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ARTHROPOD AVAILABILITY
IN RELATION TO RUFFED GROUSE BROOD HABITAT
IN THE SOUTHERN APPALACHIANS

A Thesis

Presented for the

Master of Science

Degree

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B. Kip Hollifield

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ABSTRACT

Arthropod availability to ruffed grouse (*Bonasa umbellus*) chicks was studied by sweep netting on 6 habitats considered to be brood range in the Cherokee National Forest, Tennessee. The objectives of the study were: (1) determine the abundance, biomass, and taxa of arthropods collected in these habitats, and (2) determine which forest management practices are most beneficial to ruffed grouse chicks in terms of arthropod production and vegetative structure. Arthropod abundance was highest on managed logging roads and in mature hardwood with herbaceous ground cover, while arthropod biomass was highest on managed logging roads. Managed logging roads were sowed and maintained in clover and/or orchard grass. Young clearcuts (< 3 years old) were least productive of arthropods. Arthropods representing taxa preferred by chicks were most abundant on managed logging roads and in mature hardwood with herbaceous ground cover. No significant differences were determined in arthropod abundance or biomass between unmanaged logging roads traversing mature hardwood and unmanaged logging roads passing through clearcuts. Managed logging roads planted to clover were more productive than those planted to orchard grass in terms of arthropod abundance and biomass. Arthropods from the taxa preferred by chicks were more

abundant on roads where clover was the principal vegetative component. Maintenance of ruffed grouse chicks should be highest where optimal cover (areas of high woody stem density) is located near habitat productive for arthropods.

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CHAPTER I

INTRODUCTION

In the southern part of their range ruffed grouse (*Bonasa umbellus*) are generally limited to landforms associated with the Appalachian Mountains. The southern portion is considered to be south of the range of aspen (*Populus spp.*) (Figure 1). Ruffed grouse density in this area generally is not as high as in the northern portion of the birds' range, yet populations are dense enough to allow a liberal hunting season in most locations where ruffed grouse occur.

Ruffed grouse ecology has been extensively investigated in the northern portions of the species' range. Comparatively little research, however, has been done concerning ruffed grouse ecology in the southern portion. Aspects of ruffed grouse restoration attempts in western Tennessee were investigated by White and Dimmick (1978), Jones (1979), Gudlin and Dimmick (1984), and Kalla and Dimmick (1987). Nutritional quality of ruffed grouse diets in the Southeast were studied by Norman and Kirkpatrick (1984) and Servello and Kirkpatrick (1987). Food habits in the southern Appalachians during fall and winter were described by Stafford and Dimmick (1979) and Seehorn et al. (1981). The

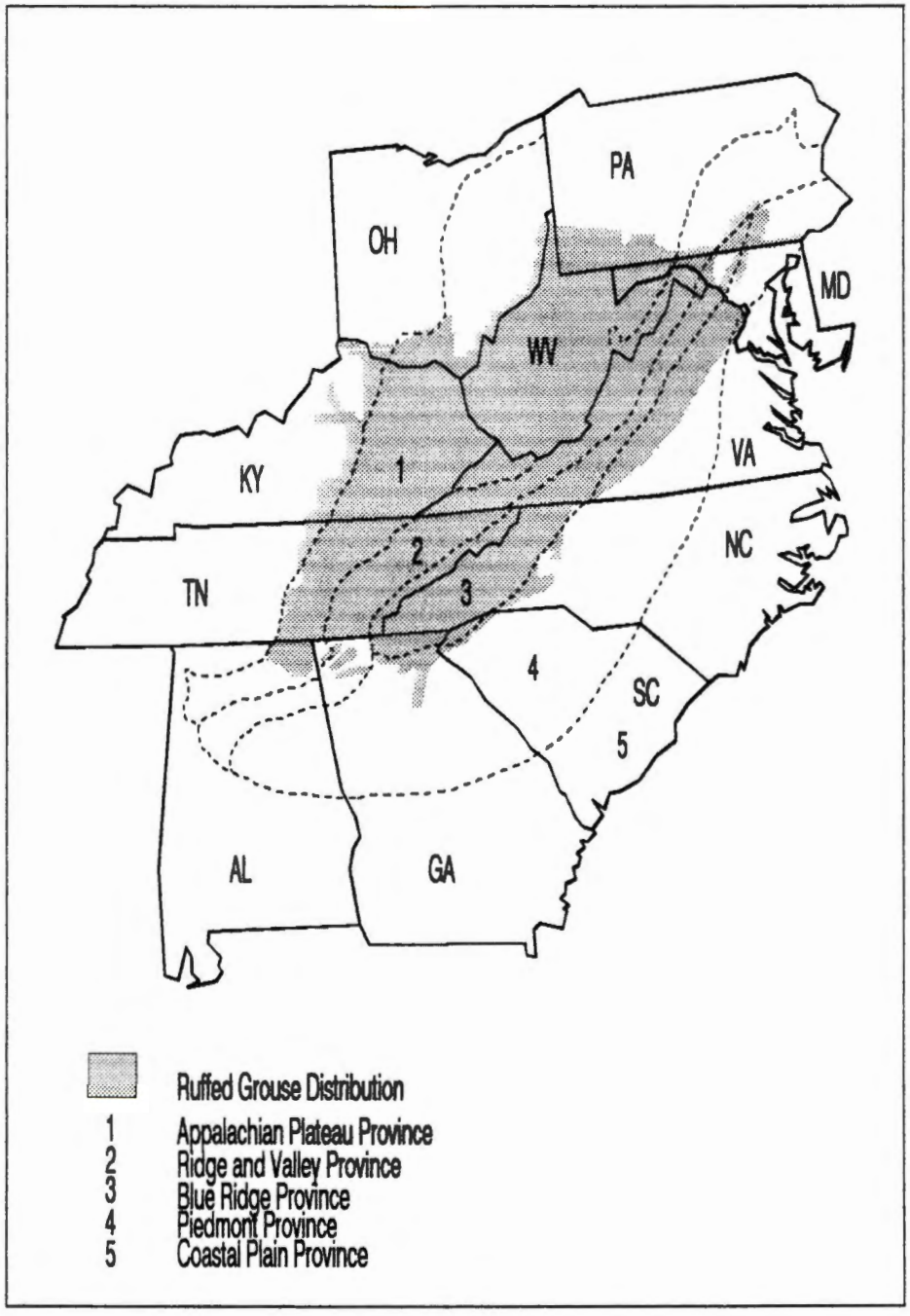

Figure 1. Distribution of ruffed grouse south of the range of aspen with respect to physiographic province (Cole and Dimmick 1991. In press.)

physical characteristics of drumming sites and logs were investigated in Tennessee (Taylor 1976) and Georgia (Hale et al. 1982). General ecology of ruffed grouse on the Cumberland Plateau in Tennessee was described by Longwitz (1985) and Epperson (1988). Population density and habitat utilization (Boyd 1990) and daily movement patterns (Pelren 1991) were studied in the Cherokee National Forest in Tennessee.

Few studies have dealt with ruffed grouse brood ecology. In Virginia, broods preferred moist forests with abundant edge habitat (Stewart 1956). In Missouri, Thompson et al. (1987) observed that understories providing both cover and food were an important component of brood habitat. Feeding rates of juvenile ruffed grouse in West Virginia were highest in old fields and lowest on mined land replanted to locust (*Robina spp.*) (Kimmel and Samuel 1984).

Habitat preferred by grouse broods in the northern portion of their continental range consists of aspen stands with stem densities ranging from 19,000 to 25,000 stems/ha (Gullion and Svoboda 1972, Gullion 1977). In the southern Appalachians, aspen occurs very infrequently. However, regenerating clearcuts provide areas of high stem density.

Availability of arthropods is of great importance for the proper maintenance of grouse chicks. The diet of chicks up to 3 weeks of age is made up of more than 90%

invertebrates, and invertebrates remain predominate in their diet for 5 weeks after hatching (Kimmel and Samuel 1984). Stewart (1956) reported that the diet of ruffed grouse chicks changes from one composed mainly of insects in June to one composed chiefly of plant foods in July and August.

Specific food habits of ruffed grouse chicks have been documented. Bump et al. (1947), Stewart (1956), and Kimmel and Samuel (1984) found that insects from the orders Hymenoptera, Coleoptera, and Homoptera were favored by grouse chicks.

Although food habits of grouse chicks are documented, research to quantify arthropod availability in brood habitat is lacking. Berner and Gysel (1969) concluded that brood range was the most important component of ruffed grouse habitat and that brood habitat management is excellent grouse management. An understanding of which habitats and forest management practices provide good supplies of arthropods as well as adequate cover should prove useful to natural resource personnel in planning management strategies. While this research was designed primarily to gain better understanding of ruffed grouse brood habitat, it is also relevant to wild turkey (*Meleagris gallapavo*) habitat. The two species overlap in habitat preference and range to a certain degree in the southern Appalachians. The major objectives of this study were:

1) to determine the abundance, biomass, and taxa of arthropods collected in different forest management conditions considered to be ruffed grouse brood range, and 2) to determine which forest management practices are most beneficial to ruffed grouse chicks in terms of arthropod production and vegetative structure.

CHAPTER II

DESCRIPTION OF STUDY AREAS

A variety of habitats available to ruffed grouse broods were selected for study. Habitats sampled for arthropod population characteristics included: (a) clearcuts of 3 age classes; (b) mature hardwood with herbaceous ground cover; (c) roads constructed to access areas of timber harvest. In this last category, logging roads managed as linear food plots were compared with those not managed as such.

