2	4.2	15.2	2.8
Pooled Average	19.9	3.0	13.0	2.0	32.0	5.2	18.2	3.4	29.0	5.8	20.5	3.6	19.0	3.3	14.6	2.2

Table 6. Average distance (m) between ruffed grouse seasonal home range centers in CMWMA, VA, 1996-1998. P-values obtained from multiresponse permutation procedure testing that the observed average distance between seasonal home range centers is greater than what would be expected by chance, with respect to the overlap of locations between each season.

		Distance (m) Between Seasonal Home Range Centers									
Bird ID	Sex	Age at capture	97Winter-Spring	97Spring-Summer	97Summer-Fall	97Fall-98Winter	98Winter-Spring	98Spring-Summer	98Summer-Fall	Pooled seasons	P-value
1252	F	A	-	174	-	-	-	-	-	174	< 0.01
1513	F	A	-	581	-	-	-	-	-	581	< 0.01
1891	F	A	-	196	160	69	-	-	-	142	< 0.01
903	F	J	-	-	-	-	106	105	36	82	< 0.01
92	M	A	381	100	72	-	-	-	-	185	< 0.01
333	M	A	168	93	59	-	-	-	-	106	0.06
1063	M	A	-	-	-	113	-	-	-	113	0.51
1103	M	A	-	49	114	49	86	10	-	61	< 0.01
1793	M	A	199	126	28	-	-	-	-	117	0.02
1832	M	A	41	61	57	58	28	26		45	0.02
703	M	J	-	-	-	-	1012	100	147	420	< 0.01
870	M	J	-	-	-	-	468	30	33	177	< 0.01
1232	M	J	-	466	174	100	160	-	-	225	< 0.01
1313	M	J	-	46	-	-	-	-	-	46	0.12
1452	M	J	193	33	-	-	-	-	-	113	< 0.01
1533	M	J	-	26	448	-	-	-	-	237	< 0.01
1633	M	J	-	217	78	-	-	-	-	147	0.03
1971	M	J	-	338	123	-	-	-	-	231	< 0.01

Table 7. Results from the multiple regression analyses relating variation in ruffed grouse home range to landscape characteristics, CMWMA, VA, 1996-1998. $n = 23$, $F_{4,18} = 10.84$, $P < 0.01$, adjusted $R^2 = 0.642$.

Predictors	Coefficient	P-value
Constant	-933.30	< 0.01
Mean Shape Index	699.10	< 0.01
Total Core Area Index	1.90	< 0.01
Patch Richness/ha	200.60	< 0.01
Total Edge Contrast Edge Index	-0.83	< 0.01

Table 8. Results from the multiple regression analyses relating variation in male ruffed grouse home range to landscape characteristics, CMWMA, VA, 1996-1998. $n = 17$, $F_{3,13} = 9.58$, $P < 0.01$, adjusted $R^2 = 0.617$.

Predictors	Coefficient	P-value
Constant	-230.4	0.17
Shannon's Diversity Index	-135.7	0.18
(Shannon's Diversity Index)^2	50.9	0.08
Mean Shape Index	264.8	0.02

Table 9. Results from the multiple regression analyses relating variation in the distance between seasonal home range centers to landscape characteristics, CMWMA, VA, 1996-1998. $n = 18$, $F_{2,15} = 2.83$, $P = 0.09$, Adjusted $R^2 = 0.177$.

Predictors	Coefficient	P-value
Constant	-276.7	0.29
Shannon's Diversity Index	261.3	0.03
Contrast Weighted Edge Density	-2.9	0.11
Mean Nearest Neighbor Distance	2.0	0.17

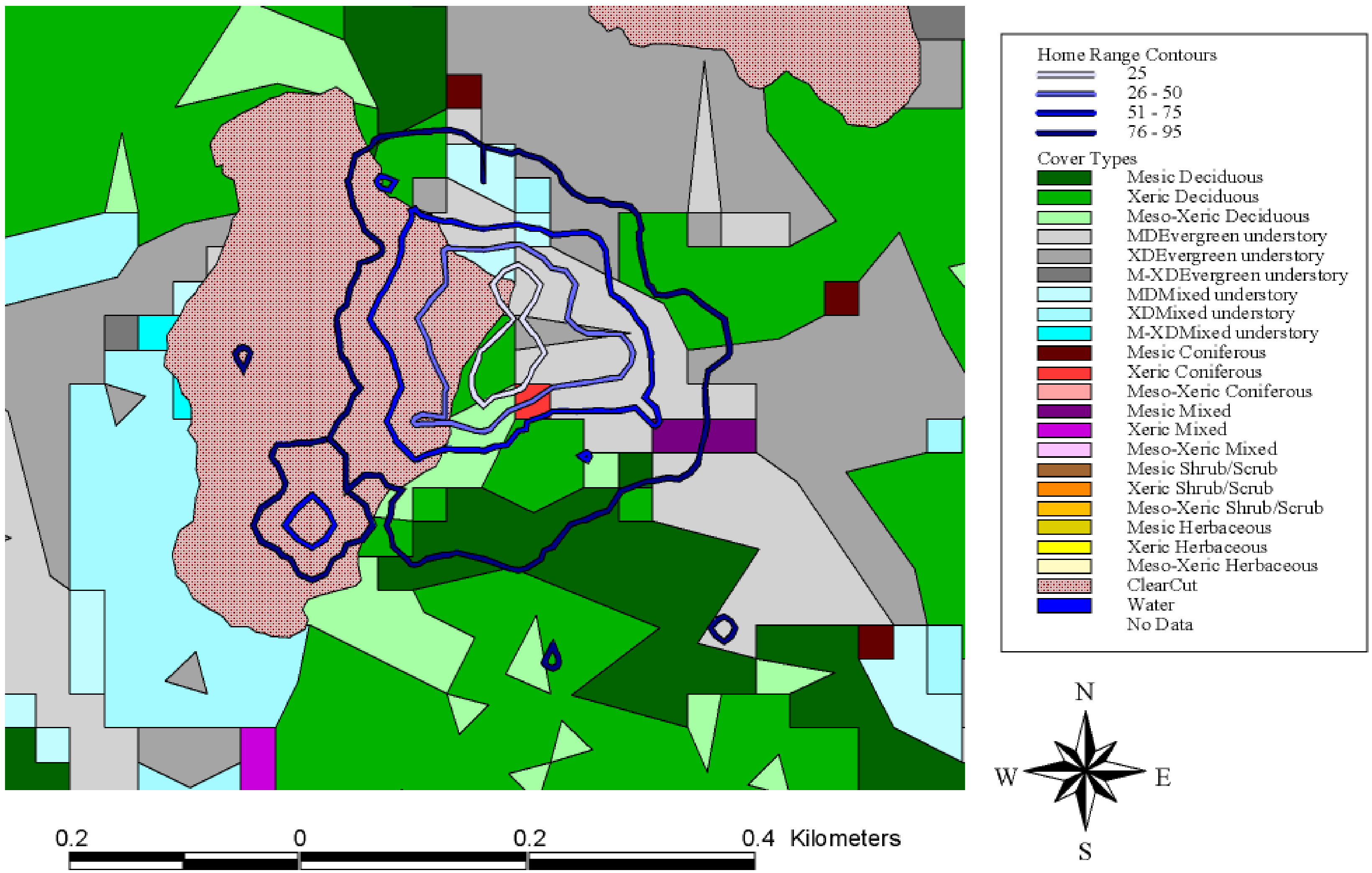

Figure 3a. Ruffed grouse home range centered on the edge of a clearcut, CMWMA, VA, 1996-1998.

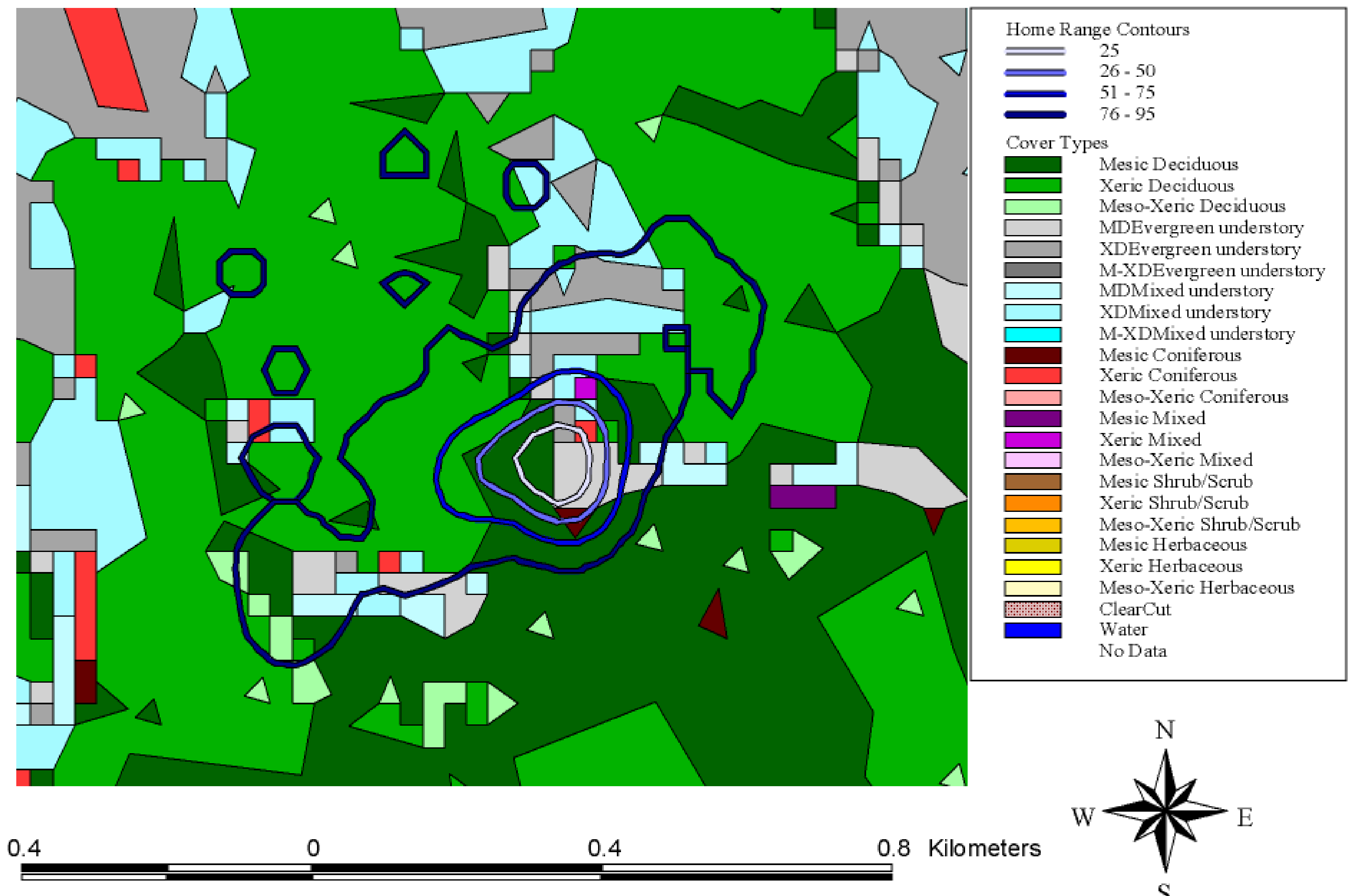

Figure 3b. Ruffed grouse home range centered on the edge of rhododendron/laurel cover, CMWMA, VA, 1996-1998.

CHAPTER 2

RELATIONSHIP OF DAILY MOVEMENT TO LANDSCAPE CHARACTERISTICS

RESULTS

Movement Estimates

I included 12 birds in my daily intensive telemetry (Table 10). Female average daily movement tended to be higher than that of males within seasons (Table 11), but the average difference between males and females (pooled across seasons) was not significant ($Z = 30.0$, $P = 0.28$). Average daily movement (pooled across seasons) for adult birds ($n = 4$, 102 ± 10 m/hr) was significantly smaller than that of juvenile birds ($n = 8$, 124 ± 6 m/hr; $Z = 43.0$, $P = 0.07$). No significant differences were detected in average daily movement between seasons (pooled across sexes and ages; $H_3 = 0.52$, $P = 0.915$). Female movement was greatest during the summer and fall (Table 11), but only 1 female was monitored during these seasons and her behavior may not be characteristic of all females in the study area. Male movement was greatest during winter and fall (Table 11). Because of small sample sizes, tests for within season, sex, and age differences or between season differences for one sex or age class were not performed.

Movement – Landscape Analyses

Since no significant differences were detected between seasonal movements, I used the annual averages for each bird for these analyses. I pooled sexes and ages to maintain an adequate sample size.

Three landscape metrics were significant predictors of ruffed grouse average daily movement (Table 12). The adjusted R^2 value for the model was 0.544 and the model was significant ($n = 12$, $F_{3,8} = 5.37$, $P = 0.03$). Average daily movement was positively related to the mean nearest neighbor distance (MNN) and the total percent of the home range in any of the 3 evergreen understory habitat types (total %EU). Average daily movement was negatively related to total edge contrast index (TECI).

DISCUSSION

Movement Estimates

While I feel these estimates of average daily movement provide valuable information, they do have some shortcomings. The first is in regard to telemetry error and overall telemetry accuracy. While radio telemetry is currently 1 of the best methods for estimating animal movements (Turchin 1998), signal variation and bounce as well as observer error influence the accuracy of all telemetry fixes obtained using triangulation (Springer 1979, White and Garrott 1990). The estimated distances reported here should be considered with these limitations in mind. Second, my sample sizes, especially during the summer and fall seasons, were not large (Tables 10 and 11). I only tracked 1 female during the summer and fall seasons, and she was without a brood during that time period. Therefore, these movement estimates do not consider behavioral variations such as brood rearing and may not be reflective of the true population average.

Several studies have examined ruffed grouse movement; however few studies considered the average distance moved per hour within a day. These studies do exhibit patterns of seasonal, sex, and age differences similar to those seen here. In Missouri, mean daily movement (mean ± SE) of territorial males was smaller during spring-summer (263 ± 16.3 m) than during fall-winter (392 ± 75.3 m), but these movement measurements were based on the distance between 2 locations approximately 24 hours apart (Thompson and Fritzell 1989). Though the seasonal variations I observed in male movements were small, spring and summer movements were less than fall or winter (Table 11). Female grouse are generally more mobile than male grouse, except in winter (Hale and Dorney 1963, Gullion 1967a), and this was evident for the birds in my study (Table 11). Movement of juvenile birds tends to be greater than that of adult birds, even after juvenile birds have stopped dispersing and established home ranges (Hale and Dorney 1963, Small et al. 1993). The movement data for the juvenile birds in my study were within home range movements (i.e. post-dispersal), and the average daily movement of the juvenile birds I tracked was significantly greater than that of adults (P = 0.07).

Movement – Landscape Analyses

Three landscape metrics were significant predictors of average daily movement (*P* ≤ 0.03). Mean nearest neighbor distance (MNN) is the distance from one patch to the nearest other patch of the same cover type, averaged across all cover types for which there are 2 or more patches present in the landscape (McGarigal and Marks 1995). As the MNN value in a bird's home range increased, their average daily movement increased.

The total edge contrast index (TECI) quantifies the overall edge contrast in the landscape, and approaches 100% when all edge is maximum contrast (McGarigal and Marks 1995). As TECI increased, the average daily movement decreased.

Total %EU is the cumulative percent of a bird's home range in any of the 3 deciduous forest habitat types with a full (~75%) rhododendron/laurel understory (Table 1). As the percent cover of a full rhododendron and/or laurel canopy increased, so did the average daily movement.

The structure and composition of cover types in the landscape can influence the rate and nature of animal movements through that landscape (Forman 1995). The degree to which ruffed grouse move through their home range in search of food or cover is influenced by the composition of cover types in their home range (Bump et al. 1947, Thompson and Dessecker 1997). As grouse have to move more through their home range, their exposure to predators as well as their overall energy expenditure may increase, leaving them more vulnerable to mortality. This may be especially important during the winter and early spring months as food supplies become limited (Servello and Kirkpatrick 1987, Hewitt et al. 1992) and birds are more exposed due to decreased foliage cover (Bump et al. 1947, Small et al. 1993). In Virginia, Hewitt and Kirkpatrick (1997a) found that grouse were active between 40% and 60% of the day during the winter, presumably searching for food. In areas of the grouse's range where aspen was present, however, feeding was limited to 15 min to 30 min periods in early morning and late evening (Svoboda and Gullion 1972, Doerr et. al. 1974). In Wisconsin, Small et al. (1993) found that juvenile males that were highly mobile exhibited increased mortality rates in winter and spring. However, they noted that this may be due in part to a juvenile bird's general lack of experience. In Missouri, ruffed grouse with above average movement had higher rates of mortality than more stationary birds, especially after leaf-fall (Kurzejeski and Root 1988, Thompson and Fritzell 1989). Maintaining a habitat structure that minimizes ruffed grouse movement should decrease energy expended searching for food and cover as well as exposure to predators and improve their survival.

The regression model indicated that landscapes having a high MNN value, or large distances between patches of the same cover type, increased average daily movement. As the size of patches in the landscape increases, the distance between patches of equivalent habitat also will increase (Forman 1995). If grouse are feeding in patches of specific cover, this increased distance between patches of equivalent cover may force them to travel through areas of poorer cover, increasing their exposure and risk of predation (Thompson and Dessecker 1997). Maintaining a landscape of small, interspersed habitat patches can minimize the distance between patches of equivalent cover types and decrease grouse movement.

This model also indicated that landscapes containing a high amount of high contrast edge decreased average daily movement. As mentioned in the previous section, these high contrast edge habitats, such as those between clearcuts and mature, deciduous stands, tend to be where grouse centered their home range. In fact, this relationship also was evident when average daily movement was plotted against the percent cover of clearcut in a grouse's home range (Fig. 4). Grouse that had 25-40% of their home range in clearcuts had a significantly lower average daily movement (88 ± 5 m) than those with <25% coverage of clearcuts (119 ± 8 m, $Z = 14.0$, $P = 0.03$). These high contrast edges between cover types can provide several of the grouse's seasonal food and cover requisites in a small area (Bump et al. 1947). Therefore, maintaining a large amount of high contrast edge in the landscape will decrease the average daily movement of ruffed grouse.

Finally, this model indicated that as the percent cover of a full (~75%) rhododendron and/or laurel understory within a grouse's home range increased, its average daily movement increased. In the absence of clearcuts or other early successional habitats, thick shrub understories in mature stands can provide adequate habitat for ruffed grouse (Bump et al. 1947, Hale et al. 1982, Epperson 1988, McDonald, et al. 1998). In the Southeast, forest stands containing rhododendron and/or laurel can provide this type of cover, but these habitats also tend to provide lower quality food sources. During the winter, evergreen leaves can become an important component of the grouse's diet in the southeast (Stafford and Dimmick 1979, Servello and Kirkpatrick 1987, Hewitt et al. 1992). Due to the high tannin levels and poor nutritional quality of many evergreen plants, such as mountain laurel and rhododendron, such foods are of questionable benefit to grouse and may even be toxic (Servello and Kirkpatrick 1987, Hewitt and Kirkpatrick 1997b). Therefore, grouse may have to search more for adequate or supplemental food sources if they are limited to this type of cover, increasing their daily movement (Hewitt and Kirkpatrick 1997a). If rhododendron/laurel thickets are the only cover types available for ruffed grouse, several more nutritionally beneficial food sources, such as acorns, greenbriers, blueberries, and grapes, should be maintained within close proximity of this cover (Norman and Kirkpatrick 1984, Servello and Kirkpatrick 1987, Servello and Kirkpatrick 1989).

As the average distance between patches of equivalent cover types increased, average daily movement increased. As the percent cover of a full (~75%) rhododendron and/or laurel understory within a grouse's home range increased, its average daily movement also increased. As the amount of high contrast edge in a bird's home range increased, average daily movement decreased. Maintaining a landscape of small, interspersed patches of different cover types, including several patches of early successional cover to increase the amount of high contrast edge, will minimize ruffed grouse average daily movement. Such a landscape would minimize the average distance between patches of equivalent cover types as well as increase the amount of high contrast edge in the landscape. This also should provide higher quality cover and food sources other than rhododendron and/or mountain laurel, further decreasing grouse movement. Minimizing the distance a grouse needs to move in a day should decrease its exposure to predators as well as its energy expenditure and increase its survival.

Table 10. Average daily movement (m/hr) on a seasonal basis for ruffed grouse at CMWMA, VA, 1998. Movement estimates based on sequential, hourly telemetry locations.

		Average Daily Movement (m/hr)											
		Winter			Spring			Summer			Fall		
	Bird ID	*n*	Mean	SE	*n*	Mean	SE	*n*	Mean	SE	*n*	Mean	SE
Adult Females													
	924	2	137	9	1	143	-	-	-	-	-	-	-
	1283	2	102	5	2	113	7	-	-	-	-	-	-
	1891	1	98	-	-	-	-	-	-	-	-	-	-
Juvenile Females													
	903	3	130	14	4	95	26	3	141	28	3	131	41
Adult Males													
	92	1	143	-	-	-	-	-	-	-	-	-	-
	1063	2	89	54	-	-	-	-	-	-	-	-	-
	1103	2	72	10	3	72	3	3	65	10	1	105	-
	1793	1	91	-	-	-	-	-	-	-	-	-	-
	1832	2	83	1	3	78	22	3	55	8	1	78	-
Juvenile Males													
	703	1	78	-	3	119	28	3	114	35	3	128	15
	870	2	124	40	3	119	22	3	107	12	3	105	1
	1533	1	143	-	-	-	-	-	-	-	-	-	-

Table 11. Average daily movement (m/hr) on a seasonal basis for ruffed grouse in CMWMA, VA, 1998. Movement estimates are averaged across all birds sampled.

		Average Daily Movement (m/hr)	
Season	*n*	Mean	SE
Winter			
Male	8	103	10
Female	4	117	9
Pooled Sexes	12	107	8
Spring			
Male	4	97	13
Female	3	117	14
Pooled Sexes	7	106	10
Summer			
Male	4	86	15
Female	1	141	-
Pooled Sexes	5	97	16
Fall			
Male	4	104	10
Female	1	131	-
Pooled Sexes	5	109	10
Pooled Seasons			
Male	8	105	10
Female	4	117	9
Pooled Sexes	12	109	7

Table 12. Results of the multiple regression analysis relating average daily movement of ruffed grouse to landscape characteristics in CMWMA, VA, 1998. $n = 12$, $F_{3,8} = 5.37$, $P = 0.03$, adjusted $R^2 = 0.544$.

Predictors	Coefficient	P-value
Constant	42.2	0.21
Mean Nearest Neighbor Distance	0.89	0.02
Total Edge Contrast Index	-1.62	0.01
Total % of Evergreen Understory Cover Types	1.2	0.03

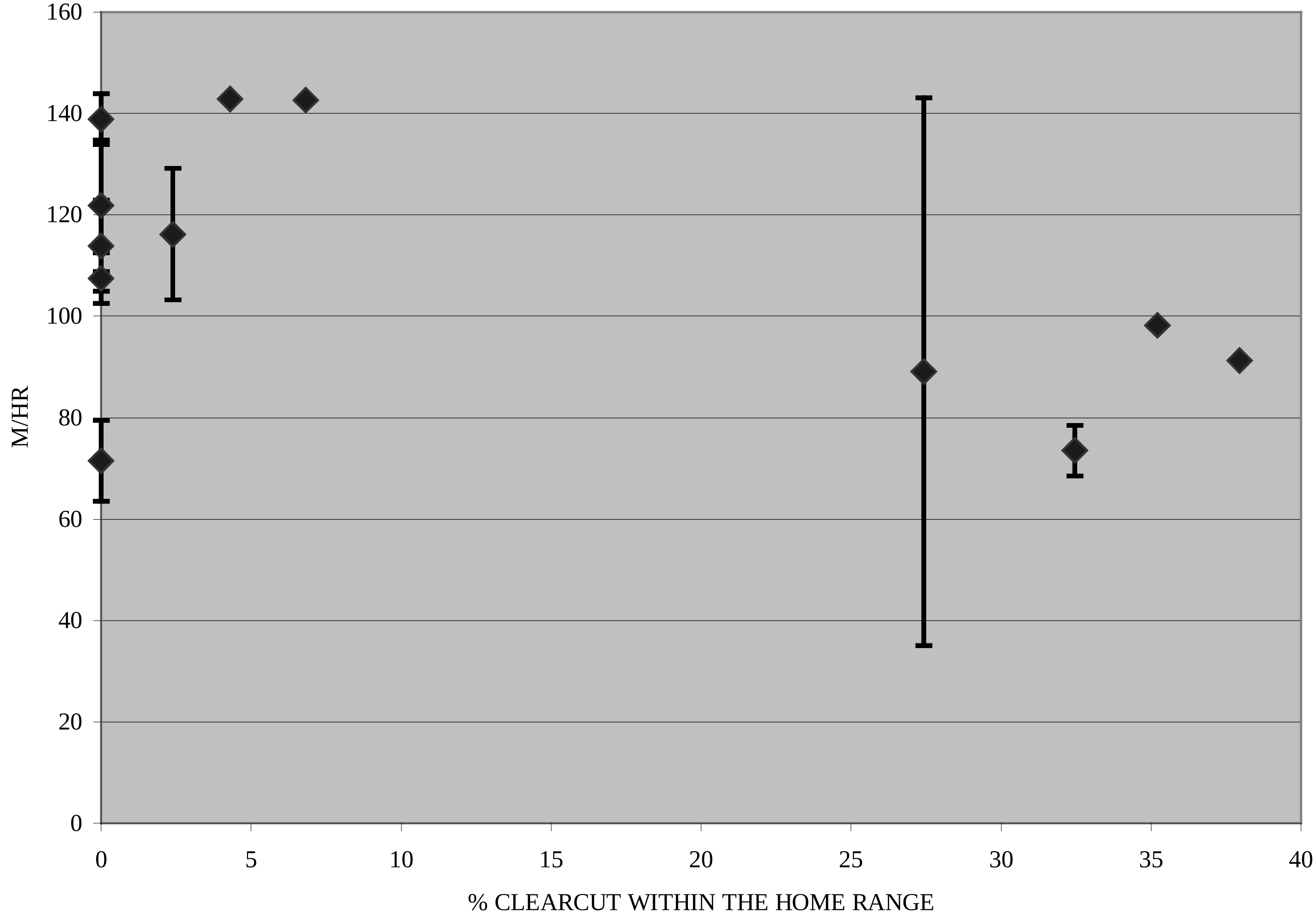

Figure 4. Average daily movement (m/hr, mean and SE bars) of ruffed grouse (pooled across ages, sexes, and seasons) relative to the percent of clearcut in their home range, CMWMA, VA, 1998.