The study was conducted in the Cherokee National Forest (CNF) in eastern Tennessee. The CNF extends along Tennessee's eastern border from Virginia to Georgia. It contains 252,455 hectares in 10 counties, and is split into southern and northern sections by Great Smoky Mountains National Park (Figure 2). The USDA Forest Service manages the land under a multiple use system which includes wildlife, water, timber, soils, minerals, cultural resources, wilderness, and outdoor recreation.

Most of the CNF lies within the Blue Ridge Province of Tennessee, with a small section falling in the Ridge and Valley Province (USDA Forest Service 1985). The topography is mountainous, with steep, narrow ridges drained by fast flowing streams. Elevation averages 915 m above mean sea

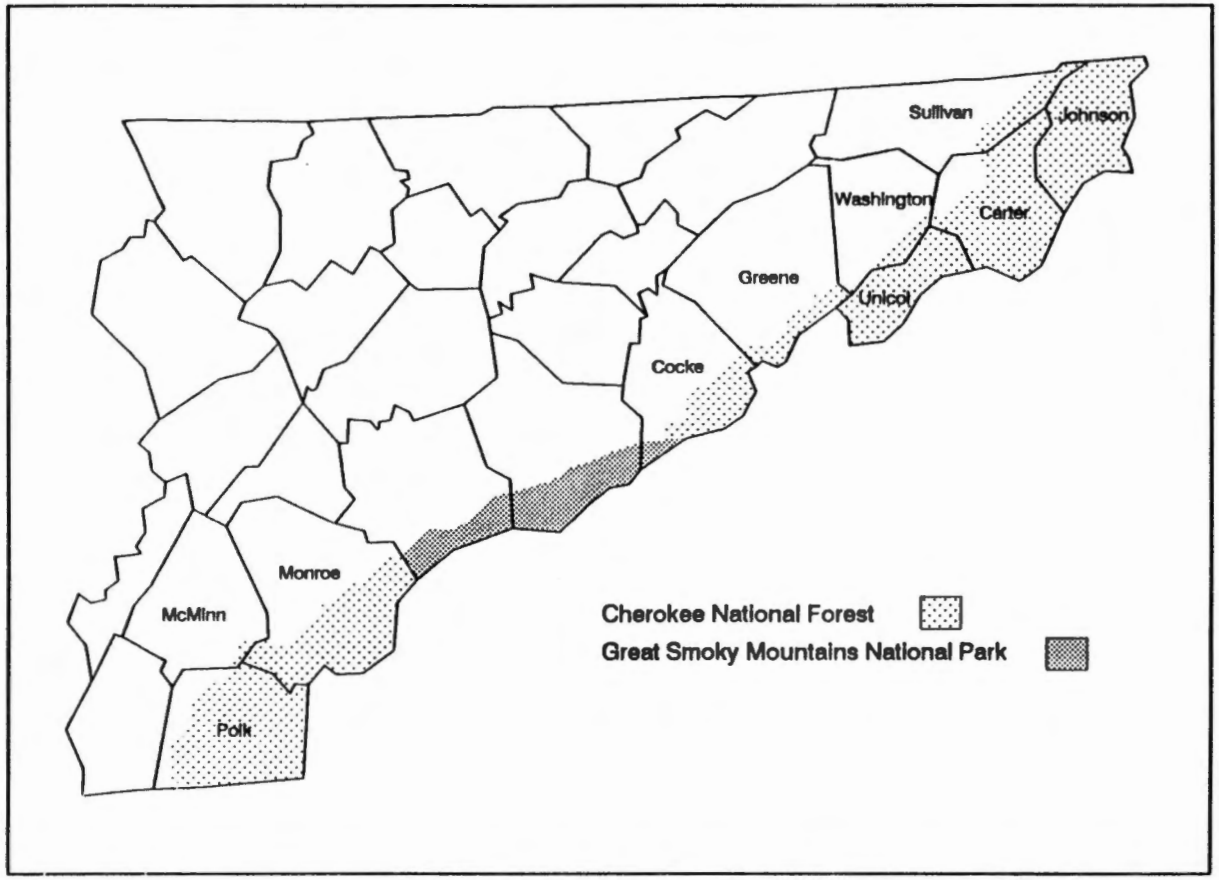

Figure 2. Location of the Cherokee National Forest and Great Smoky Mountains National Park in Eastern Tennessee.

level (ASL) and ranges from 305 to 1830 m ASL (USDA Forest Service 1985). The climate is classified as humid subtropical, which is characterized by having mean monthly temperatures which do not fall below -3°C, hot muggy summers, and relatively mild, yet unpredictable winters (Ahrens 1988). Mean yearly rainfall varies from 102 cm at lower elevations to greater than 190 cm at higher elevations (USDA Forest Service 1985).

The CNF supports a diverse community of plants and animals. Although hundreds of individual plant species are present, 5 major forest types are dominant in the region: cove hardwoods, oak-hickory, pine, mesic hemlock, and northern hardwoods (USDA Forest Service 1976). The forest provides habitat to approximately 150 species of birds, 140 species of fish, 43 species of mammals, 32 species of amphibians, and 23 species of reptiles (USDA Forest Service 1985). Wildlife is jointly managed by the USDA Forest Service and the Tennessee Wildlife Resources Agency (TWRA). Major game species include white-tailed deer (*Odocoileus virginianus*), black bear (*Ursus americanus*), wild turkey, wild boar (*Sus scrofa*), ruffed grouse, raccoon (*Procyon lotor*), and gray squirrel (*Sciurus carolinensis*). Streams in the locality support both stocked and self-sustaining populations of rainbow (*Oncorhychus mykiss*), brown (*Salmo*

trutta), and brook trout (*Salvelinus fontinalis*). The CNF was described in greater detail by Boyd (1990).

Study plots were established in the Tellico Ranger District in the southern zone and the Nolichucky Ranger District in the northern zone of the forest. Tellico District study plots were established in Big Cove and Sugar Cove along Forest Service Route 217 (Figure 3). Seven study plots, consisting of 3 class II clearcuts (age 5-12 years), 2 class III clearcuts (age 13-26 years), 1 mature hardwood plot, and 1 unmanaged logging road, were situated in Big Cove adjacent to North River (Figure 4). These plots were within Forest Service Compartments 81 and 417. Study plots in Sugar Cove included 3 class I clearcuts (age 1-4 years), 2 mature hardwood plots, 2 unmanaged logging roads, and 1 class III clearcut (Figure 5). All were within Forest Service Compartments 70, 79, and 80. In fall 1990 one unmanaged logging road in Sugar Cove was planted to clover. Consequently during the 1991 collection season this logging road was no longer unmanaged. It was subsequently replaced with an unmanaged logging road approximately 3 km east of the Big Cove study plots (Figure 6).

Nolichucky Ranger District plots were established in Houston Valley near State Route 107 (Figure 7). The plots consisted of 4 managed logging roads (Figure 8).