CHAPTER 3

LANDSCAPE CHARACTERISTIC SELECTION AND PREFERENTIAL USE OF COVER TYPES

RESULTS

Habitat Data

I completed 201 habitat plots between May and December of 1998. Habitat data were gathered in 13 of the 22 GIS cover types (Tables 13 and 14), which accounted for 94% of the total area within the study site. Data for all herbaceous plots were similar and pooled into 1 herbaceous category for summary purposes. The remaining 9 cover types (mesic coniferous, xeric coniferous, meso-xeric coniferous, mesic mixed, meso-xeric mixed, meso-xeric shrub/scrub, xeric shrub/scrub, meso-xeric deciduous w/ evergreen understory, meso-xeric deciduous w/ mixed understory) occurred in the management area in very small proportions and/or in some of the remote parts of the study area, and none of the habitat plots fell within these cover types.

Clearcuts (CC) had the highest stem densities (<8 cm dbh; 9439 stems/ha) and the herbaceous cover types had the lowest (136 stems/ha; Table 13). Downed dead woody cover was highest in CC (18%), while it was similar across the other forested cover types (5%-9%). Deciduous canopy cover was similar across all the deciduous cover types, as well as the CC cover type (71%-83%). Coniferous cover was minimal (≤6%) in all cover types except for the xeric mixed (XM) type (22%). Shrub canopy cover was highest in mesic deciduous w/ an evergreen understory (MDEU; 76%), and ranged from 50% to 56% in the other 3 cover types with the rhododendron/laurel understory component (mesic deciduous w/ mixed understory, xeric deciduous w/ evergreen understory, xeric deciduous w/ mixed understory). Mesic deciduous w/ evergreen understory also had the highest stem density of those 4 cover types (Table 13). The shrub canopy height was similar across all the deciduous cover types (1.6-2.0 m), and stand height varied little across these types as well (17-21 m). Basal area was much more variable across the deciduous cover types (13-22 m^2/ha), with the xeric types being consistently higher.

Tree species composition varied among the cover types (Table 14). However, red maple (*Acer rubrum*) was the most dominant tree species in 7 of the cover types. Shrub species composition also varied between cover types, but rhododendron (*Rhododendron* spp.) was the most dominant shrub in 7 of the cover types, including the evergreen and mixed understory cover types. Mountain laurel (*Kalmia latifolia*) was the second most dominant species in 3 of the evergreen or mixed understory cover types (Table 14).

Landscape Characteristic Selection

Home Range Scale. – Several landscape metrics were significantly different between home ranges and the area encompassed by the home ranges plus their 300 m buffer (HR+B; Table 15). Total core area index, patch size standard deviation, mean shape index, and mean patch size were all significantly smaller ($P \leq 0.01$) within the home ranges. Number of patches per hectare, largest patch index, and total edge contrast index were significantly larger ($P \leq 0.07$) within the home ranges (Table 15). No significant differences ($P > 0.10$) were detected between Shannon's diversity index and mean nearest neighbor distance (Table 15).

Study Area Scale. – All landscape metrics included at this scale were significantly different between home ranges and the random plots on the study area. Total core area index, patch size standard deviation, mean shape index, mean patch size, and largest patch index were significantly smaller ($P < 0.01$) within the home ranges (Table 16). Shannon's diversity index, number of patches per hectare, mean nearest neighbor distance, total edge contrast index, and patch richness per hectare were significantly greater ($P < 0.01$) within home ranges (Table 16).

Preferential Use of Cover Types

Five of the GIS cover types were used little by ruffed grouse (xeric shrub/scrub, mesic shrub/scrub, xeric mixed, meso-xeric mixed, mesic mixed; each with <2% coverage within any home range) and 3 were not used (meso-xeric shrub/scrub, xeric herbaceous, meso-xeric herbaceous). These 8 cover types also had a very low overall coverage in the study area (each ≤0.77%). Therefore, these cover types were pooled into an 'other' category for compositional analyses (Table 17).

Study Area Scale. – At this scale, the percent of each cover type within a bird's home range was compared to the availability of that cover type across the study area. Ruffed grouse used cover types disproportionally to their availability at the study area scale ($F_{14, 9}$ = 16.2, P < 0.01). Clearcuts (CC) were the most preferred cover type, followed by mesic deciduous with a mixed understory (MDMU) and then mesic deciduous with an evergreen understory (MDEU; Table 18). However, no significant difference in selection was detected among these 3 cover types (P > 0.10). Mesic coniferous (MC), xeric coniferous (XC), mesic herbaceous (MH), the 'other' group, and meso-xeric coniferous (MXC) were the least preferred cover types (Table 18). No significant difference in selection was detected among the MH, 'other', and MXC cover types (P > 0.10). The MC and XC cover types were significantly more preferred over the MXC cover type (P < 0.10), and MC also was significantly more preferred over the 'other' and MH cover types (P < 0.10; Table 18).

Home Range Scale. – Ruffed grouse also used cover types disproportionally to their availability at the home range ($F_{14, 9}$ = 4.03, P = 0.02) scale. Mesic deciduous w/ mixed understory, MDEU, and CC were the first, second, and third most preferred cover types, respectively (Table 19). No significant difference in selection was detected among these 3 cover types (P > 0.10). Meso-xeric coniferous, XC, MC, and the 'other' cover types were the least preferred at this scale (Table 19), and no significant differences in selection were detected among these 4 cover types (P > 0.10).

DISCUSSION

It is important to examine animals' selection for specific landscape characteristics and cover types at multiple spatial scales (Wiens 1981). Considering only 1 scale when conducting studies examining selection of cover types or landscape characteristics may lead to inaccurate results due to an arbitrary selection of scale. Examining landscape characteristic selection and cover type preference at the study area scale provided a general comparison of what grouse were selecting given what was available within in the landscape. Conducting the same analyses at the home range scale provided a more definitive comparison of which cover types grouse were selecting at a finer scale. As a result, it allowed me to better address the question of why a grouse centered its home range in a particular location.

Habitat Data

Habitat data were collected for 13 of the 22 GIS cover types (Tables 13 and 14). Of the 9 remaining cover types not included in the habitat sampling, 8 occurred in at least 1 of the grouse home ranges included in my analyses. However, 3 of these cover types (meso-xeric coniferous, meso-xeric mixed, and xeric shrub/scrub) had <1% coverage in any individual home range, and 4 others had <5% coverage (mesic coniferous, mesic mixed, meso-xeric deciduous w/ an evergreen understory, meso-xeric deciduous w/ a mixed understory). Xeric coniferous had 6.4% coverage in 1 home range, and <4% in all others. Also of those 9 cover types not included in the habitat sampling, only 2 had >1% coverage across the study area: mesic coniferous and xeric coniferous. The majority of this coverage occurred on 1 of the remote mountains in the study area as a red spruce (*Picea rubens*) forest, and none of the birds included in my analyses were located in this area. Since these cover types had relatively small, if any, coverage in the home ranges, and were not a considerable component of the coverage across the study area, I do not feel that my analyses were substantially affected by having no habitat data for them. Also, 3 of the GIS cover types were sampled with ≤4 plots (mesic shrub/scrub, xeric mixed, meso-xeric deciduous). Therefore, the data provided by these plots may not accurately summarize the characteristics of these cover types.

Several patterns and differences in the structure and species composition of the cover types were evident in the habitat data. Mesic deciduous (MD) had greater shrub cover and stem density than xeric deciduous (XD), while XD had a greater basal area (Table 13). The tree and shrub species compositions also were different between these cover types. Black birch (*Betula lenta*) was the dominant tree species in MD, and red maple was the dominant species the XD (Table 14). With the exception of the xeric mixed cover type, MD was the only forested cover type where red maple was not the most dominant tree species. Rhododendron was the most dominant shrub species in the MD cover type, while winterberry (*Ilex verticillata*) was the most dominant species in XD (Table 14).

Mesic deciduous w/ an evergreen understory (MDEU) had the greatest shrub canopy cover and stem density of the 4 evergreen or mixed understory cover types (Table 13). Surprisingly, xeric deciduous w/ an evergreen understory (XDEU) had the lowest stem density of these 4 cover types, and its canopy cover was similar to mesic deciduous w/ a mixed understory (MDMU) and xeric deciduous w/ a mixed understory (XDMU). Xeric deciduous w/ evergreen understory and XDMU had greater basal areas than the MDEU or MDMU cover types.

Landscape Characteristic Selection

Home Range Scale. **–** Four landscape metrics had significantly smaller values within grouse home ranges compared to the home ranges plus their buffers (HR+B; Table 15). Total core area index (TCAI) is the percentage of the home range that is core area (area >50 m inside a patch perimeter). Grouse had significantly less core area in their home range ($P < 0.01$) than what was present in the HR+B area, indicating they were selecting areas with smaller patches containing minimal core area.

Patch size standard deviation (PSSD) is a measure of the variation in patch size in the landscape. PSSD was significantly less ($P < 0.01$) within home ranges compared to the HR+B area, indicating grouse were selecting areas containing patches of similar sizes.

Mean shape index (MSI) quantifies the average shape of the habitat patches in the landscape. This metric was significantly smaller ($P < 0.01$) within grouse home ranges than within the HR+B area, indicating grouse were selecting areas containing patches of uniform (e.g. circular or square) shape.

Mean patch size (MPS) is the average size in hectares of the patches in the landscape. Grouse home ranges had a significantly smaller MPS ($P < 0.01$) than did the HR+B area, indicating grouse were selecting areas of small patches.

Three landscape metrics had significantly larger values within the grouse home ranges compared to the HR+B area (Table 15). The number of patches per hectare (NP/ha) within a grouse's home range was significantly greater ($P < 0.01$) than the HR+B area, indicating grouse were selecting areas with a higher density of patches.

Total edge contrast index (TECI) quantifies the overall edge contrast in the landscape, and approaches 100% when all edge is maximum contrast. TECI was significantly higher within grouse home ranges than in the HR+B area ($P < 0.01$), indicating grouse were selecting areas containing a large amount of high contrast edge.

The largest patch index (LPI) is the percentage of the landscape or home range that the largest patch comprises. The LPI was significantly greater ($P = 0.07$) within grouse home ranges than in the HR+B area. This indicates that grouse had 1 patch of a particular cover type in their home range that was larger relative to the other patches. The difference in size between that 1 patch and the other patches within a bird's home range was greater than difference in size between the largest patch and other patches in the HR+B area.

Study Area Scale. – Five landscape metrics had significantly smaller values within grouse home ranges than across the study area (Table 16). Total core area index, PSSD, MSI, and MPS were all smaller within grouse home ranges than across the study area ($P < 0.01$). As they were at the home range scale, grouse were selecting areas with smaller patches, thereby minimizing core area, and these patches were of uniform size and shape. The LPI also was significantly smaller ($P < 0.01$) within grouse home ranges than across the study area, which is opposite of what was seen at the home range scale.

Five landscape metrics were significantly greater within grouse home ranges than across the study area (Table 16). The NP/ha and TECI were significantly greater within grouse home ranges than across the study area. Grouse were selecting areas with a higher density of patches per hectare and a larger amount of high contrast edge.

Shannon's diversity index (SHDI) was greater within home ranges than across the study area. This indicates that grouse were choosing areas containing a greater than average diversity and distribution of cover types.

The number of different cover types per hectare (HRCPR/ha) was greater within grouse home ranges than across the landscape. Grouse were choosing areas with a greater than average diversity of cover types.

Mean nearest neighbor distance (MNN) is the average distance (m) between patches of the same cover type, and was significantly greater within grouse home ranges ($P = 0.02$) than across the study area. This indicates that grouse were selecting areas with a greater than average distance between patches of the same cover type. This result is actually opposite of what I expected. Given the previous results indicating grouse preferred areas with several small patches, it seems logical that the MNN value within home ranges would be smaller than the overall value for the landscape, indicating a smaller distance between patches of the same cover type existed within home ranges. Unfortunately, I am not sure exactly why I obtained this result. One possibility is that this was a reflection of the greater diversity of cover types within the home ranges. As the diversity of cover types increased, the average distance between patches of the same cover type also increased. However, I note that the difference in the MNN values calculated for the home ranges and study area was only 10 m. Statistically, this difference was significant, but I question if it was truly biologically significant.

For the most part, the home range and study area scale results for the landscape characteristic selection complement each other. At both scales, grouse were selecting areas containing smaller patches, thereby minimizing the core area within these patches. Grouse home ranges also had high patch densities at both scales, as seen with the higher NP/ha values in the home ranges, which further reinforces the selection for smaller patches. Grouse also were selecting areas where patches were more uniform in both shape and size, and contained more high contrast edge.

Shannon's diversity index was greater within home ranges at the study area scale, but no significant difference was detected in the SHDI values at the home range scale. The number of different cover types per hectare also was greater within home ranges at the study area scale. Due to the nature in which I calculated this variable, comparisons at the home range scale were not possible. The majority of the study site was mature, contiguous deciduous forest, and grouse were choosing areas within the study site with a greater diversity of cover types. Within those areas, however, local differences in cover diversity did not appear to be important.

Landscapes containing the characteristics described above were more preferable to grouse because they probably contained the highest quality habitat. Areas containing several small patches of different cover types should provide the habitat diversity that grouse require throughout the year (Bump et al. 1947, Gullion 1972, 1989c). Patches that are of uniform size and shape can increase the interspersion of different cover types, providing more cover types within a smaller area. The presence of several small patches versus a few large ones also can maximize the amount of edge in the landscape, another important habitat component for grouse (Bump et al. 1947, Kubisiak et al. 1980, DeStefano and Rusch 1984, Schulz et al. 1989).

The results for the largest patch index (LPI) metric differed between the 2 scales. The LPI is the percentage of the landscape or home range the largest patch comprises. At the study area scale, LPI was greater in the study area than within the home ranges. At the home range scale, LPI was greater within the home ranges than the HR+B area. The study site contained several large, contiguous patches of mature forest that dominated the landscape (Fig. 1), and this was reflected in the large LPI value for the study site. Grouse were not choosing areas in the landscape having a patch structure where 1 or 2 large patches dominated their home range. Instead, they were choosing areas within the landscape containing several small, less contiguous patches, resulting in a smaller LPI value for the home ranges relative to the study area. At the home range scale, it is probable that better than half of a grouse's home range contained 1 or 2 patches that provided 1 or several key habitat requirements. For example, almost 50% of a grouse's home range may be in a clearcut or some other patch that provides cover and several food sources for most of the year. The rest of its home range contains parts of other patches that provide the rest of its habitat requirements. When the bird's home range and immediate area are considered (i.e. the home range plus its 300 m buffer), the size of the clearcut is not different than the average size of the rest of the patches in the surrounding area. However, since about half of the bird's home range is in that clearcut patch and only relatively smaller parts of the other patches, the LPI value within the bird's home range is larger than LPI for the HR+B area.

Preferential Use of Cover Types

When considering the ranked results for the compositional analyses, it is important to remember that preferential use of any cover type is relative to its availability at the scale being considered. Because 1 cover typed was ranked as more preferred over another does not imply that there was consistently more of that cover type in the bird's home range relative to the other cover type. Rather, it implies that the preference for that particular cover type given its availability was greater than the preference for a lower ranked cover type given that cover type's availability. For example, clearcuts were more preferred than xeric deciduous cover at both scales, even though clearcuts comprised an average of 14% of any bird's home range, while xeric deciduous cover comprised an average of 28% (Table 17). However, xeric deciduous cover was at least 8X more available in the landscape than clearcuts, so grouse were choosing clearcuts more than xeric deciduous cover relative to their respective availabilities.

Study Area Scale. – Clearcuts (CC) were the most preferred cover type relative to their availability at the study area scale, followed by mesic deciduous w/ mixed understory (MDMU) and mesic deciduous with an evergreen understory (MDEU; Table 16). However, while CC was ranked as the most preferred cover type, it was significantly more preferred over only 7 of the other cover types ($P \leq 0.05$). Mesic deciduous w/ mixed understory was significantly more preferred over 12 of the other cover types, and MDEU was significantly more preferred over 9 of the other cover types ($P < 0.07$; Table 18). These discrepancies were the result of variation in selection for cover types by birds. While CC was ranked as the most preferred relative to its availability, the amount of CC in the home ranges was highly variable. This produced a large confidence interval for CC selection, decreasing the probability of detecting significant differences in selection between CC and other cover types. The amount of the other cover types in the home ranges was more consistent, decreasing their confidence intervals and increasing the probability of detecting significant differences in selection.

The meso-xeric deciduous (MXD) and mesic deciduous (MD) cover types were ranked fourth and fifth in preference at the study area scale (Table 18). It is interesting that these cover types were more preferred than the other 4 evergreen and mixed understory cover types, and in fact MXD was significantly more preferred over 2 of them ($P < 0.06$). Both of these cover types also were significantly more preferred than the xeric deciduous (XD) cover type ($P < 0.05$).

Home Range Scale. – Cover type preference at the home range scale was similar to that at the study area scale; however, fewer significant differences in preference were detected at this scale. Mesic deciduous w/ mixed understory, MDEU, and CC were the 3 most preferred cover types in that order (Table 19). Mesic deciduous w/ mixed understory was significantly more preferred over 11 cover types ($P < 0.03$), MDEU was significantly more preferred over 8 ($P < 0.10$), and CC was only significantly more preferred over 3 cover types ($P \leq 0.09$; Table 19). Meso-xeric deciduous with a mixed understory (MXDMU) was ranked fourth in preference at this scale, followed my MD and MXD. Mesic deciduous and MXD were more preferred over the xeric and meso-xeric deciduous with an evergreen understory (XDEU, MXDEU), as well as xeric deciduous w/ mixed understory (XDMU) cover types, but this preference was not significant ($P > 0.10$). As was seen at the study area scale, MD and MXD also were more preferred over XD, with MD being significantly more preferred ($P < 0.02$)

The strong preference seen for CC as well as the MDMU and MDEU cover types at both scales is not surprising. The early successional forest structure provided by clearcuts is an important habitat component for ruffed grouse (Bump et al. 1947, Thompson and Fritzell 1989, Wiggers et al. 1992, Thompson and Dessecker 1997). In the absence of such early successional habitats, thick shrub understories in mature stands, such as those provided by rhododendron and/or mountain laurel, can provide adequate habitat for ruffed grouse (Bump et al. 1947, Hale et al. 1982, Epperson 1988, McDonald et al. 1998). It was surprising, however, that the MDEU and MDMU cover types were more preferred over the MXDMU, XDEU, XDMU, and MXDEU at both scales. Since all these cover types provided the rhododendron/laurel understory cover component, I expected the selection for these cover types to be similar. The XDEU and XDMU had the highest availability in the landscape at both scales relative to the other 4 types, and this probably accounts for some of the difference. However, the differences in availability between XDEU and XDMU cover types and the MDEU and MDMU cover types was only 1%-5% at both scales (Table 17). I feel the differences in the habitat characteristics between the XDEU, XDMU, MDEU, and MDMU cover types provide some additional explanation for the differing ranks. The MDEU cover type had the greatest % shrub cover of these 4 cover types, and the MDEU and MDMU cover types had higher stem densities than the XDMU and especially the XDEU cover types (Table 13). Given these structural differences in the shrub cover between these cover types, the

MDMU and MDEU cover types probably provided more adequate habitat than the XDEU or XDMU cover types.

The ranking of CC cover third behind MDMU and MDEU cover at the home range scale, while not significant, was still an unexpected result. While availability of CC cover was similar to MDEU and MDMU availability at this scale (6%, 7%, and 3%, respectively), CC cover was not as evenly distributed in the landscape as MDEU and MDMU cover. At this scale CC cover was not available to 6 birds, while MDMU and MDEU cover always were available and always used when they were available. It is because of these differences in distribution that I feel MDMU and MDEU were ranked as more preferred than clearcuts.

I feel the shifts in preference among the CC, MDEU, and MDMU cover types between the 2 scales (Tables 18 and 19) were a result of the differences in availability of these cover types at these 2 scales. At the home range scale, CC cover was 10X more available than it was at the study area scale, while MDEU and MDMU were only 5% and 2% more available at the home range scale, respectively. Therefore, when use of CC was considered at the study area scale, it was much more preferred relative to its availability than the MDEU and MDMU covers.

The significant preference of MD cover over XD at both scales, as well as the relatively high rank of MD cover was a result I did not expect. Since both these cover types represent predominantly mature hardwood stands, I expected selection for them to be similar and relatively low. Again, the differences in availability of these cover types at both scales contributed to these results. Xeric deciduous was the most available cover type in the landscape at both scales, and was approximately 3X more available than MD at both scales (Table 17). There also were several differences in the habitat structure between these cover types that I feel also contributed to their different ranks. MD had greater % shrub cover and greater stem densities than XD (Table 13). The dominant tree species in the MD cover type were black birch, and red oak and black cherry also were common (Table 14). These 3 species provide a nutritional and diverse food source for grouse (Servello and Kirkpatrick 1987, 1989). Red maple was the dominant tree species in the XD cover type, with red oak and chestnut oak being the only common tree species providing a potential food source. The dominant shrub species in the MD cover type was rhododendron, while neither rhododendron nor laurel were dominant shrubs in the XD cover type. Considering these differences, MD probably provided better habitat than the XD cover type, contributing to its higher rank.

The overall ranking of the cover types observed in my study follows the known habitat preferences for ruffed grouse elsewhere within their range. Grouse require a diversity of cover types throughout the year to meet seasonal variations in habitat requirements (Bump et al. 1947, Kubisiak 1978, Gullion 1989c, Thompson and Dessecker 1997). Early successional cover, such as clearcuts, or other covers that provide similar structure, such as mature forest stands with a thick shrub understory, are the most preferred cover types of ruffed grouse and provide several of the grouse's habitat requirements (Bump et al. 1947, Hale et al. 1982, Epperson 1988, Thompson and Fritzell 1989, Wiggers et al. 1992, Thompson and Dessecker 1997, McDonald et al. 1998). Rhododendron and/or laurel also can be an important habitat component in winter, as the evergreen leaves of these shrubs can provide good thermal cover (Bump et al. 1947, Barber 1989). Providing adjacent areas of mature forest that contain several food sources, such as birch catkins, grapes, acorns, and cherries, also is important for maintaining a healthy grouse population, especially if rhododendron and/or laurel thickets are the primary source of cover (Norman and Kirkpatrick 1984, Servello and Kirkpatrick 1987, Servello and Kirkpatrick 1989, Hewitt and Kirkpatrick 1997a).

At both the study area and home range scales, ruffed grouse were selecting areas with high densities of smaller than average patches, thereby minimizing the core area within these patches. These patches were of uniform size and shape, and contained higher than average amounts of high contrast edge. Areas containing a greater diversity of cover types than what was available in the study area also were preferred. The presence of these characteristics in the landscape helps provide the highest quality habitat for ruffed grouse. Within these areas, clearcuts, mesic deciduous with mixed understory and mesic deciduous with an evergreen understory were the most preferred cover types. These covers had the highest stem densities and provided the early successional habitats preferred by grouse. The rhododendron and/or laurel in the evergreen and mixed understory cover types also provide winter cover. Stands of mesic deciduous cover also were relatively preferred, probably because they provided supplemental food sources for grouse.

Table 13. Mean and SE values of random plot habitat data stratified by GIS cover type, CMWMA, VA, 1996-1998. Data were collected in 20 m radius circular plots located throughout the study area. Plot locations stratified by deciduous, coniferous, mixed, clearcut, herbaceous, deciduous w/ rhododendron/laurel understory, shrub/scrub cover types.

		% Decid. Cover		% Conif. Cover		% Dead Woody Cover		% Shrub Cover		Shrub Canopy Height (m)		Stems/Ha		Stand Height (m)		Basal Area (m^2/ha)	
Cover Type	*n*	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Clearcut	8	83	3	0	0	18	2	29	9	1.2	0.2	9439	1249	9	1	6.1	0.5
Herbaceous	8	2	2.0	1	1	0	0	2	1	0.6	0.4	136	65	0	0	0.0	0.0
Mesic shrub/scrub	2	10	0.0	3	3	5	5	28	3	1.2	0.1	1891	288	4	1	0.0	0.0
Xeric mixed	3	57	12.0	22	11	3	2	55	25	1.9	0.4	8098	4357	14	7	16.0	6.6
Mesic deciduous	36	85	2.0	2	1	7	1	30	4	1.8	0.2	3403	333	20	1	13.7	1.8
Xeric deciduous	84	85	1.0	1	0	9	1	21	2	1.6	0.2	2925	215	21	1	20.7	1.0
Meso-xeric deciduous	4	89	3.0	0	0	8	1	23	3	1.7	0.3	4920	790	19	2	17.2	3.0
Mesic deciduous w/ evergreen understory	14	75	5.0	3	2	7	2	76	4	2.0	0.1	4968	687	20	2	13.2	2.3
Mesic deciduous w/ mixed understory	10	71	7.0	6	5	5	1	50	6	1.7	0.1	4413	565	17	2	16.9	2.8
Xeric deciduous w/ evergreen understory	13	83	2.0	5	4	6	1	53	8	1.7	0.1	3521	390	21	2	21.3	2.6
Xeric deciduous w/ mixed understory	19	82	3.0	1	1	7	2	56	5	1.9	0.1	4399	403	19	1	22.4	2.9

Table 14. Summary of dominant tree and shrub species stratified by GIS cover type, CMWMA, VA, 1996-1998. Tree and shrub species data were collected in 10 m x 10 m square plots nested in the 20 m radius circular plots used for general habitat data collection. Dominance within cover types was based on presence of a species across plots as well as abundance within each plot.