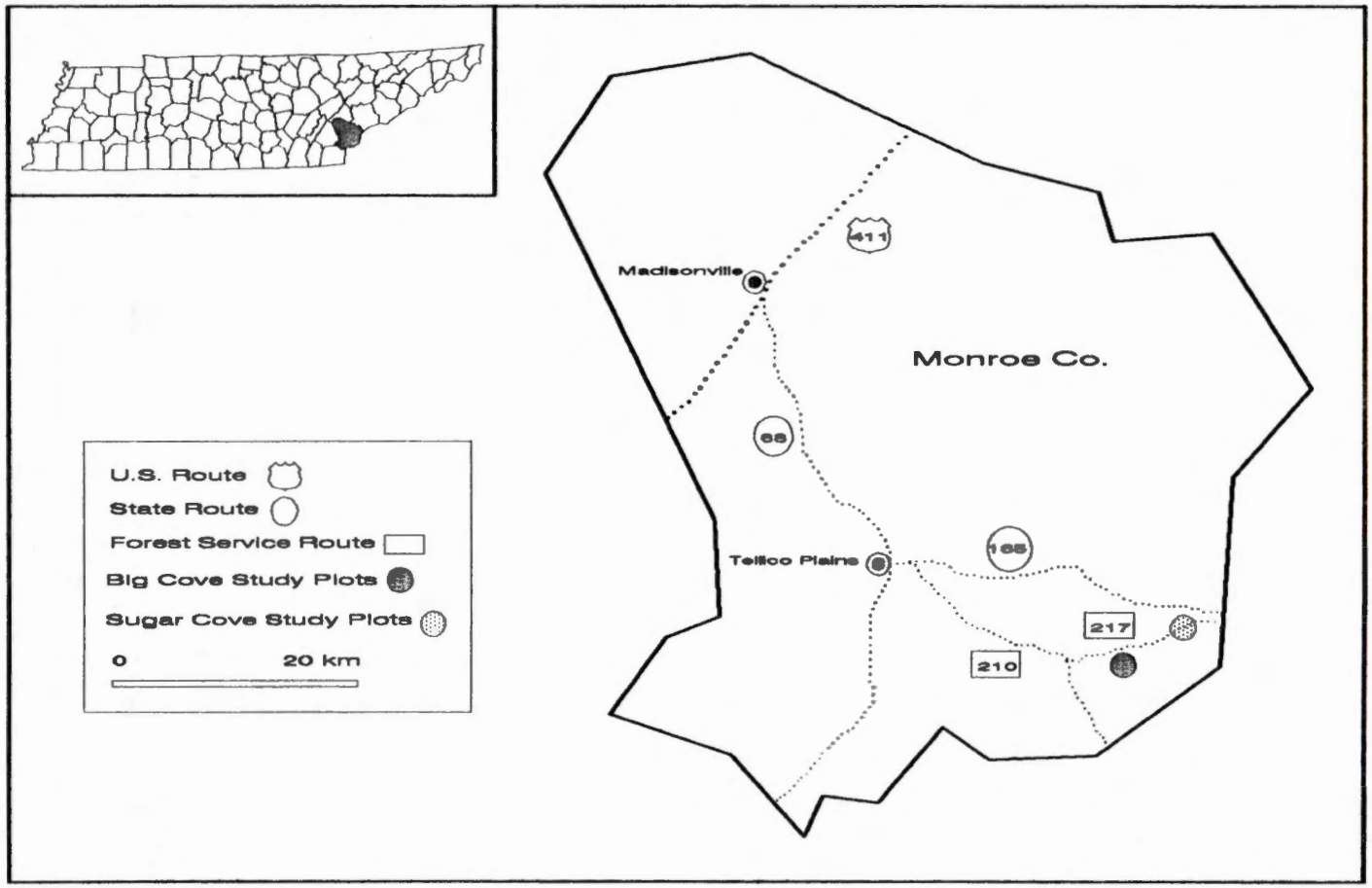

Figure 3. General location of Tellico Ranger District study plots, Cherokee National Forest, Monroe Co., Tennessee.

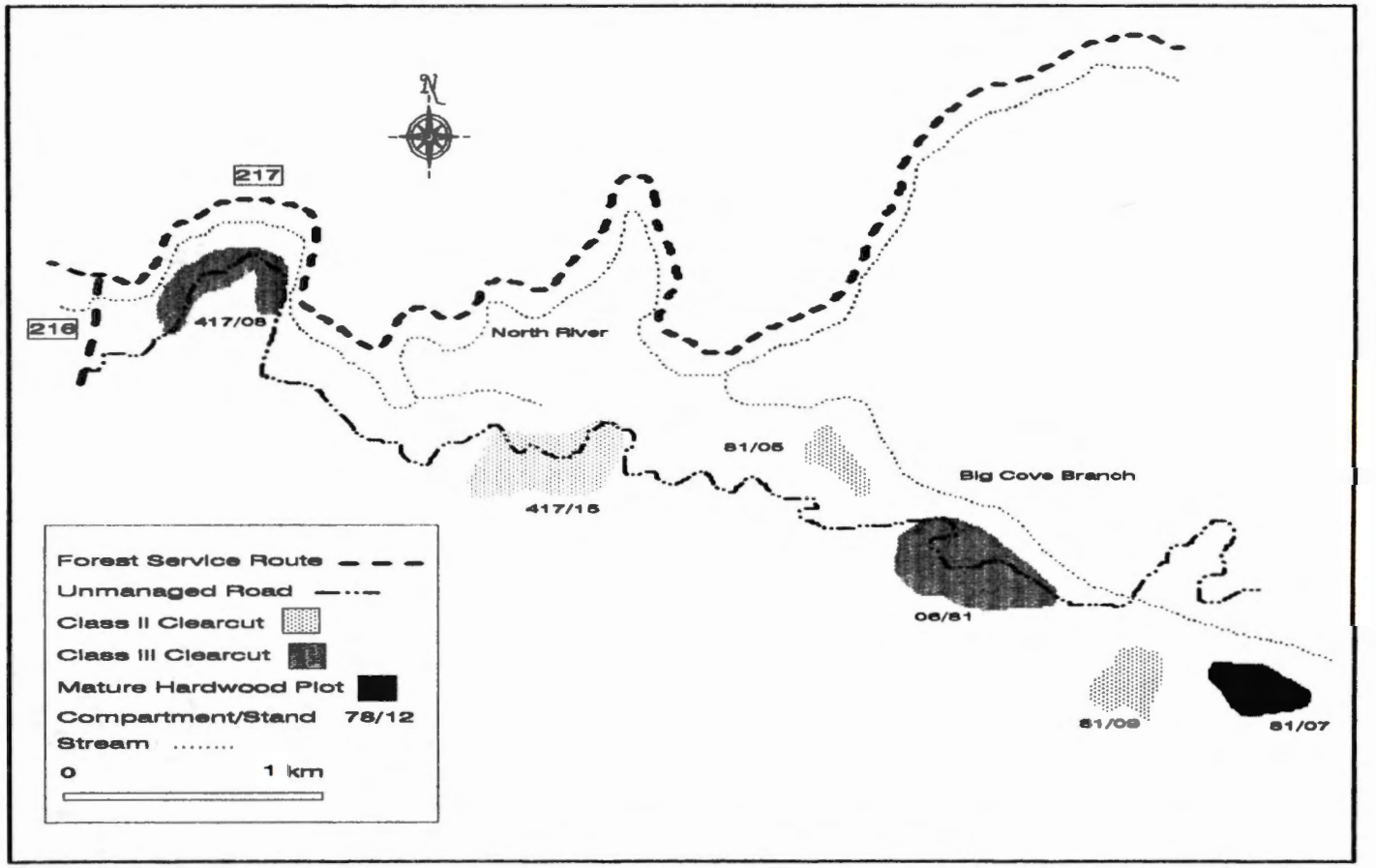

Figure 4. Location of Big Cove study plots, Tellico Ranger District, Cherokee National Forest, Monroe Co., Tennessee.

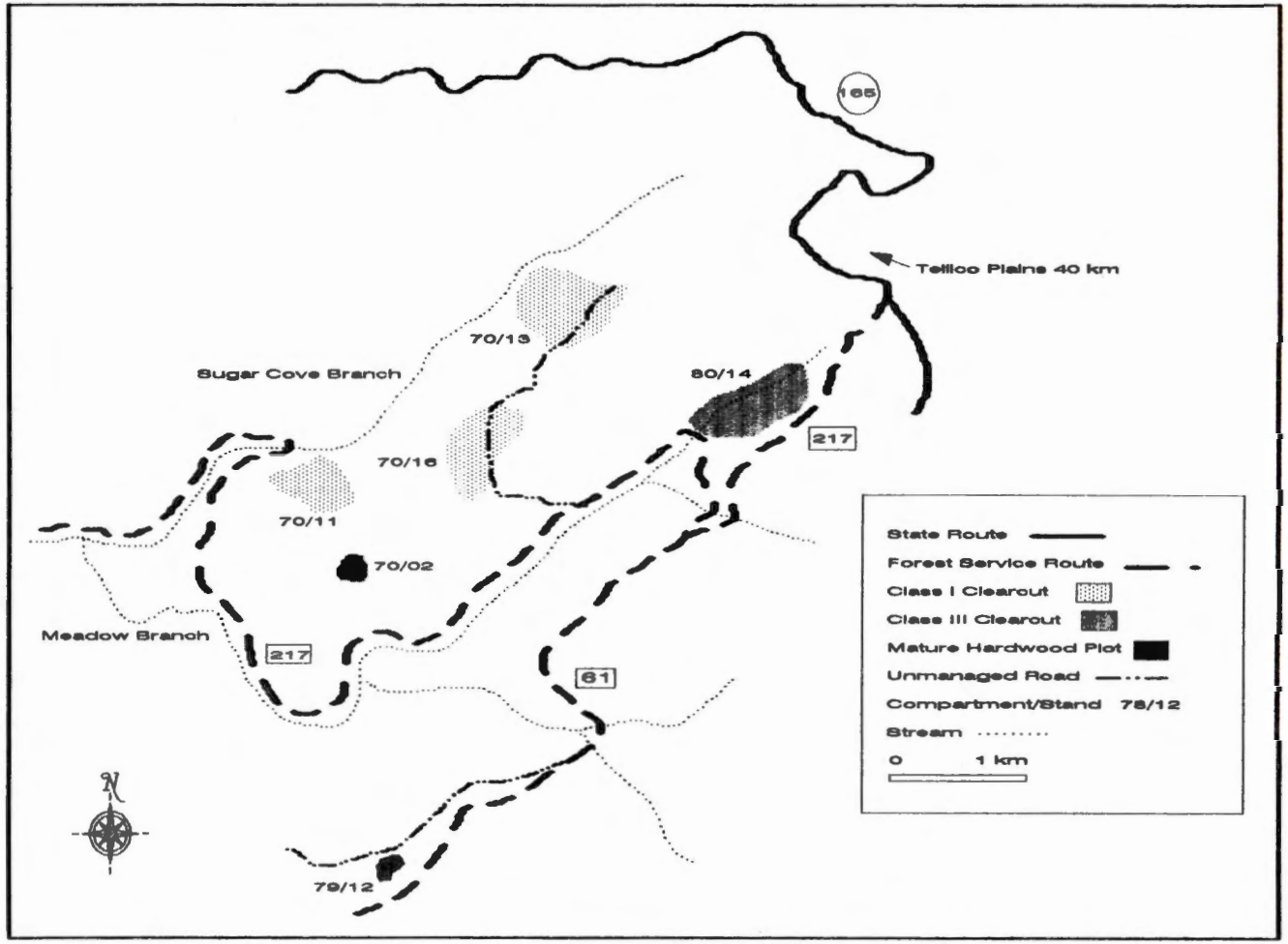

Figure 5. Location of Sugar Cove study plots, Tellico Ranger District, Cherokee National Forest, Monroe Co., Tennessee.

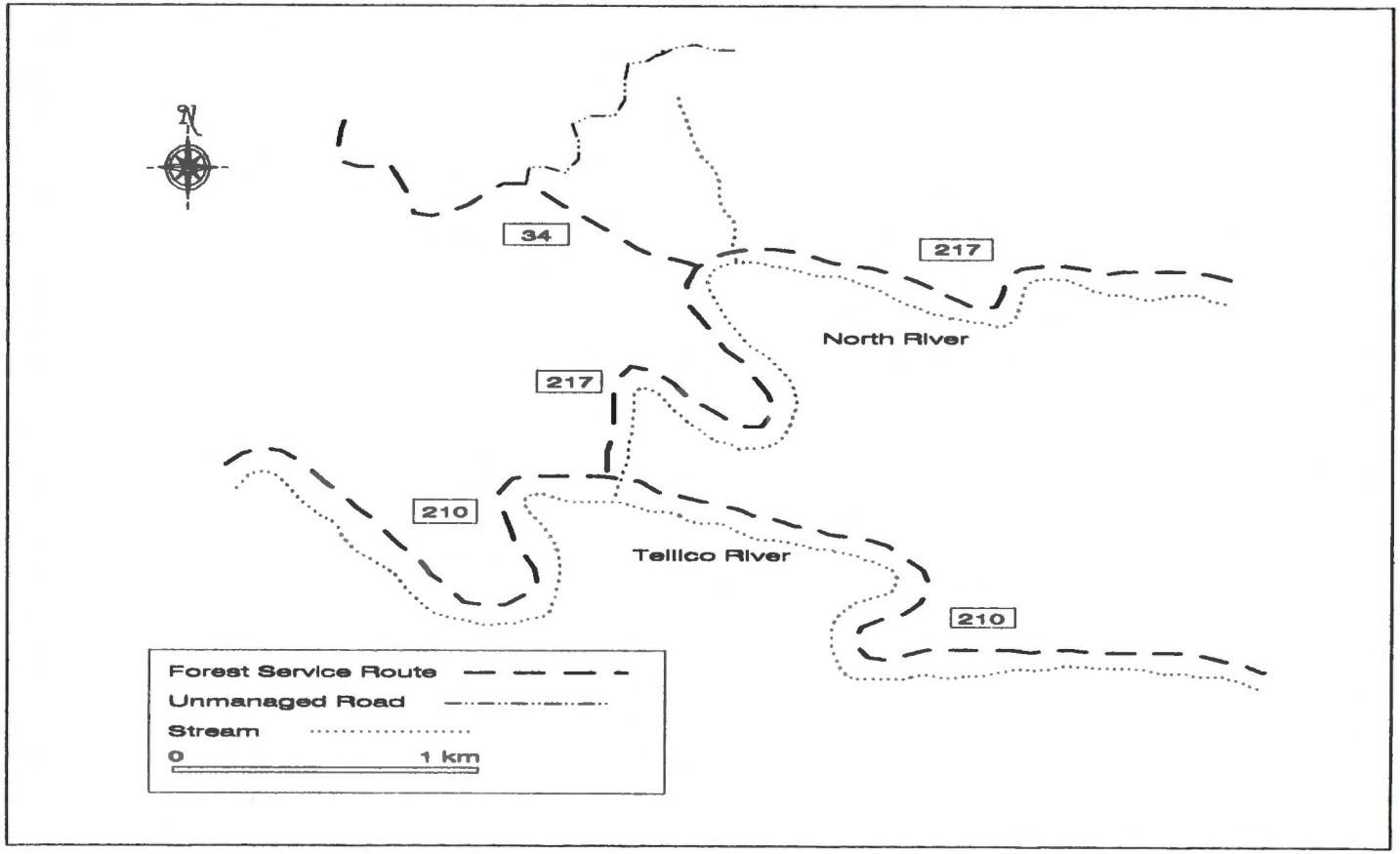

Figure 6. Location of replacement unmanaged road for the 1991 collection season, Tellico Ranger District, Cherokee National Forest, Monroe Co., Tennessee.

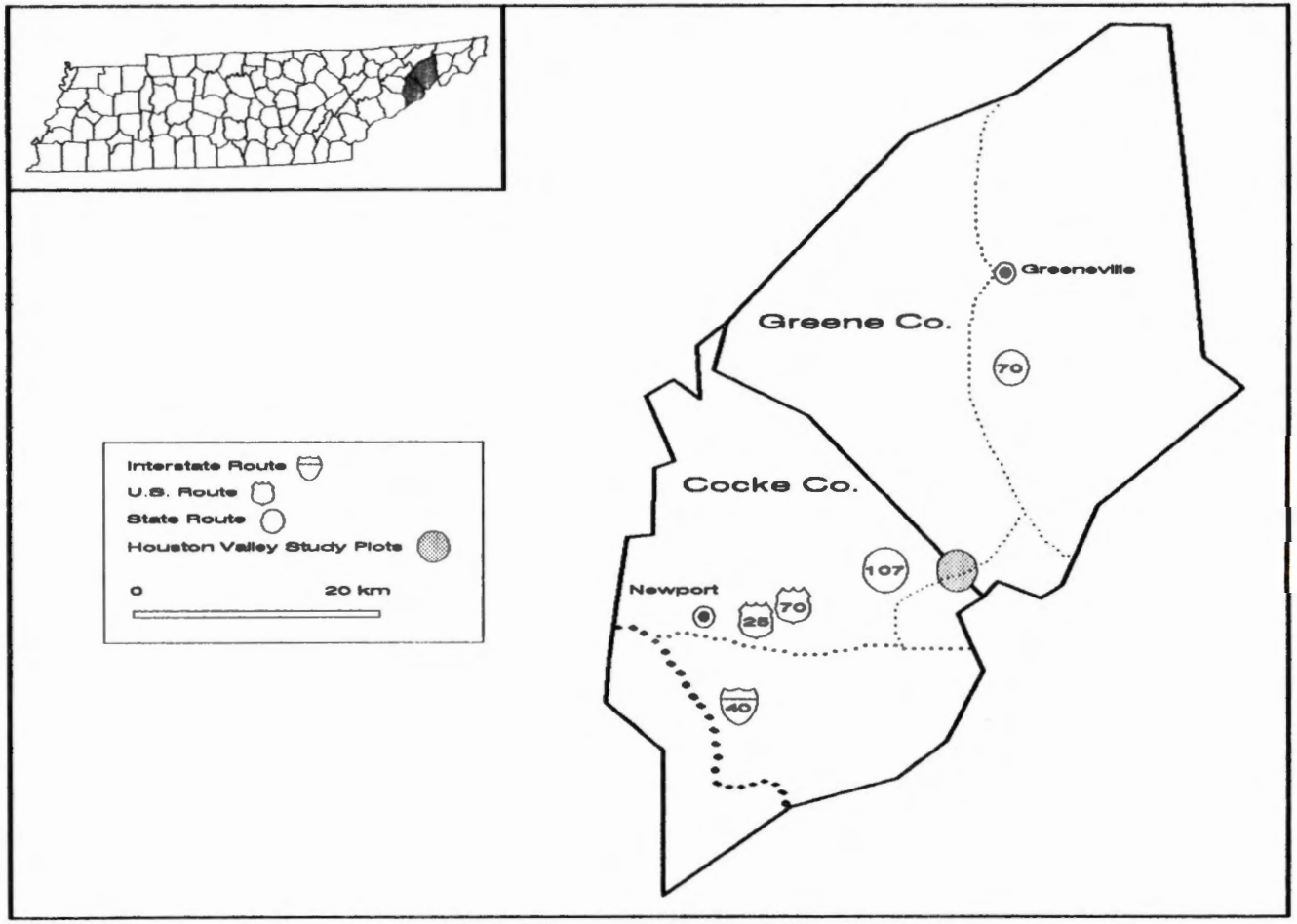

Figure 7. General Location of Nolichucky Ranger District study plots, Cherokee National Forest, Cocke and Greene Counties, Tennessee.