Cover Type	*n*	Dominant Tree Species				
		1	2	3	4	5
Clearcut	8	*Acer rubrum*	*Magnolia acuminata*	*Prunus serotina*	*P. pensylvanica*	*Nyssa sylvatica*
Herbaceous	8	-	-	-	-	-
Mesic shrub/scrub	2	-	-	-	-	-
Xeric mixed	3	*Quercus rubra*	*Picea rubens*	*Betula alleghaniensis*	*B. lenta*	*P. serotina*
Mesic deciduous	36	*B. lenta*	*A. rubrum*	*Q. rubra*	*A. saccharum*	*P. serotina*
Xeric deciduous	84	*A. rubrum*	*Q. rubra*	*A. saccharum*	*Q. prinus*	*N. sylvatica*
Meso-xeric deciduous	4	*A. rubrum*	*Q. prinus*	*Q. rubra*	*N. sylvatica*	*Q. alba*
Mesic deciduous w/ evergreen understory	14	*A. rubrum*	*Q. rubra*	*P. serotina*	*M. fraseri*	*Liriodendron tuplipifera*
Mesic deciduous w/ mixed understory	10	*A. rubrum*	*L. tulpifera*	*B. alleghaniensis*	*B. lenta*	*Q. alba*
Xeric deciduous w/ evergreen understory	13	*A. rubrum*	*P. serotina*	*B. lenta*	*Q. rubra*	*L. tulipifera*
Xeric deciduous w/ mixed understory	19	*A. rubrum*	*Q. prinus*	*N. sylvatica*	*L. tulipifera*	*Q. rubra*

Table 14. Continued.

GIS Cover Type	Dominant Shrub Species 1	2	3
Clearcut	*Rubus* spp.	*Vaccinium* spp.	*Smilax* spp.
Herbaceous	*Rubus* spp.	-	-
Mesic shrub/scrub	*Rhododendron* spp.	*Vaccinum* spp.	*Kalmia latifolia*
Xeric mixed	*Rhododendron* spp.	*K. latifolia*	*Vaccinum* spp.
Mesic deciduous	*Rhododendron* spp.	*Hamamelis virginiana*	*Crataegus* spp.
Xeric deciduous	*Ilex verticillata*	*Smilax* spp.	*Vaccinum* spp.
Meso-xeric deciduous	*Vaccinum* spp.	*I. verticillata*	*Smilax* spp.
Mesic deciduous w/ evergreen understory	*Rhododendron* spp.	*H. virginiana*	*K. latifolia*
Mesic deciduous w/ mixed understory	*Rhododendron* spp.	*K. latifolia*	*Vaccinum* spp.
Xeric deciduous w/ evergreen understory	*Rhododendron* spp.	*K. latifolia*	*I. verticillata*
Xeric deciduous w/ mixed understory	*Rhododendron* spp.	*K. latifolia*	*H. virginiana*

Table 15. Results of Wilcoxon signed rank tests of ruffed grouse selection for specific landscape characteristics at the home range scale, CMWMA, VA, 1996-1998. Paired differences were calculated between 23 home ranges and the home ranges plus their respective 300 m buffers.

Landscape Metric	Median Difference*	Test Statistic	P-Value
Total Core Area Index (%)	-5.69	16.0	<0.01
Patch Size Standard Deviation (ha)	-2.05	2.0	<0.01
Mean Patch Size (ha)	-0.29	8.5	<0.01
Mean Shape Index	-0.03	24.0	<0.01
Shannon's Diversity Index	-0.01	129.5	0.61
Number of Patches/ha	2.10	276.0	<0.01
Mean Nearest Neighbor Distance (m)	2.71	119.0	0.71
Largest Patch Index (%)	4.01	188.0	0.07
Total Edge Contrast Index (%)	5.68	232.0	<0.01

*Positive median difference indicates home range > home range+buffer; negative median difference indicates home range < home range+buffer

Table 16. Results of Wilcoxon rank sum tests of ruffed grouse selection for specific landscape characteristics at the study area scale, CMWMA, VA, 1996-1998. Median values were calculated from 23 home ranges and 50 33 ha random plots.

	Median			
Landscape Metric	Home Range	Random Plot	Test Statistic	P-Value
Total Core Area Index (%)	5.59	11.05	2146.0	<0.01
Patch Size Standard Deviation (ha)	1.07	3.40	2288.5	<0.01
Mean Patch Size (ha)	0.44	1.11	2286.5	<0.01
Mean Shape Index	1.26	1.32	2247.0	<0.01
Shannon's Diversity Index	1.78	1.13	1448.0	<0.01
Number of Patches/ha	2.28	0.90	1409.0	<0.01
Mean Nearest Neighbor Distance (m)	102.14	92.93	1615.0	0.02
Largest Patch Index (%)	25.40	54.60	2229.0	<0.01
Total Edge Contrast Index (%)	31.67	21.40	1535.0	<0.01
Patch Richness/ha	0.55	0.32	1468.0	<0.01

Table 17. Average percent use of cover types by ruffed grouse (n = 23) and availability of cover types at the home range (home range plus 300m buffer) and study area scales, CMWMA, VA, 1996-1998.

	% Use		% Available at Home Range Scale		
Cover Type	Mean	SE	Mean	SE	% Available at Study Area Scale
Clearcut	14.0	3.3	5.9	1.2	0.5
Mesic coniferous	1.3	0.3	1.3	0.2	1.5
Mesic deciduous	16.5	1.7	17.7	1.3	14.4
Mesic deciduous w/ evergreen understory	10.9	2.0	7.4	1.2	2.5
Mesic deciduous w/ mixed understory	4.1	0.6	3.2	0.5	1.4
Meso-xeric coniferous	0.1	0.04	0.2	0.1	0.5
Meso-xeric deciduous	5.1	0.9	5.0	0.7	2.5
Meso-xeric deciduous w/ evergreen understory	1.0	0.2	0.7	0.1	0.4
Meso-xeric deciduous w/ mixed understory	1.0	0.2	0.7	0.1	0.2
Mesic herbaceous	1.8	1.4	0.9	0.6	0.2
Xeric coniferous	1.2	0.3	1.5	0.2	2.5
Xeric deciduous	28.5	4.0	40.6	3.3	59.1
Xeric deciduous w/ evergreen understory	8.1	1.3	8.1	0.8	7.9
Xeric deciduous w/ mixed understory	5.6	1.1	6.1	0.5	4.4
Other	0.5	0.1	0.9	0.2	1.9

Table 18. Ranks of cover type use at the study site scale based on compositional analysis for ruffed grouse in CMWMA, VA, 1996-1998. The most preferred cover types have the highest ranks. Columns are ordered most preferred to least preferred; rows are ordered least preferred to most preferred. Within columns, 3 plus symbols indicates the column cover type was significantly preferred ($p < 0.10$) over the row cover type, while 1 plus symbol indicates the column type was preferred over the row type, but the preference was not significant ($p > 0.10$).

Rank		14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
	Cover Type	Clear cut	Mesic deciduous w/ mixed understory	Mesic deciduous w/ evergreen understory	Meso-xeric deciduous	Mesic deciduous	Meso-xeric deciduous w/ mixed understory	Xeric deciduous w/ evergreen understory	Xeric deciduous w/ mixed understory	Meso-xeric deciduous w/ evergreen understory	Xeric deciduous	Mesic coniferous	Xeric coniferous	Mesic herbaceous	Other	Meso-xeric coniferous
0	Meso-xeric coniferous	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++	+	+	
1	Other	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++	+	+		
2	Mesic herbaceous	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++	+			
3	Xeric coniferous	+++	+++	+++	+++	+++	+++	+++	+++	+	+	+				
4	Mesic coniferous	+++	+++	+++	+++	+++	+++	+++	+++	+	+					
5	Xeric deciduous	+++	+++	+++	+++	+++	+	+	+	+						
6	Meso-xeric deciduous w/ evergreen understory	+++	+++	+++	+++	+	+	+	+							
7	Xeric deciduous w/ mixed understory	+	+++	+++	+++	+	+	+								
8	Xeric deciduous w/ evergreen understory	+	+++	+++	+	+	+									
9	Meso-xeric deciduous w/ mixed understory	+	+++	+	+	+										
10	Mesic deciduous	+	+++	+	+											
11	Meso-xeric deciduous	+	+++	+												
12	Mesic deciduous w/ evergreen understory	+	+													
13	Mesic deciduous w/ mixed understory	+														
14	Clear cut															

Table 19. Ranks of cover type use at the home range scale based on compositional analysis for ruffed grouse in CMWMA, VA, 1996-1998. The most preferred cover types have the highest ranks. Columns are ordered most preferred to least preferred; rows are ordered least preferred to most preferred. Within columns, 3 plus symbols indicates the column cover type was significantly preferred ($p < 0.10$) over the row cover type, while 1 plus symbol indicates the column type was preferred over the row type, but the preference was not significant ($p > 0.10$).

Rank		14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
	Cover Type	Mesic deciduous w/ mixed understory	Mesic deciduous w/ evergreen understory	Clearcut	Meso-xeric deciduous w/ mixed understory	Mesic deciduous	Meso-xeric deciduous	Xeric deciduous w/ evergreen understory	Meso-xeric deciduous w/ evergreen understory	Xeric deciduous	Mesic herbaceous	Xeric deciduous w/ mixed understory	Meso-xeric coniferous	Xeric coniferous	Mesic coniferous	Other
0	Other	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++	+	+	+	
1	Mesic coniferous	+++	+++	+++	+++	+++	+++	+	+	+	+	+	+	+		
2	Xeric coniferous	+++	+++	+++	+++	+++	+++	+++	+++	+	+	+	+			
3	Meso-xeric coniferous	+++	+++	+	+++	+++	+++	+++	+	+	+	+				
4	Xeric deciduous w/ mixed understory	+++	+++	+	+	+++	+++	+	+	+	+					
5	Mesic herbaceous	+++	+++	+	+	+	+	+	+	+						
6	Xeric deciduous	+++	+++	+	+	+++	+	+	+							
7	Meso-xeric deciduous w/ evergreen understory	+++	+	+	+	+	+	+								
8	Xeric deciduous w/ evergreen understory	+++	+	+	+	+	+									
9	Meso-xeric deciduous	+++	+	+	+	+										
10	Mesic deciduous	+++	+++	+	+											
11	Meso-xeric deciduous w/ mixed understory	+	+	+												
12	Clearcut	+	+													
13	Mesic deciduous w/ evergreen understory	+														
14	Mesic deciduous w/ mixed understory															

SUMMARY AND CONCLUSIONS

The results from home range regression models, daily movement regression model, landscape characteristic selection, and use-availability analyses complement each other.

1) Preference for high contrast edge
    a) The regression models for home range (all birds), seasonal home range shifts, and daily movement contained edge metrics (Tables 7, 9, and 12), and the increased presence of high contrast edge decreased ruffed grouse home range size and movement.
    b) Grouse were selecting areas within the landscape that contained the greatest amount of high contrast edge (Tables 15 and 16).
    c) The preferential use of clearcut (CC), mesic deciduous w/ evergreen understory (MDEU), and mesic deciduous w/ mixed understory (MDMU) cover types with the meso-xeric and mesic deciduous (MXD and MD) cover types provided these high contrast edge habitats (Tables 18 and 19).
2) Landscapes containing high density of small patches of uniform size and regular shape
    a) These characteristics decreased home range size, and landscapes with shorter distances between patches of the equivalent cover types decreased daily movement and the distance between seasonal home range centers (Tables 7 and 8).
    b) Grouse selected areas in the landscape with a high density of small patches that were of uniform size and shape (Tables 15 and 16).

Areas containing several small patches of appropriate cover types should provide the habitat diversity that grouse require throughout the year (Bump et al. 1947, Gullion 1972, 1989c). Patches that are of uniform size and shape can increase the interspersion of different cover types, providing more cover types within a smaller area. Large, narrow, elongated patches also seldom provide the proper interspersion of different cover types preferred by grouse (Bump et al. 1947). The presence of several small patches in the landscape, versus a few large ones, also can increase the amount of edge.

The regression models and the landscape selection analysis contradicted each other with regard to the diversity of cover types per hectare. The regression models for all birds and male birds indicated that home range size increased with an increasing diversity of cover types, and the seasonal home range shift model also indicated that higher cover type diversity increased the distance between seasonal home ranges (Tables 7, 8, and 9). However, grouse were selecting areas within the landscape that had a greater than average diversity of cover types (Table 16). The xeric deciduous and mesic deciduous cover types dominated the study site (Fig. 1), comprising 73.5% of the area (Table 17). However, grouse preferred the CC, MDMU, and MDEU cover types over the deciduous cover types (Tables 18 and 19). Given this preference, grouse were biasing themselves to areas in the landscape with greater than average cover type diversity. However, I believe there was a threshold value for the cover type diversity. Grouse did not need or use every cover type. As the diversity of cover types in the landscape increased, non-preferred cover types were present in the landscape. If these non-preferred cover types were interspersed with preferred cover types, this would likely decrease the overall habitat quality and increase grouse home range size.