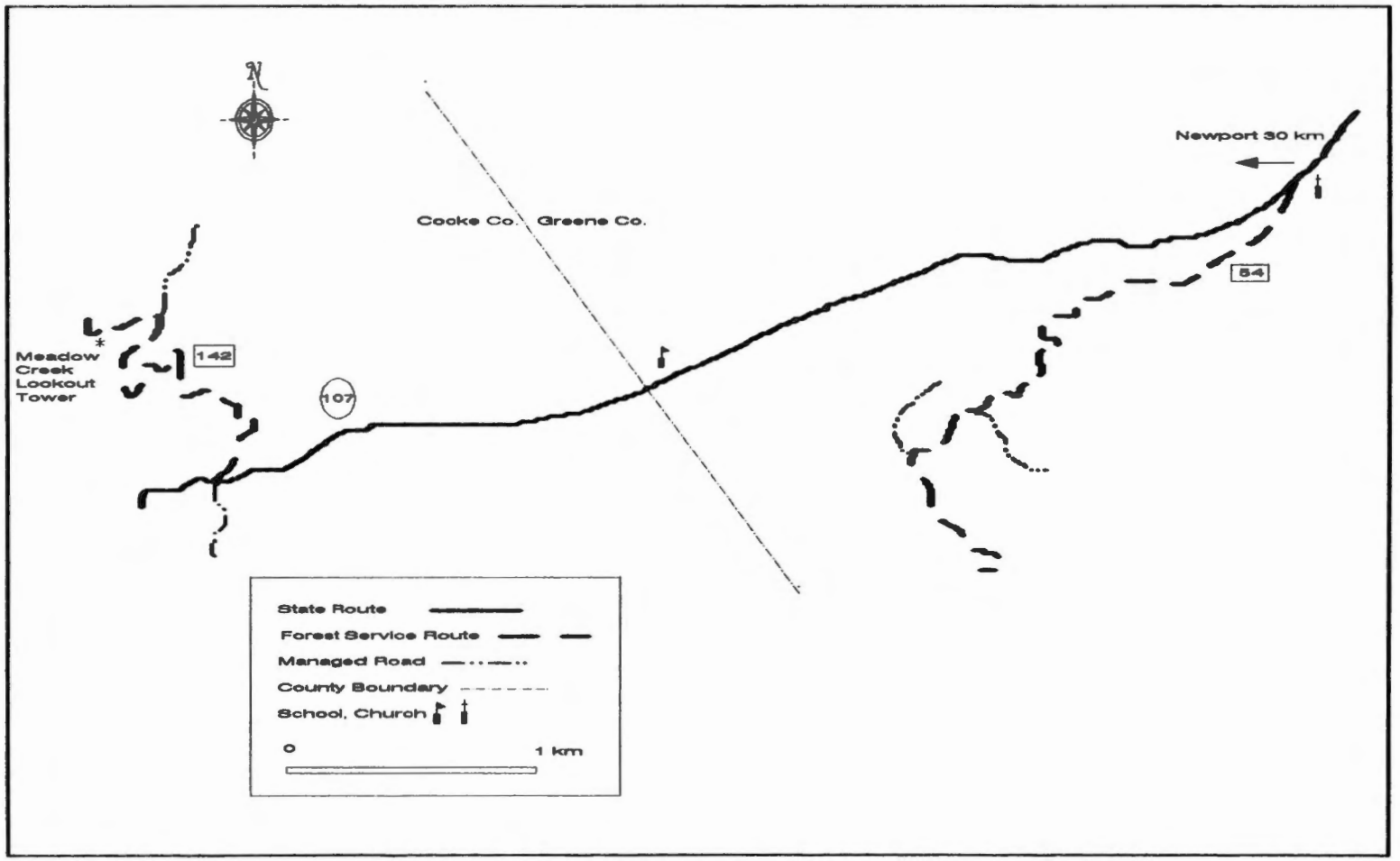

Figure 8. Location of Houston Valley study plots, Nolichucky Ranger District, Cherokee National Forest, Cocke and Greene Counties, Tennessee.

I. Class I Clearcuts

Class I clearcuts (1-4 years post timber harvest) were composed of stands 11, 13, and 16 of Compartment 70. Stands 13 and 16 were regenerated in 1988 and stand 11 in 1989. Prominent forest types were yellow poplar-white oak-northern red oak in stands 11 and 13 and sugar maple-beech-yellow birch in stand 16. Site indices are 120 for stands 11 and 13 and 80 for stand 16. Although some herbaceous vegetation was present on these plots, the principal flora consisted of blackberry (*Rubus spp.*), raspberry (*Rubus spp.*), and the regenerating overstory species. A variety of species were present, with yellow poplar (*Liriodendron tulipifera*), silverbell (*Halesia spp.*), black cherry (*Prunus serotina*), fire cherry (*P. pennsylvanica*), northern red oak (*Quercus rubra*), and sugar maple (*Acer saccharum*) well represented. Plots averaged 2.7 years in age and 12.9 ha in size (Table 4, Appendix A).

II. Class II Clearcuts

Class II clearcuts (5-12 years post timber harvest) included stands 5 and 9 of Compartment 81, and stand 15 of Compartment 417. Each stand was characterized as yellow poplar-white oak-northern red oak. Stands 5 and 9 were

harvested in 1982, stand 15 in 1979. Site indices are 100 for stands 5 and 9 and 90 for stand 15. Stands 9 and 15 had lush herbaceous understories, with horsemint (*Monarda spp.*), jewelweed (*Impatiens spp.*), blackberry, and various species of ferns frequently occurring. Understory in stand 5 was dominated by rhododendron (*Rhododendron spp.*), blackberry, and greenbriar (*Smilax spp.*). Grapes (*Vitis spp.*) were common in each clearcut. Size of class II clearcuts averaged 7.9 ha, with age averaging 9 years at the time of study (Table 4, Appendix A).

III. Class III Clearcuts

Class III clearcuts (13-26 years post timber harvest) included stand 6 of compartment 81, stand 8 of compartment 417, and stand 14 of compartment 80. Stand 6 was harvested in 1977, 8 in 1975, and 14 in 1965. Yellow poplar-white oak-northern red oak was the principal forest type in stands 6 and 8, while the sugar maple-beech-yellow birch type was characteristic of stand 14. Stands 6 and 8 have site indices of 100 and stand 14 a site index of 70. Herbaceous ground cover was abundant in stands 6 and 14 with horsemint, jewelweed, and blackberry comprising the primary components. Forbs occurred infrequently in stand 8, with rhododendron, greenbriar, and ferns constituting the principal understory

species. Grapes were common in stands 6 and 8. These clearcuts averaged 12.5 ha in size and 17.7 years in age (Table 4, Appendix A).

IV. Mature Hardwood Plots

All mature hardwood sites were characterized by rich herbaceous ground cover. Study plots were approximately 6 ha in size and were selected from portions of stand 2 in Compartment 70, stand 12 in Compartment 79, and stand 7 in Compartment 81. Stands 7 and 12 were classified as yellow poplar-white oak-northern red oak forest types. The primary forest type in stand 2 was white oak-northern red oak-hickory. Stand 2 has a site index of 80 and stands 7 and 12 site indices of 100. Common understory species in all plots were horsemint and jewelweed. Saplings were common in the midstory on all sites. Average age of these stands was 70 years (Table 4, Appendix A).

V. Unmanaged Logging Roads

Unmanaged logging roads intersected with either forest service routes 61, 216, or 217. A cover crop was planted on the logging roads after timber harvest was completed in areas they serviced, but due to a combination of occasional

vehicular use and/or lack of maintenance it had been replaced to a great extent by more vigorous endemic species. Principal vegetation on the logging roads included several species of annual weeds and fescue (*Festuca spp.*). Orchard grass (*Dactylis glomerata*) and clover (*Trifolium spp.*) also occurred in small quantities. Vegetation on road edges ranged from very dense in sections of roads traversing clearcuts to sparse in portions of roads dissecting mature hardwoods. Common species on the borders of roads included blackberry, raspberry, golden rod (*Soladago spp.*), and willow grass (*Microstegium vimenium*). Although gated, these roads received enough vehicular traffic to preclude vegetation growing in the tire ruts. Gravel still remained on some road sections placed there during previous timber harvesting operations.

VI. Managed Logging Roads

Two managed logging roads each were selected from Forest Service Routes 54 and 142. These roads were actively managed as linear food plots for wildlife. The primary vegetative components were either orchard grass, clover, or kobe lespedeza (*Lespedeza spp.*). Little transition zone was present between the logging roads and the adjacent forest. Where a transition zone occurred, primary flora included

annual weeds and saplings. All roads were gated, and they received minimal vehicular use.

CHAPTER III

MATERIALS AND METHODS

I. Collection of Arthropods

Study plots for each habitat type were sampled for arthropod abundance, biomass, and taxonomic structure. Unmanaged logging roads were sampled in a manner that allowed comparison of roads traversing clearcuts and roads traversing mature hardwood. Managed logging roads were sampled so that those dominated by clover could be compared with ones on which orchard grass was the principal vegetative component.

Arthropods were sampled during June. The sampling period coincided with the time when grouse chicks are most dependent on arthropods as a food source (Stewart 1956). Two methods were used to sample arthropod abundance and biomass. A sweep net with a hoop diameter of 38 cm and a bag depth of 77 cm was used to capture arthropods that reside on the vegetation. Pitfall traps with a diameter of 9.5 cm and a depth of 12 cm were used in 1990 only to collect arthropods that are predominately ground dwellers.

II. Sweep Net Sampling

The most practical method of sampling habitats was the sweep net. Sweep net sampling has been criticized for some of its limitations. Not all arthropods are captured at the same rate. Abundance of ground dwellers (Stuen and Spidso 1988) and very active insects such as leafhoppers and grasshoppers may be underestimated (DeLong 1932). Some species are better able to grasp the vegetation than others and thus are more likely to avoid capture (Whittaker 1952). Temperature affects the metabolic rate and the rapidity of the "flight" reaction in arthropods and could create a source of bias in estimates of abundance (DeLong 1932). Strong winds also negatively impact abundance of insects located on the vegetation (DeLong 1932). However, it is unlikely that either temperature or wind velocity significantly affected results of this study. Air temperature when samples were taken was usually near the 20-25°C range, which is optimal for many insects (Uvarov 1931), and high winds during June were local and associated with thunderstorms.

In lieu of these considerations relative rather than absolute abundance of the population is measured by sweep net sampling (Hillhouse and Petrie 1974). This is of little significance though as the objectives of the study were not

to measure number of arthropods per unit area, but to determine differences in abundance among various habitats.

Sweep net sampling is particularly suited for measuring abundance of arthropods available to gallinaceous chicks. Erikstad and Spidso (1982) postulated that willow grouse chicks forage for insects on the vegetation rather than on the ground. This is further substantiated by Healy (1985) who determined wild turkey poults feed mostly on insects found on plant leaves, rarely taking food items from the ground. Since a sweep net samples the vegetative rather than the ground layer it should give good estimates of the availability of arthropods to ruffed grouse chicks.

i. Forest Stands

Sweep net sampling occurred via transects. Samples were taken while walking. Thirty-five sweeps constituted one transect. One sweep consisted of one forehand or one backhand motion of the net. The net was swept as close to the ground as possible. After a transect was completed the contents of the net were emptied into a 20 x 40 cm plastic bag. A paper label with study plot information and the date written in waterproof ink was sealed inside the plastic bag. Samples were frozen until laboratory analysis could be

performed. Each study plot was sampled once weekly. Four transects/plot were taken on the day of sampling.

Starting points for transects were determined in the following manner. Maps of clearcuts and mature hardwood plots were overlaid with a numbered grid scaled in 20 m increments. For each study plot a known point of origin was established and served as reference point for sampling. A random number table was used to select the starting point for sweep net transects. The first number selected that coincided with a number on the grid and fell within the study plot was the x coordinate, and the second was the y coordinate.

When the starting point for a transect was reached the researcher faced uphill and selected another random number. If an odd number was selected the researcher sampled to the right of the starting point. If an even number was selected sampling occurred to the left of the starting point. All samples were taken while walking parallel with the contour.

ii. Logging Roads

Sweep net samples on logging roads followed a procedure similar to that described for forest stands. Starting points for transects were established as described in the following paragraphs.

Unmanaged logging roads were divided into segments. From the beginning of the road to the first clearcut was designated section 1. The section of the road that dissected the first clearcut was designated section 2, etc. On the day of sampling, 2 transects were taken from portions of the road that traversed clearcuts and 2 were taken from portions outside of clearcuts.

A random number table was used to select starting points for transects. When a number was reached that corresponded to a section of road designated on the map, another random number was selected. The first number represented a section number of the road and the second the number of paces from the proximal end of the section to where sampling began. The number of paces was selected so that sampling started at least 10 m from the beginning of the section and stopped no less than 10 m from the end of the segment. All sections to be sampled were determined prior to entering the road. Transects were run in sequence, starting with the one nearest the road entrance. This was done to avoid disturbing the vegetation and arthropods prior to sampling.

Starting points for sampling managed logging roads were determined in the following manner. Four random numbers between 010 and 100 were selected. The first number selected represented the number of paces from the entrance of the road where sampling began. The second number represented the

number of paces from the end of the first transect to where the second sample began. The starting points for transects 3 and 4 were reached in similar fashion.

III. Pitfall Sampling

Two pitfall traps were placed randomly on each study plot applying the technique used to determine starting points for transects in forest stands and logging roads. For unmanaged logging roads one pitfall each was placed in a section of the road passing through a clearcut and mature hardwood.

A pair of 500 ml plastic cups served as the pitfall trap. Before the first cup was placed in the ground the bottom of the cup was removed to facilitate drainage. This cup was placed in the ground so the lip was just below ground level. This portion of the pitfall was left permanently in the ground during the collection period. The second cup was placed inside the first and served to collect arthropods. Ethylene glycol (anti-freeze) was added to the pitfall to a depth of .5 cm. This served to kill and temporarily preserve arthropods that fell into the trap. The two cup system was used so the entire trap wouldn't have to be replaced each time arthropods were removed.

Pitfall traps remained set during June. Arthropods from each pitfall were removed and the ethylene glycol replaced once weekly. Insects taken from pitfalls were placed inside a plastic bag with an appropriate label and frozen for laboratory analysis.

IV. Laboratory Work

Arthropods from samples were identified to order and counted with the aid of a dissecting scope. Arthropods were sorted into small, medium, and large subsamples. Small arthropods were those less than 0.5 cm, medium were those greater than 0.5 cm and less than 1.0 cm, and large insects were those greater than 1 cm. Arthropods from each subsample were placed in separate plastic vials. Vials were sealed with a labeled cardboard lid. Subsamples were oven dried in a Fischer Isotemp® oven for 7 hours at 80°C. Biomass for each subsample was recorded to the nearest .001 g using a digital analytical balance. Total mass of each sample was determined by adding masses of subsamples. Arthropods from sweep net and pitfall samples were handled similarly.

V. Data Analysis

Data were entered into a General Linear Mixed Model (GLMM) program (Blouin and Saxton 1990). Analysis of variance (ANOVA) was used to determine differences in arthropod abundance, biomass, and taxonomic structure.

Arthropod abundance was defined as number of arthropods per 35 sweeps. Biomass was grams of arthropods per 35 sweeps. The taxonomic structure included the number of arthropods from representative taxa per 35 sweeps.

A logarithmic transformation was performed as part of the analysis of arthropod abundance data. To report means in the text log numbers were back-transformed to actual numbers, however standard errors could not be converted to actual numbers due to an asymmetrical distribution of the standard error around the mean after conversion.

A square root transformation was performed on taxa data. Means reported in the text were back-transformed to actual scale. Standard errors could not be converted due to an asymmetrical distribution around the mean after conversion. Biomass data were not transformed.

Differences in total arthropod abundance by habitat type, by week, and by week within habitat type were investigated. Differences in medium-sized arthropod abundance by habitat type, by week, and by week within

habitat type were analyzed. Differences in arthropod biomass by habitat type, by week, and by week within habitat type were investigated. Differences concerning arthropod taxa were analyzed for habitat type and week.

The comparative abundance and taxonomic structure of arthropods on logging roads traversing clearcuts vs. logging roads traversing mature hardwood was evaluated. Differences in the arthropod communities of roads dominated by orchard grass and ones dominated by clover were also investigated. Abundance and taxa data were transformed as above.

CHAPTER IV

RESULTS

Arthropods were sampled in 6 habitats over 2 seasons of the early brooding period for ruffed grouse. Two facets of the arthropod population, abundance and biomass, were analyzed. Results represent 531 sweep net samples and 856 trap nights of pitfall sampling. The average 35 sweep sample contained 71.9 arthropods and 0.141 g of arthropod biomass. Arthropods from 16 taxa were encountered while doing laboratory work.

I. Arthropod Abundance

Arthropods were more abundant during 1991 than 1990 ($P=0.0001$). To illustrate annual variation in the population the total arthropod abundance data for each year were analyzed separately. Although abundance varied between years, the differences among habitats for each year changed little. Because of this, other abundance data were pooled for both years to simplify results. While abundance of medium-sized arthropods was analyzed, the results were not included since this size class represented such a small portion of the total arthropod population. Small and large

arthropods were not analyzed independently. There was no significant difference between total number of arthropods and number of small arthropods (P=0.44). Large arthropods occurred too infrequently in samples for meaningful analysis to be undertaken.

i. Variation by Year

1990

Samples contained an average of 24% fewer arthropods during 1990 than in 1991. Abundance varied among habitat types during 1990. Managed logging roads produced more arthropods than all other habitats ($\bar{x}$=125.2/sample) (P≤0.01), except mature hardwood ($\bar{x}$=84.8/sample) from which this habitat type was not significantly different (Table 1). Abundance generally increased on forested habitats from early to late successional stages. Class I clearcuts were the least productive habitat yielding only 29.7 arthropods/sample. Arthropod abundance did not differ significantly among Class III clearcuts, mature hardwoods, and unmanaged logging roads. Arthropod abundance generally rose as the season advanced. They were most plentiful, averaging 75.2/sample, during 22-30 June (P≤0.001) (Table 1). Fewest numbers of arthropods occurred early in the month (1-7) ($\bar{x}$=48.9/sample) (P≤0.09).

Table 1. Comparison of mean arthropod abundance by habitat and week, June 1990- 91, Cherokee National Forest, Tennessee.

Classification	Mean Number of Arthropods per 35 Sweeps ± S.E. (Logarithmic Scale)	Mean Number of Arthropods per 35 Sweeps (Back-Transformed)	
1990			
Class I Clearcuts	3.39 ± 0.19	29.7	A[a]
Class II Clearcuts	3.80 ± 0.19	44.7	AB
Class III Clearcuts	4.10 ± 0.20	60.3	BC
Mature Hardwood	4.44 ± 0.20	84.8	CD
Unmanaged Logging Roads	4.19 ± 0.20	66.0	BC
Managed Logging Roads	4.83 ± 0.20	125.2	D
1-7 June	3.89 ± 0.10	48.9	A
8-14 June	4.12 ± 0.08	61.6	C
15-21 June	4.02 ± 0.09	55.7	B
22-30 June	4.32 ± 0.08	75.2	D
1991			
Class I Clearcuts	4.21 ± 0.23	67.4	AB
Class II Clearcuts	4.00 ± 0.24	54.6	A
Class III Clearcuts	3.98 ± 0.23	53.5	A
Mature Hardwood	4.65 ± 0.23	104.6	BCD
Unmanaged Logging Roads	4.46 ± 0.23	86.5	ABC
Managed Logging Roads	5.06 ± 0.20	157.6	D
1-7 June	4.43 ± 0.10	83.9	BC
8-14 June	4.52 ± 0.10	91.8	C
15-21 June	4.30 ± 0.11	73.7	A
22-30 June	4.33 ± 0.10	75.9	AB

[a] Means in each block not followed by the same capital letter are significantly different ($P \leq 0.09$)

Abundance by week within habitat was analyzed (Table 5, Appendix A), but in only one case could differences among weeks be attributed to anything but random causes. During 15-21 June sampling on managed logging roads occurred on a damp, cloudy day. Arthropods were least plentiful on managed logging roads ($\bar{x}$=62.7/sample) during this period ($P \leq 0.0001$).