Some management recommendations suggest that creating large clearcuts may be most beneficial for grouse (Thompson and Dessecker 1997). Several grouse in my study centered their home ranges on the edges of clearcuts, and few spent long periods of time in the centers of clearcuts or similar cover types (Figs. 3a,b). Also, based on the habitat data I gathered, grouse may not have adequate year-round food sources within clearcuts. Cherries were the only predominant mast producing tree species occurring in the clearcuts in my study area (Table 14). Blackberries, blueberries, and greenbriers were the dominant shrub species, but the overall shrub cover in clearcuts was only 29%, suggesting that these shrubs may not be in abundance (Tables 13 and 14). Grouse will consume woody material (twigs and buds), but these items constitute a relatively small part of their diet relative to other food sources, especially hard and soft mast (Seehorn et al. 1981). Therefore, I feel that maintaining smaller patches of clearcuts (e.g. 2-10 ha) interspersed with mature deciduous stands that contain oaks, grapes, and other food sources would be the most beneficial for ruffed grouse in this region.

While the MDMU and MDEU cover types were preferred by grouse, the movement regression model indicated that daily movement increased as the percent cover of a full rhododendron and/or laurel canopy increased. In the absence of clearcuts or other early successional covers, these rhododendron/laurel thickets can provide adequate habitat for ruffed grouse (Bump et al. 1947, Hale et al. 1982, Epperson 1988, McDonald, et al. 1998). However, these habitats also tend to provide lower quality food sources. If rhododendron/laurel thickets are the only cover types available for ruffed grouse, several more nutritionally beneficial food sources, such as oaks, greenbriers, blueberries, and grapes, should be maintained within close proximity of these cover types (Norman and Kirkpatrick 1984, Servello and Kirkpatrick 1987, Servello and Kirkpatrick 1989).

Based on the results of my study, I feel creating and maintaining a landscape with high densities of small patches that are of uniform size and shape would provide the highest quality ruffed grouse habitat in this region. Several of these patches should be early successional cover, such as clearcuts, to provide an abundance of high contrast edge. Rhododendron and/or laurel thickets also may be beneficial as supplemental cover, as they may provide better thermal cover in winter and structure similar to early successional forest cover. Mesic stands of mature hardwoods should be well interspersed with these cover types. These stands should contain several food sources, such as oaks, grapes, and birches, to supplement the grouse's diet. I provide one example of what I feel would be an ideal landscape given these characteristics and cover type preferences (Fig. 5). However, there are a multitude of possible landscape configurations that could contain the characteristics and mixture of cover types I describe (Guthery 1999). Landscapes with these characteristics will provide several of the grouse's habitat requirements in a small area, decreasing their home range size as well as daily and seasonal movement. Minimizing home range size and movement will minimize the energy grouse expend searching for food and cover as well as their exposure to predators. This should increase their survival as well as increase the density of birds and sustainability of the population over a given area.

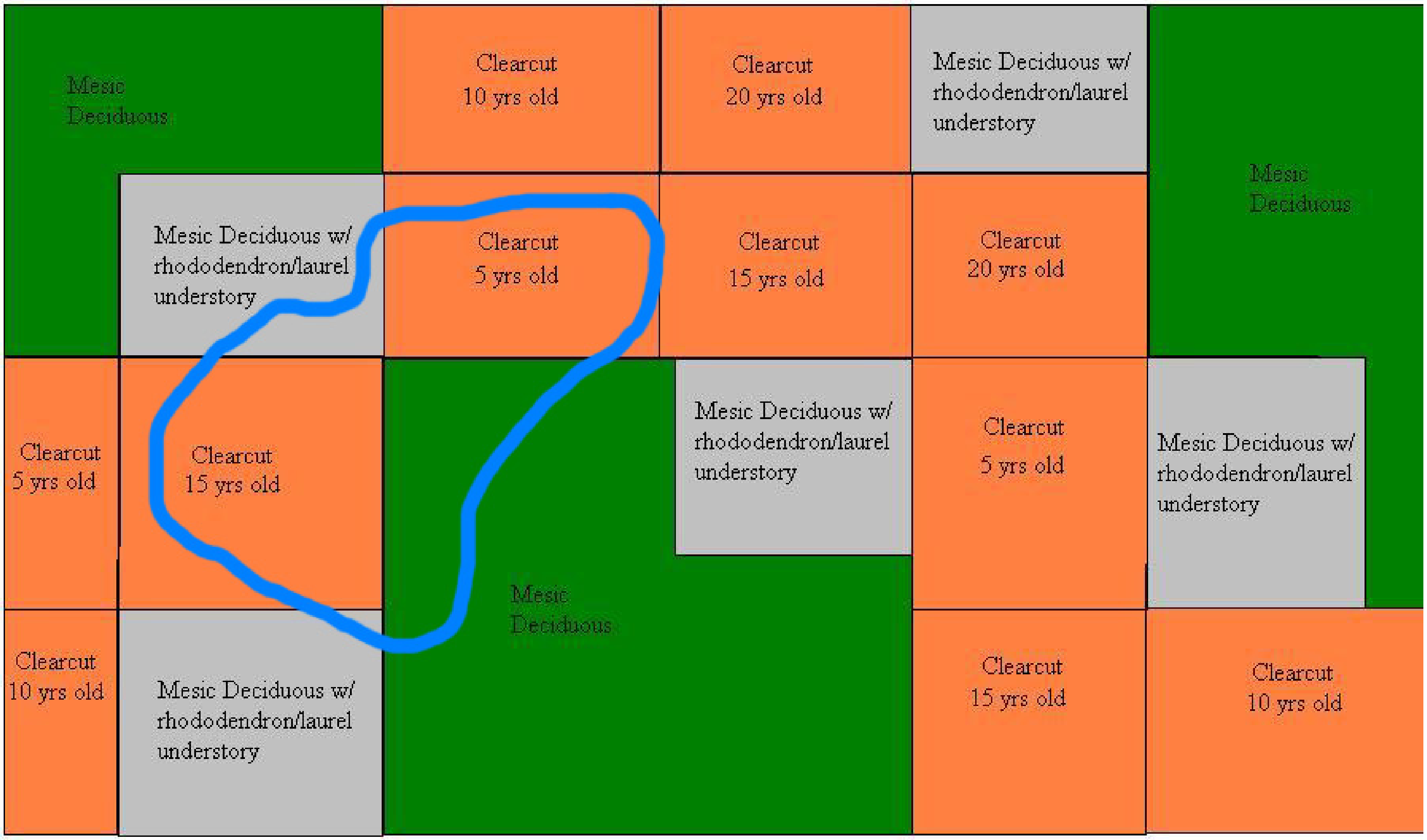

Figure 5. An example of a landscape configuration for ruffed grouse that would contain the preferred landscape characteristics and cover types described in this thesis. The clearcut and mesic deciduous w/ rhododendron/laurel understory patches are each about 5 ha in size, and the mesic deciduous patches are about 20 ha in size. Each clearcut patch would be on a 20-year harvest rotation. This pattern would repeat itself across the landscape. The blue outline represents the possible placement of a ruffed grouse home range.

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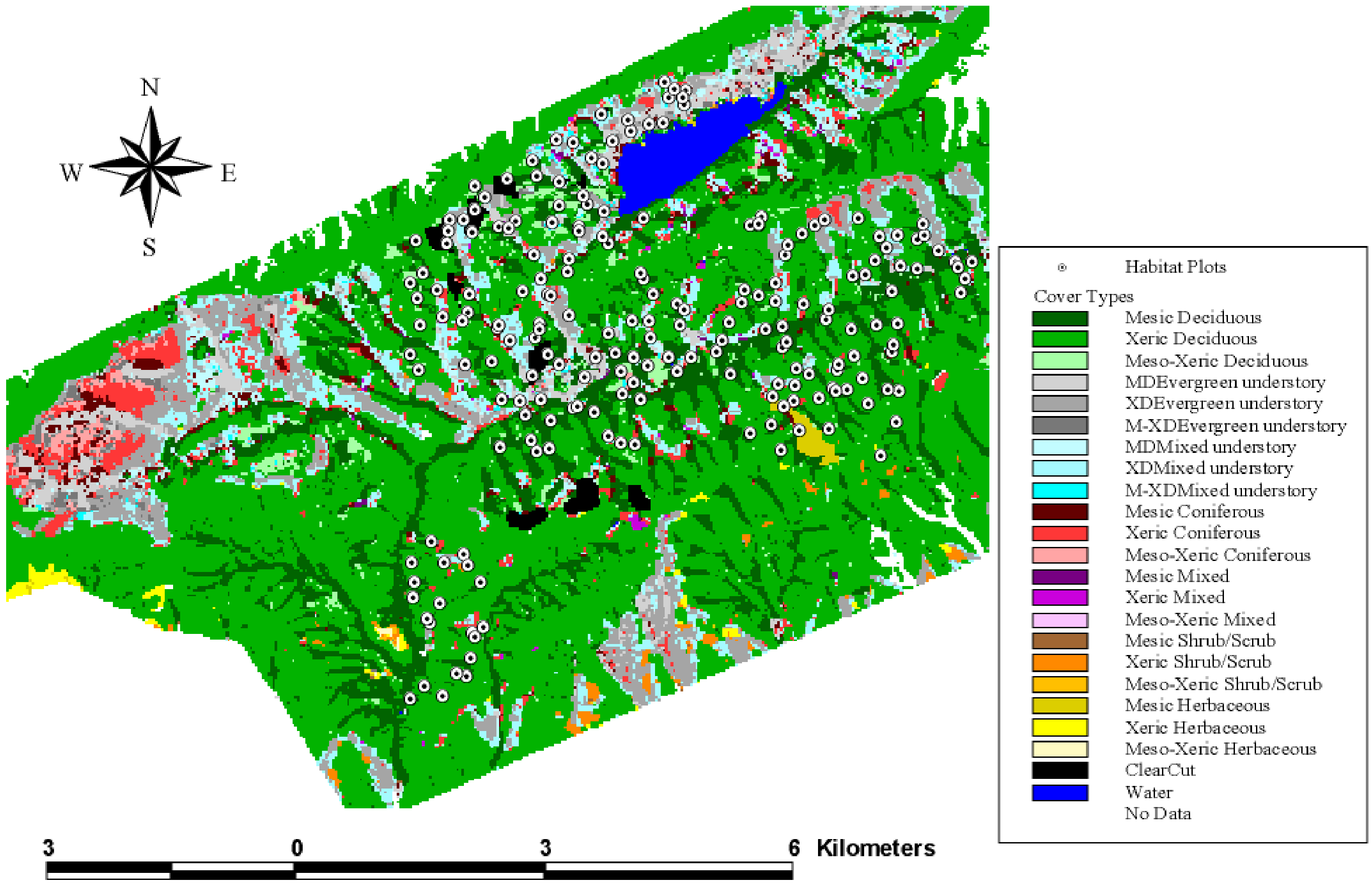
APPENDICES

Appendix A. Locations of the 20 m radius plots used to characterize the GIS cover types, CMWMA, VA, 1996-1998.



Appendix B. Edge weights used in all FRAGSTATS weighted edge calculations.

Cover Type A	Cover Type B	Edge Weight
Clearcut	Mesic Coniferous	1.00
Clearcut	Mesic Deciduous	1.00
Clearcut	Mesic Deciduous w/ Evergreen Understory	0.75
Clearcut	Mesic Deciduous w/ Mixed Understory	1.00
Clearcut	Mesic Herbaceous	1.00
Clearcut	Mesic Mixed	1.00
Clearcut	Mesic Shrub/Scrub	1.00
Clearcut	Meso-xeric Coniferous	1.00
Clearcut	Meso-xeric Deciduous	1.00
Clearcut	Meso-xeric Deciduous w/ Evergreen Understory	0.75
Clearcut	Meso-xeric Deciduous w/ Mixed Understory	1.00
Clearcut	Meso-xeric Herbaceous	1.00
Clearcut	Meso-xeric Mixed	1.00
Clearcut	Meso-xeric Shrub/Scrub	1.00
Clearcut	Xeric Coniferous	1.00
Clearcut	Xeric Deciduous	1.00
Clearcut	Xeric Deciduous w/ Evergreen Understory	0.75
Clearcut	Xeric Deciduous w/ Mixed Understory	1.00
Clearcut	Xeric Herbaceous	1.00
Clearcut	Xeric Mixed	1.00
Clearcut	Xeric Shrub/Shrub	1.00
Mesic Coniferous	Mesic Deciduous	0.10
Mesic Coniferous	Mesic Deciduous w/ Evergreen Understory	0.75
Mesic Coniferous	Mesic Deciduous w/ Mixed Understory	0.50
Mesic Coniferous	Mesic Herbaceous	1.00
Mesic Coniferous	Mesic Mixed	0.05
Mesic Coniferous	Mesic Shrub/Scrub	1.00
Mesic Coniferous	Meso-xeric Coniferous	0.00
Mesic Coniferous	Meso-xeric Deciduous	0.10
Mesic Coniferous	Meso-xeric Deciduous w/ Evergreen Understory	0.75
Mesic Coniferous	Meso-xeric Deciduous w/ Mixed Understory	0.50
Mesic Coniferous	Meso-xeric Herbaceous	1.00
Mesic Coniferous	Meso-xeric Mixed	0.05
Mesic Coniferous	Meso-xeric Shrub/Scrub	1.00
Mesic Coniferous	Xeric Coniferous	0.00
Mesic Coniferous	Xeric Deciduous	0.10
Mesic Coniferous	Xeric Deciduous w/ Evergreen Understory	0.75
Mesic Coniferous	Xeric Deciduous w/ Mixed Understory	0.50
Mesic Coniferous	Xeric Herbaceous	1.00
Mesic Coniferous	Xeric Mixed	0.05
Mesic Coniferous	Xeric Shrub/Shrub	1.00
Mesic Deciduous	Mesic Deciduous w/ Evergreen Understory	0.75
Mesic Deciduous	Mesic Deciduous w/ Mixed Understory	0.50
Mesic Deciduous	Mesic Herbaceous	1.00
Mesic Deciduous	Mesic Mixed	0.05
Mesic Deciduous	Mesic Shrub/Scrub	1.00
Mesic Deciduous	Meso-xeric Coniferous	0.10
Mesic Deciduous	Meso-xeric Deciduous	0.00
Mesic Deciduous	Meso-xeric Deciduous w/ Evergreen Understory	0.75

Appendix B. Continued.