1991

Arthropod abundance during 1991, as in 1990, was dissimilar among habitat types. Managed logging roads ($\bar{x}$=157.6/sample) proved superior to all habitats except mature hardwood ($\bar{x}$=104.6/sample) ($P \leq 0.05$) (Table 1). No significant difference between managed logging roads and mature hardwood was determined. Mature hardwoods were more productive than either class II or III clearcuts ($P \leq 0.05$). Abundance did not vary significantly among classes I, II, and III clearcuts, or unmanaged logging roads.

Arthropod abundance varied among weeks, but not in the same pattern as in 1990. Abundance peaked during 8-14 June ($\bar{x}$=91.8/sample) and was lowest during the last half of the month (15-30) ($\bar{x}$=74.8/sample) ($P \leq 0.01$) (Table 1).

Reasons for differences in abundance among weeks within habitats were more easily recognized during 1991 than in 1990. Sampling of class II and III clearcuts during 15-30 June, was hampered by frequent showers. Damp vegetation caused significant decreases in collection rates from the

first half of the month on these habitats. Arthropods were more numerous on class II clearcuts during 1-7 June than during 15-30 ($P \leq 0.05$) (Table 5, Appendix A). Arthropods were more abundant during the first half of June than during the last on class III clearcuts ($P \leq 0.01$).

Mowing operations on unmanaged logging roads likely affected arthropod numbers. Abundance was significantly higher before mowing (8-21 June) than after (22-30 June) ($P \leq 0.05$) (Table 5, Appendix A).

ii. Relations Between Taxa and Habitat Type

Sixteen taxa were identified while counting arthropods. However, only 8 taxa were represented often enough to be analyzed. Common names of arthropods in taxa analyzed are given in Table 6, Appendix A. Most frequently represented were arthropods from the taxa Diptera and Homoptera (Figure 9). Significant differences among habitats were established for each taxon analyzed, while differences among weeks occurred in 5 of 8.

Diptera

Dipterons were the most frequently collected arthropods. Managed logging roads ($\bar{x}$=50.1/sample) and mature hardwood ($\bar{x}$=52.0/sample) outproduced class I and II clearcuts and unmanaged logging roads and were the most fertile habitats

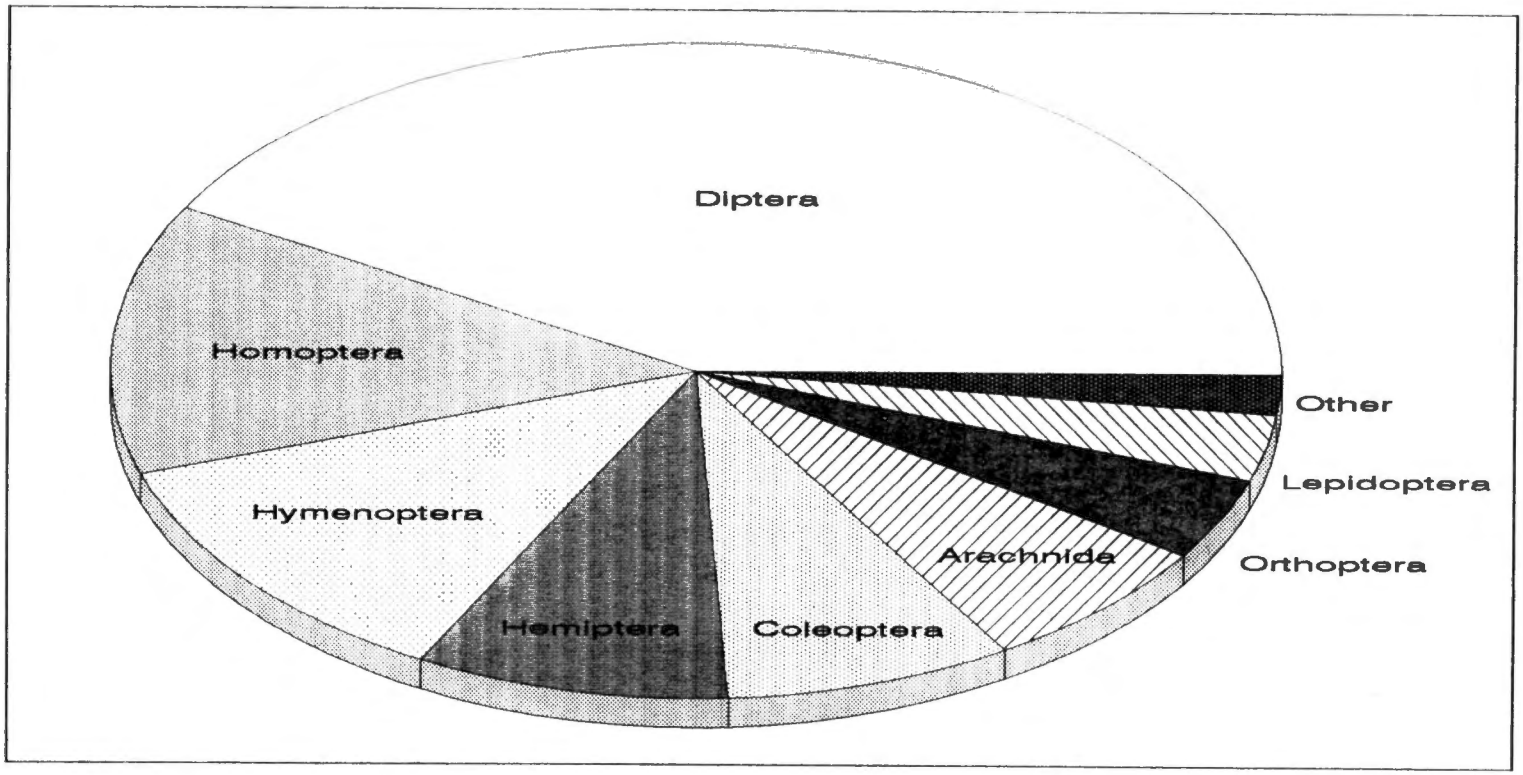

Figure 9. Relative abundance of different arthropod taxa across all habitats, June 1990-91, Cherokee National Forest, Tennessee.

for dipterons (P≤0.10) (Table 2). Dipterons were least plentiful during week 3 (15-21 June) than any other period (P≤0.001).

Homoptera

Homopterons were among the most abundant of arthropods collected, especially on logging roads. Managed and unmanaged logging roads contained more members of this order than forested habitats (P≤0.06). Managed roads ($\bar{x}$=41.3/sample) were more heavily populated than unmanaged roads (P≤0.0006) (Table 2). Among forested habitats homopterons were more plentiful in class I clearcuts ($\bar{x}$=10.0/sample) than in either class II and III clearcuts or mature hardwoods (P≤0.09). Homopteron abundance did not vary significantly among weeks.

Hymenoptera

In late successional habitat hymenopterons were a major component of the arthropod community. Mature hardwoods proved more productive ($\bar{x}$=17.3/sample) than any other habitat (P≤0.009) (Table 2). No significant differences were discovered among other habitats. Largest counts of hymenopterons ($\bar{x}$=12.4/sample) were recorded during 1-7 June (P≤0.02).

Hemiptera

Managed logging roads were richer in hemipteron abundance ($\bar{x}$=23.2/sample) than any other habitat (P≤0.02)

Table 2. Comparison of mean arthropod abundance within taxa by habitat and week, June 1990-91, Cherokee National Forest, Tennessee.

Classification	Mean Number of Arthropods per 35 Sweeps ± S.E. (Square Root Scale)	Mean Number of Arthropods per 35 Sweeps (Back-Transformed)	
Diptera			
Class I Clearcuts	3.92 ± 0.83	15.4	A[a]
Class II Clearcuts	5.28 ± 0.83	27.9	A
Class III Clearcuts	5.73 ± 0.83	32.8	AB
Mature Hardwood	7.21 ± 0.83	52.0	B
Unmanaged Logging Roads	4.72 ± 0.83	22.3	A
Managed Logging Roads	7.08 ± 0.72	50.1	B
1-7 June	5.63 ± 0.36	31.7	B
8-14 June	6.18 ± 0.35	38.2	C
15-21 June	4.92 ± 0.36	24.2	A
22-30 June	5.89 ± 0.35	34.7	BC
Homoptera			
Class I Clearcuts	3.17 ± 0.45	10.0	B
Class II Clearcuts	1.87 ± 0.45	3.5	A
Class III Clearcuts	2.12 ± 0.45	4.5	A
Mature Hardwood	2.11 ± 0.45	4.5	A
Unmanaged Logging Roads	4.38 ± 0.45	19.2	C
Managed Logging Roads	6.43 ± 0.39	41.3	D
1-7 June	3.27 ± 0.22	10.7	A
8-14 June	3.25 ± 0.21	10.6	A
15-21 June	3.49 ± 0.22	12.2	A
22-30 June	3.36 ± 0.21	11.3	A
Hymenoptera			
Class I Clearcuts	2.65 ± 0.27	7.0	A
Class II Clearcuts	3.07 ± 0.27	9.4	A
Class III Clearcuts	3.00 ± 0.28	9.0	A
Mature Hardwood	4.16 ± 0.27	17.3	B
Unmanaged Logging Roads	2.95 ± 0.27	8.7	A
Managed Logging Roads	3.21 ± 0.24	10.3	A
1-7 June	3.52 ± 0.14	12.4	E
8-14 June	3.10 ± 0.13	9.6	BC
15-21 June	2.84 ± 0.13	8.1	A
22-30 June	3.24 ± 0.13	10.5	CD

Table 2. (cont.)