Cover Type A	Cover Type B	Edge Weight
Mesic Deciduous	Meso-xeric Deciduous w/ Mixed Understory	0.50
Mesic Deciduous	Meso-xeric Herbaceous	1.00
Mesic Deciduous	Meso-xeric Mixed	0.05
Mesic Deciduous	Meso-xeric Shrub/Scrub	1.00
Mesic Deciduous	Xeric Coniferous	0.10
Mesic Deciduous	Xeric Deciduous	0.00
Mesic Deciduous	Xeric Deciduous w/ Evergreen Understory	0.75
Mesic Deciduous	Xeric Deciduous w/ Mixed Understory	0.50
Mesic Deciduous	Xeric Herbaceous	1.00
Mesic Deciduous	Xeric Mixed	0.05
Mesic Deciduous	Xeric Shrub/Shrub	1.00
Mesic Deciduous w/ Evergreen Understory	Mesic Deciduous w/ Mixed Understory	0.10
Mesic Deciduous w/ Evergreen Understory	Mesic Herbaceous	1.00
Mesic Deciduous w/ Evergreen Understory	Mesic Mixed	0.75
Mesic Deciduous w/ Evergreen Understory	Mesic Shrub/Scrub	1.00
Mesic Deciduous w/ Evergreen Understory	Meso-xeric Coniferous	0.75
Mesic Deciduous w/ Evergreen Understory	Meso-xeric Deciduous	0.75
Mesic Deciduous w/ Evergreen Understory	Meso-xeric Deciduous w/ Evergreen Understory	0.00
Mesic Deciduous w/ Evergreen Understory	Meso-xeric Deciduous w/ Mixed Understory	0.10
Mesic Deciduous w/ Evergreen Understory	Meso-xeric Herbaceous	1.00
Mesic Deciduous w/ Evergreen Understory	Meso-xeric Mixed	0.75
Mesic Deciduous w/ Evergreen Understory	Meso-xeric Shrub/Scrub	1.00
Mesic Deciduous w/ Evergreen Understory	Xeric Coniferous	0.75
Mesic Deciduous w/ Evergreen Understory	Xeric Deciduous	0.75
Mesic Deciduous w/ Evergreen Understory	Xeric Deciduous w/ Evergreen Understory	0.00
Mesic Deciduous w/ Evergreen Understory	Xeric Deciduous w/ Mixed Understory	0.10
Mesic Deciduous w/ Evergreen Understory	Xeric Herbaceous	1.00
Mesic Deciduous w/ Evergreen Understory	Xeric Mixed	0.75
Mesic Deciduous w/ Evergreen Understory	Xeric Shrub/Shrub	1.00
Mesic Deciduous w/ Mixed Understory	Mesic Herbaceous	1.00
Mesic Deciduous w/ Mixed Understory	Mesic Mixed	0.50
Mesic Deciduous w/ Mixed Understory	Mesic Shrub/Scrub	1.00
Mesic Deciduous w/ Mixed Understory	Meso-xeric Coniferous	0.50
Mesic Deciduous w/ Mixed Understory	Meso-xeric Deciduous	0.50
Mesic Deciduous w/ Mixed Understory	Meso-xeric Deciduous w/ Evergreen Understory	0.10
Mesic Deciduous w/ Mixed Understory	Meso-xeric Deciduous w/ Mixed Understory	0.00
Mesic Deciduous w/ Mixed Understory	Meso-xeric Herbaceous	1.00
Mesic Deciduous w/ Mixed Understory	Meso-xeric Mixed	0.50
Mesic Deciduous w/ Mixed Understory	Meso-xeric Shrub/Scrub	1.00
Mesic Deciduous w/ Mixed Understory	Xeric Coniferous	0.50
Mesic Deciduous w/ Mixed Understory	Xeric Deciduous	0.50
Mesic Deciduous w/ Mixed Understory	Xeric Deciduous w/ Evergreen Understory	0.10
Mesic Deciduous w/ Mixed Understory	Xeric Deciduous w/ Mixed Understory	0.00
Mesic Deciduous w/ Mixed Understory	Xeric Herbaceous	1.00
Mesic Deciduous w/ Mixed Understory	Xeric Mixed	0.50
Mesic Deciduous w/ Mixed Understory	Xeric Shrub/Shrub	1.00
Mesic Herbaceous	Mesic Mixed	1.00
Mesic Herbaceous	Mesic Shrub/Scrub	1.00
Mesic Herbaceous	Meso-xeric Coniferous	1.00

Appendix B. Continued.

Cover Type A	Cover Type B	Edge Weight
Mesic Herbaceous	Meso-xeric Deciduous	1.00
Mesic Herbaceous	Meso-xeric Deciduous w/ Evergreen Understory	1.00
Mesic Herbaceous	Meso-xeric Deciduous w/ Mixed Understory	1.00
Mesic Herbaceous	Meso-xeric Herbaceous	0.00
Mesic Herbaceous	Meso-xeric Mixed	1.00
Mesic Herbaceous	Meso-xeric Shrub/Scrub	1.00
Mesic Herbaceous	Xeric Coniferous	1.00
Mesic Herbaceous	Xeric Deciduous	1.00
Mesic Herbaceous	Xeric Deciduous w/ Evergreen Understory	1.00
Mesic Herbaceous	Xeric Deciduous w/ Mixed Understory	1.00
Mesic Herbaceous	Xeric Herbaceous	0.00
Mesic Herbaceous	Xeric Mixed	1.00
Mesic Herbaceous	Xeric Shrub/Shrub	1.00
Mesic Mixed	Mesic Shrub/Scrub	1.00
Mesic Mixed	Meso-xeric Coniferous	0.05
Mesic Mixed	Meso-xeric Deciduous	0.05
Mesic Mixed	Meso-xeric Deciduous w/ Evergreen Understory	0.75
Mesic Mixed	Meso-xeric Deciduous w/ Mixed Understory	0.50
Mesic Mixed	Meso-xeric Herbaceous	1.00
Mesic Mixed	Meso-xeric Mixed	0.00
Mesic Mixed	Meso-xeric Shrub/Scrub	1.00
Mesic Mixed	Xeric Coniferous	0.05
Mesic Mixed	Xeric Deciduous	0.05
Mesic Mixed	Xeric Deciduous w/ Evergreen Understory	0.75
Mesic Mixed	Xeric Deciduous w/ Mixed Understory	0.50
Mesic Mixed	Xeric Herbaceous	1.00
Mesic Mixed	Xeric Mixed	0.00
Mesic Mixed	Xeric Shrub/Shrub	1.00
Mesic Shrub/Scrub	Meso-xeric Coniferous	1.00
Mesic Shrub/Scrub	Meso-xeric Deciduous	1.00
Mesic Shrub/Scrub	Meso-xeric Deciduous w/ Evergreen Understory	1.00
Mesic Shrub/Scrub	Meso-xeric Deciduous w/ Mixed Understory	1.00
Mesic Shrub/Scrub	Meso-xeric Herbaceous	1.00
Mesic Shrub/Scrub	Meso-xeric Mixed	1.00
Mesic Shrub/Scrub	Meso-xeric Shrub/Scrub	0.00
Mesic Shrub/Scrub	Xeric Coniferous	1.00
Mesic Shrub/Scrub	Xeric Deciduous	1.00
Mesic Shrub/Scrub	Xeric Deciduous w/ Evergreen Understory	1.00
Mesic Shrub/Scrub	Xeric Deciduous w/ Mixed Understory	1.00
Mesic Shrub/Scrub	Xeric Herbaceous	1.00
Mesic Shrub/Scrub	Xeric Mixed	1.00
Mesic Shrub/Scrub	Xeric Shrub/Shrub	0.00
Meso-xeric Coniferous	Meso-xeric Deciduous	0.10
Meso-xeric Coniferous	Meso-xeric Deciduous w/ Evergreen Understory	0.75
Meso-xeric Coniferous	Meso-xeric Deciduous w/ Mixed Understory	0.50
Meso-xeric Coniferous	Meso-xeric Herbaceous	1.00
Meso-xeric Coniferous	Meso-xeric Mixed	0.05
Meso-xeric Coniferous	Meso-xeric Shrub/Scrub	1.00
Meso-xeric Coniferous	Xeric Coniferous	0.00

Appendix B. Continued.

Cover Type A	Cover Type B	Edge Weight
Meso-xeric Coniferous	Xeric Deciduous	0.10
Meso-xeric Coniferous	Xeric Deciduous w/ Evergreen Understory	0.75
Meso-xeric Coniferous	Xeric Deciduous w/ Mixed Understory	0.50
Meso-xeric Coniferous	Xeric Herbaceous	1.00
Meso-xeric Coniferous	Xeric Mixed	0.05
Meso-xeric Coniferous	Xeric Shrub/Shrub	1.00
Meso-xeric Deciduous	Meso-xeric Deciduous w/ Evergreen Understory	0.75
Meso-xeric Deciduous	Meso-xeric Deciduous w/ Mixed Understory	0.50
Meso-xeric Deciduous	Meso-xeric Herbaceous	1.00
Meso-xeric Deciduous	Meso-xeric Mixed	0.05
Meso-xeric Deciduous	Meso-xeric Shrub/Scrub	1.00
Meso-xeric Deciduous	Xeric Coniferous	0.10
Meso-xeric Deciduous	Xeric Deciduous	0.00
Meso-xeric Deciduous	Xeric Deciduous w/ Evergreen Understory	0.75
Meso-xeric Deciduous	Xeric Deciduous w/ Mixed Understory	0.50
Meso-xeric Deciduous	Xeric Herbaceous	1.00
Meso-xeric Deciduous	Xeric Mixed	0.05
Meso-xeric Deciduous	Xeric Shrub/Shrub	1.00
Meso-xeric Deciduous w/ Evergreen Understory	Meso-xeric Deciduous w/ Mixed Understory	0.50
Meso-xeric Deciduous w/ Evergreen Understory	Meso-xeric Herbaceous	1.00
Meso-xeric Deciduous w/ Evergreen Understory	Meso-xeric Mixed	0.75
Meso-xeric Deciduous w/ Evergreen Understory	Meso-xeric Shrub/Scrub	1.00
Meso-xeric Deciduous w/ Evergreen Understory	Xeric Coniferous	0.75
Meso-xeric Deciduous w/ Evergreen Understory	Xeric Deciduous	0.75
Meso-xeric Deciduous w/ Evergreen Understory	Xeric Deciduous w/ Evergreen Understory	0.00
Meso-xeric Deciduous w/ Evergreen Understory	Xeric Deciduous w/ Mixed Understory	0.10
Meso-xeric Deciduous w/ Evergreen Understory	Xeric Herbaceous	1.00
Meso-xeric Deciduous w/ Evergreen Understory	Xeric Mixed	0.75
Meso-xeric Deciduous w/ Evergreen Understory	Xeric Shrub/Shrub	1.00
Meso-xeric Deciduous w/ Mixed Understory	Meso-xeric Herbaceous	1.00
Meso-xeric Deciduous w/ Mixed Understory	Meso-xeric Mixed	0.50
Meso-xeric Deciduous w/ Mixed Understory	Meso-xeric Shrub/Scrub	1.00
Meso-xeric Deciduous w/ Mixed Understory	Xeric Coniferous	0.50
Meso-xeric Deciduous w/ Mixed Understory	Xeric Deciduous	0.50
Meso-xeric Deciduous w/ Mixed Understory	Xeric Deciduous w/ Evergreen Understory	0.10
Meso-xeric Deciduous w/ Mixed Understory	Xeric Deciduous w/ Mixed Understory	0.00
Meso-xeric Deciduous w/ Mixed Understory	Xeric Herbaceous	1.00
Meso-xeric Deciduous w/ Mixed Understory	Xeric Mixed	0.50
Meso-xeric Deciduous w/ Mixed Understory	Xeric Shrub/Shrub	1.00
Meso-xeric Herbaceous	Meso-xeric Mixed	1.00
Meso-xeric Herbaceous	Meso-xeric Shrub/Scrub	1.00
Meso-xeric Herbaceous	Xeric Coniferous	1.00
Meso-xeric Herbaceous	Xeric Deciduous	1.00
Meso-xeric Herbaceous	Xeric Deciduous w/ Evergreen Understory	1.00
Meso-xeric Herbaceous	Xeric Deciduous w/ Mixed Understory	1.00
Meso-xeric Herbaceous	Xeric Herbaceous	0.00
Meso-xeric Herbaceous	Xeric Mixed	1.00
Meso-xeric Herbaceous	Xeric Shrub/Shrub	1.00
Meso-xeric Mixed	Meso-xeric Shrub/Scrub	1.00

Appendix B. Continued.

Cover Type A	Cover Type B	Edge Weight
Meso-xeric Mixed	Xeric Coniferous	0.05
Meso-xeric Mixed	Xeric Deciduous	0.05
Meso-xeric Mixed	Xeric Deciduous w/ Evergreen Understory	0.75
Meso-xeric Mixed	Xeric Deciduous w/ Mixed Understory	0.50
Meso-xeric Mixed	Xeric Herbaceous	1.00
Meso-xeric Mixed	Xeric Mixed	0.00
Meso-xeric Mixed	Xeric Shrub/Shrub	1.00
Meso-xeric Shrub/Scrub	Xeric Coniferous	1.00
Meso-xeric Shrub/Scrub	Xeric Deciduous	1.00
Meso-xeric Shrub/Scrub	Xeric Deciduous w/ Evergreen Understory	1.00
Meso-xeric Shrub/Scrub	Xeric Deciduous w/ Mixed Understory	1.00
Meso-xeric Shrub/Scrub	Xeric Herbaceous	1.00
Meso-xeric Shrub/Scrub	Xeric Mixed	1.00
Meso-xeric Shrub/Scrub	Xeric Shrub/Shrub	0.00
Xeric Coniferous	Xeric Deciduous	0.10
Xeric Coniferous	Xeric Deciduous w/ Evergreen Understory	0.75
Xeric Coniferous	Xeric Deciduous w/ Mixed Understory	0.50
Xeric Coniferous	Xeric Herbaceous	1.00
Xeric Coniferous	Xeric Mixed	0.05
Xeric Coniferous	Xeric Shrub/Shrub	1.00
Xeric Deciduous	Xeric Deciduous w/ Evergreen Understory	0.75
Xeric Deciduous	Xeric Deciduous w/ Mixed Understory	0.50
Xeric Deciduous	Xeric Herbaceous	1.00
Xeric Deciduous	Xeric Mixed	0.05
Xeric Deciduous	Xeric Shrub/Shrub	1.00
Xeric Deciduous w/ Evergreen Understory	Xeric Deciduous w/ Mixed Understory	0.10
Xeric Deciduous w/ Evergreen Understory	Xeric Herbaceous	1.00
Xeric Deciduous w/ Evergreen Understory	Xeric Mixed	0.75
Xeric Deciduous w/ Evergreen Understory	Xeric Shrub/Shrub	1.00
Xeric Deciduous w/ Mixed Understory	Xeric Herbaceous	1.00
Xeric Deciduous w/ Mixed Understory	Xeric Mixed	0.75
Xeric Deciduous w/ Mixed Understory	Xeric Shrub/Shrub	1.00
Xeric Herbaceous	Xeric Mixed	1.00
Xeric Herbaceous	Xeric Shrub/Shrub	1.00
Xeric Mixed	Xeric Shrub/Shrub	1.00

Appendix C. Correlation matrix for all landscape metrics used in regression or landscape characteristic selection analyses.

	Number of Patches/ha	Largest Patch Index	Mean Patch Size	Mean Shape Index	Area Weighted Mean Shape Index	Total Core Area Index	Mean Core Area Index	Patch Size Standard Deviation
Largest Patch Index	-0.469							
Mean Patch Size	-0.904	0.296						
Mean Shape Index	-0.730	0.096	0.673					
Area Weighted Mean Shape Index	-0.671	0.448	0.712	0.719				
Total Core Area Index	-0.792	0.543	0.804	0.308	0.447			
Mean Core Area Index	-0.843	0.383	0.911	0.435	0.507	0.921		
Patch Size Standard Deviation	-0.881	0.387	0.975	0.643	0.789	0.835	0.886	
Mean Nearest Neighbor Distance	-0.393	0.209	0.269	0.091	0.169	0.407	0.383	0.321
Cover Types/ha	0.783	-0.413	-0.718	-0.777	-0.650	-0.502	-0.579	-0.693
Shannon's Diversity Index	0.785	-0.648	-0.793	-0.446	-0.619	-0.738	-0.795	-0.782
Contrast Weighted Edge Density	0.574	-0.129	-0.698	-0.492	-0.544	-0.398	-0.560	-0.668
Total Edge Contrast Index	-0.001	0.331	-0.294	-0.235	-0.349	0.107	-0.032	-0.289
Total%EU	0.630	-0.507	-0.595	-0.449	-0.507	-0.578	-0.525	-0.629
Total%MU	0.741	-0.534	-0.605	-0.460	-0.527	-0.568	-0.611	-0.621
%Clearcut	-0.003	0.298	-0.174	-0.465	-0.465	0.302	0.129	-0.154

Appendix C. Continued

	Mean Nearest Neighbor Distance	Cover Types/ha	Shannon's Diversity Index	Contrast Weighted Edge Density	Total Edge Contrast Index	Total%EU	Total%MU
Cover Types/ha	-0.088						
Shannon's Diversity Index	-0.217	0.772					
Contrast Weighted Edge Density	-0.218	0.723	0.696				
Total Edge Contrast Index	0.188	0.283	0.146	0.695			
Total%EU	-0.311	0.747	0.723	0.681	0.255		
Total%MU	-0.351	0.597	0.628	0.408	-0.100	0.371	
%Clearcut	0.324	0.396	0.068	0.527	0.806	0.150	-0.124

Appendix D. Values of all landscape metrics used in the regression and landscape selection analyses for each bird and for the study area.

Bird ID	Sex	Age at Capture	Home Range(ha)	Number Patches/ha	Largest Patch Index	Mean Patch Size	Mean Shape Index	Area Weighted Mean Shape Index	Total Core Area Index	Mean Core Area Index
1513	F	A	17.8	2.978	16.500	0.340	1.209	1.387	1.500	0.181
1891	F	A	35.0	1.800	24.165	0.556	1.258	1.546	6.741	0.479
1252	F	A	46.0	2.848	18.235	0.350	1.246	1.567	4.031	0.169
1283	F	A	56.7	0.670	32.911	1.497	1.285	2.144	19.937	2.162
924	F	A	91.2	0.921	25.440	1.095	1.334	2.385	10.796	1.125
903	F	J	26.2	2.176	27.551	0.464	1.260	1.636	3.212	0.205
1832	M	A	8.3	3.253	20.430	0.310	1.253	1.511	0.000	0.000
1103	M	A	10.1	2.574	32.456	0.395	1.235	1.536	0.195	0.027
1793	M	A	17.3	1.445	28.205	0.702	1.275	1.502	9.003	1.322
333	M	A	18.9	1.905	42.254	0.533	1.258	1.836	7.668	0.673
92	M	A	31.2	3.141	20.115	0.320	1.247	1.667	0.287	0.014
612	M	A	34.0	2.735	23.810	0.366	1.228	1.477	5.585	0.252
1063	M	A	35.6	1.685	23.940	0.602	1.265	1.556	7.204	0.503
1633	M	J	12.5	1.520	69.504	0.668	1.282	2.373	7.407	0.562
1971	M	J	16.2	2.284	49.451	0.443	1.224	1.591	11.111	0.606
1452	M	J	17.2	2.384	43.979	0.419	1.213	1.406	12.449	0.691
1313	M	J	21.8	2.431	18.107	0.413	1.271	1.540	0.777	0.081
870	M	J	22.0	2.182	27.273	0.495	1.274	1.757	2.104	0.168
1232	M	J	37.4	1.364	32.464	0.745	1.325	1.896	9.005	0.673
1871	M	J	38.2	1.204	34.346	0.837	1.327	1.843	8.307	0.745
1533	M	J	41.0	2.659	16.300	0.375	1.258	1.582	0.734	0.077
1333	M	J	53.8	2.955	12.126	0.341	1.253	1.610	0.314	0.031
703	M	J	77.3	2.911	9.222	0.334	1.258	1.747	0.226	0.018
	Average across study area			1.002	52.921	1.393	1.337	2.083	14.726	1.356

Appendix D. Continued

Bird ID	Sex	Age at Capture	Home Range(ha)	Patch Size Standard Deviation	Mean Nearest Neighbor Distance	Cover Types/ha	Shannon's Diversity Index	Contrast Weighted Edge Density	Total Edge Contrast Index	Total%EU
1513	F	A	17.8	0.570	121.503	0.591	2.026	42.500	18.613	16.5
1891	F	A	35.0	1.205	129.436	0.591	1.849	80.848	45.144	15.2
1252	F	A	46.0	0.832	95.553	0.591	2.131	98.170	34.930	34.9
1283	F	A	56.7	4.157	102.144	0.318	0.690	4.430	4.421	0.6
924	F	A	91.2	3.440	141.580	0.364	1.474	33.464	22.017	2.3
903	F	J	26.2	1.049	100.518	0.364	1.429	33.673	18.333	8.8
1832	M	A	8.3	0.412	74.068	0.545	1.784	72.222	25.188	9.7
1103	M	A	10.1	0.721	72.039	0.591	1.826	93.275	40.897	32.5
1793	M	A	17.3	1.373	121.456	0.455	1.392	71.368	61.397	31.3
333	M	A	18.9	1.458	143.349	0.455	1.614	63.380	38.208	6.1
92	M	A	31.2	0.684	91.542	0.682	2.179	85.057	28.738	44.5
612	M	A	34.0	0.901	83.783	0.591	2.101	98.854	38.000	29.6
1063	M	A	35.6	1.262	114.157	0.591	1.996	95.012	48.432	28.9
1633	M	J	12.5	1.989	95.325	0.364	1.152	61.466	37.681	9.9
1971	M	J	16.2	1.360	145.839	0.591	1.560	90.751	52.713	12.1
1452	M	J	17.2	1.171	104.577	0.591	1.731	85.428	50.990	19.4
1313	M	J	21.8	0.686	96.130	0.455	1.954	69.479	30.512	35.4
870	M	J	22.0	1.073	112.471	0.455	1.511	52.588	27.222	15.2
1232	M	J	37.4	1.890	78.428	0.273	1.572	69.708	40.297	0.9
1871	M	J	38.2	2.153	117.504	0.318	1.580	40.109	24.408	6.3
1533	M	J	41.0	0.775	91.578	0.545	2.107	58.664	22.381	18.9
1333	M	J	53.8	0.656	109.608	0.591	2.260	95.210	31.667	35.9
703	M	J	77.3	0.716	93.188	0.682	2.222	85.848	27.016	45.5
Average across study area				3.872	93.390	0.337	1.140	32.324	19.943	10.8

Appendix D. Continued

Bird ID	Sex	Age at Capture	Home Range(ha)	Total%MU	%Clearcut
1513	F	A	17.8	17.5	3.0
1891	F	A	35.0	13.6	35.2
1252	F	A	46.0	15.9	18.2
1283	F	A	56.7	0.6	0.0
924	F	A	91.2	5.0	0.0
903	F	J	26.2	5.8	0.0
1832	M	A	8.3	34.4	0.0
1103	M	A	10.1	4.4	32.5
1793	M	A	17.3	1.5	37.9
333	M	A	18.9	3.3	21.1
92	M	A	31.2	13.8	4.3
612	M	A	34.0	21.2	23.8
1063	M	A	35.6	14.7	27.4
1633	M	J	12.5	3.5	0.0
1971	M	J	16.2	6.0	49.5
1452	M	J	17.2	11.5	46.6
1313	M	J	21.8	15.6	0.0
870	M	J	22.0	11.4	0.0
1232	M	J	37.4	2.4	0.0
1871	M	J	38.2	3.0	9.6
1533	M	J	41.0	11.7	6.8
1333	M	J	53.8	14.5	4.2
703	M	J	77.3	15.4	2.4
Average across study area				6.0	0.5

Vita

Todd M. Fearer was born in Oakland, MD on July 28, 1973. After graduating from Southern Garrett High School in 1991, he attended The Pennsylvania State University for four and a half years. While at Penn State, he was a member of the Penn State Ski Team and served as the team's treasurer, president, and assistant coach. He also worked as a technician in the Penn State Cooperative Wetlands Center where he conducted a pilot study investigating the feasibility of using amphibians as ecological indicators of wetland health. He also assisted with a project investigating the feasibility of using birds for the same purpose, as well as a project investigating bird use of beaver ponds. He graduated from Penn State in December of 1995 with a Bachelor of Science degree in Wildlife and Fisheries Science and minors in Forestry Science and International Agriculture. He remained at Penn State through the spring of 1996 working as a research assistant in the Department of Geography. In the summer of 1996, he began his work as a graduate research assistant at Virginia Polytechnic Institute and State University, where he pursued a Master of Science degree in Wildlife Sciences. His research was part of the Appalachian Cooperative Research Project. While at Virginia Tech, he was active in their chapter of the Wildlife Society, and served as vice president from August 1997 – May 1998. He received his Master of Science degree in June of 1999.