Classification	Mean Number of Arthropods per 35 Sweeps ± S.E. (Square Root Scale)	Mean Number of Arthropods per 35 Sweeps (Back-Transformed)	
Hemiptera			
Class I Clearcuts	2.42 ± 0.71	5.9	A
Class II Clearcuts	1.82 ± 0.71	3.3	A
Class III Clearcuts	1.87 ± 0.71	3.5	A
Mature Hardwood	1.95 ± 0.71	3.8	A
Unmanaged Logging Roads	2.64 ± 0.71	7.0	A
Managed Logging Roads	4.82 ± 0.62	23.2	B
1-7 June	2.51 ± 0.31	6.3	B
8-14 June	2.41 ± 0.31	5.8	AB
15-21 June	2.11 ± 0.31	4.5	A
22-30 June	3.32 ± 0.31	11.0	C
Coleoptera			
Class I Clearcuts	2.43 ± 0.18	5.9	A
Class II Clearcuts	2.36 ± 0.18	5.6	A
Class III Clearcuts	2.37 ± 0.18	5.6	A
Mature Hardwood	2.47 ± 0.18	6.1	A
Unmanaged Logging Roads	2.51 ± 0.18	6.3	A
Managed Logging Roads	2.90 ± 0.15	8.4	B
1-7 June	2.54 ± 0.11	6.5	A
8-14 June	2.57 ± 0.10	6.6	A
15-21 June	2.50 ± 0.10	6.3	A
22-30 June	2.42 ± 0.10	5.9	A
Arachnida			
Class I Clearcuts	1.85 ± 0.21	3.4	A
Class II Clearcuts	2.23 ± 0.21	5.0	ABC
Class III Clearcuts	2.49 ± 0.21	6.2	BC
Mature Hardwood	2.71 ± 0.21	7.3	C
Unmanaged Logging Roads	2.24 ± 0.21	5.0	ABC
Managed Logging Roads	2.19 ± 0.18	4.8	AB
1-7 June	2.30 ± 0.11	5.3	B
8-14 June	2.12 ± 0.11	4.5	A
15-21 June	2.16 ± 0.11	4.7	AB
22-30 June	2.64 ± 0.10	7.0	C

Table 2. (cont.)

Classification	Mean Number of Arthropods per 35 Sweeps ± S.E. (Square Root Scale)	Mean Number of Arthropods per 35 Sweeps (Back-Transformed)	
Orthoptera			
Class I Clearcuts	1.30 ± 0.33	1.7	A
Class II Clearcuts	1.22 ± 0.33	1.5	A
Class III Clearcuts	1.41 ± 0.33	2.0	A
Mature Hardwood	1.34 ± 0.33	1.8	A
Unmanaged Logging Roads	2.29 ± 0.33	5.2	B
Managed Logging Roads	3.47 ± 0.29	12.0	C
1-7 June	2.06 ± 0.15	4.2	B
8-14 June	1.90 ± 0.14	3.6	B
15-21 June	1.71 ± 0.15	2.9	A
22-30 June	1.70 ± 0.15	2.9	A
Lepidoptera			
Class I Clearcuts	1.59 ± 0.10	2.5	AB
Class II Clearcuts	1.42 ± 0.10	2.0	A
Class III Clearcuts	1.41 ± 0.10	2.0	A
Mature Hardwood	1.70 ± 0.10	3.0	BC
Unmanaged Logging Roads	1.62 ± 0.10	2.6	AB
Managed Logging Roads	1.87 ± 0.09	3.5	C
1-7 June	1.60 ± 0.06	2.6	A
8-14 June	1.64 ± 0.05	2.7	A
15-21 June	1.56 ± 0.05	2.4	A
22-30 June	1.59 ± 0.05	2.5	A

[a] Means in each block not followed by same capital letter are significantly different ($P \leq 0.10$)

(Table 2). No significant differences among other habitats were discovered. Hemipterons were most plentiful during the last week in June (22-30) ($\bar{x}$=11.0/sample) (P≤0.0001).

Coleoptera

Coleopterons were more abundant on managed logging roads ($\bar{x}$=8.4/sample) than any other habitat (P≤0.10) (Table 2). All other habitats produced similar numbers of coleopterons. Coleopteron abundance did not vary significantly among weeks.

Arachnida

Arachnids generally increased in abundance from early to late successional habitat (Table 2). Mature hardwood produced more arachnids ($\bar{x}$=7.3/sample) than either class I clearcuts or managed logging roads (P≤0.06). Arachnids were more common in class III than class I clearcuts (P=0.03). Arachnid abundance peaked during the last week of June (22-30) ($\bar{x}$=7.0/sample) (P≤0.002).

Orthoptera

Orthopterons were most prolific on logging roads and least abundant on forested habitats (P≤0.06) (Table 2). Managed logging roads were more productive ($\bar{x}$=12.0/sample) than unmanaged roads (P=0.007). Orthopterons were more frequently collected during the first half (1-15) than the last half of June (p≤0.05).

Lepidoptera

Lepidopterons showed no easily recognizable patterns of abundance. They were more common on managed logging roads ($\bar{x}$=3.5/sample) than in all classes of clearcuts or on unmanaged logging roads ($P \leq 0.05$) (Table 2). Mature hardwood was more heavily populated than both class II and III clearcuts ($P \leq 0.04$). Lepidopteron abundance did not vary significantly among weeks.

iii. Ground Dwelling Arthropods

Pitfalls traps were used to sample ground dwelling arthropods. Arthropods from 3 orders comprised 84% of those collected in pitfall traps. Fifty-two percent were from the order Coleoptera. Although beetles are an important food source to ruffed grouse chicks, most of the ones collected in pitfalls were nocturnal in activity (Borror et al. 1981) and thus largely unavailable to diurnally feeding grouse chicks. Families frequently represented included: Carabidae (ground beetles), Silphidae (carrion beetles), and Scarabaeidae (Scarab beetles). Orthopterons represented 16% of arthropods collected in pitfalls. Most belonged to the nocturnal subfamily Rhaphidophorinae (cave crickets). Arthropods from the order Hymenoptera represented 16% of all collected. Most were from the family Formicidae (ants). This method of

sampling was discontinued after the 1990 season since few arthropods that appeared important to foraging grouse chicks were captured.

II. Arthropod Biomass

Although arthropod biomass varied between years, the 2 sets of data were pooled since the variation was similar to that described for arthropod abundance. Managed logging roads were richer in arthropod biomass ($\bar{x}$=0.244 g/sample) than any other habitat ($P \leq 0.07$) (Table 3). Arthropod biomass did not differ significantly among classes I, II, and III clearcuts, mature hardwood, or unmanaged logging roads.

Biomass was greater during the first week in June (1-7) ($\bar{x}$=0.166 g/sample) than any other week ($P \leq 0.05$) (Table 6). Differences in biomass among weeks within habitats appeared to occur randomly and are not reported in the text. Analysis of these data is given in Table 7, Appendix A.

III. Special Case - Arthropod Production on Logging Roads

Since management of logging roads for wildlife is currently an important topic to natural resources personnel, an in-depth analysis of the arthropod community on this habitat type was addressed. Arthropod characteristics found

Table 3. Comparison of mean arthropod biomass by habitat, June 1990-91, Cherokee National Forest, Tennessee.

Classification	Mean Arthropod Biomass (g) per 35 Sweeps ± S.E.	
Class I Clearcuts	0.088 ± 0.035	A[a]
Class II Clearcuts	0.083 ± 0.036	A
Class III Clearcuts	0.126 ± 0.036	A
Mature Hardwood	0.146 ± 0.036	A
Unmanaged Logging Roads	0.159 ± 0.035	A
Managed Logging Roads	0.244 ± 0.031	B
1-7 June	0.166 ± 0.016	C
8-14 June	0.132 ± 0.016	AB
15-21 June	0.120 ± 0.016	A
22-30 June	0.144 ± 0.016	B

[a] Means in each block not followed by same capital letter are significantly different ($P \leq 0.07$)

on unmanaged logging roads traversing mature hardwood were compared to those dissecting clearcuts. Aspects of arthropod distribution on managed logging roads dominated by orchard grass were compared to those on which clover was the primary vegetative component. A breakdown of these analyses are given in Tables 8 and 9, Appendix A.

i. Logging Roads Traversing Clearcuts vs. Logging Roads Traversing Mature Hardwood

Arthropod abundance and biomass did not vary significantly between unmanaged logging roads within clearcuts and those dissecting mature hardwoods (Figure 10a&b). Unmanaged logging roads crossing clearcuts produced a greater abundance of hemipterons and homopterons than those traversing mature hardwood ($P \leq 0.03$) (Figure 10c). No differences between road classifications were found for other taxa analyzed.

ii. Logging Roads Planted to Orchard Grass vs. Logging Roads Planted to Clover

Arthropod abundance on managed logging roads dominated by clover was greater than on managed roads planted to orchard grass ($P \leq 0.0001$) (Figure 11a). Managed logging roads

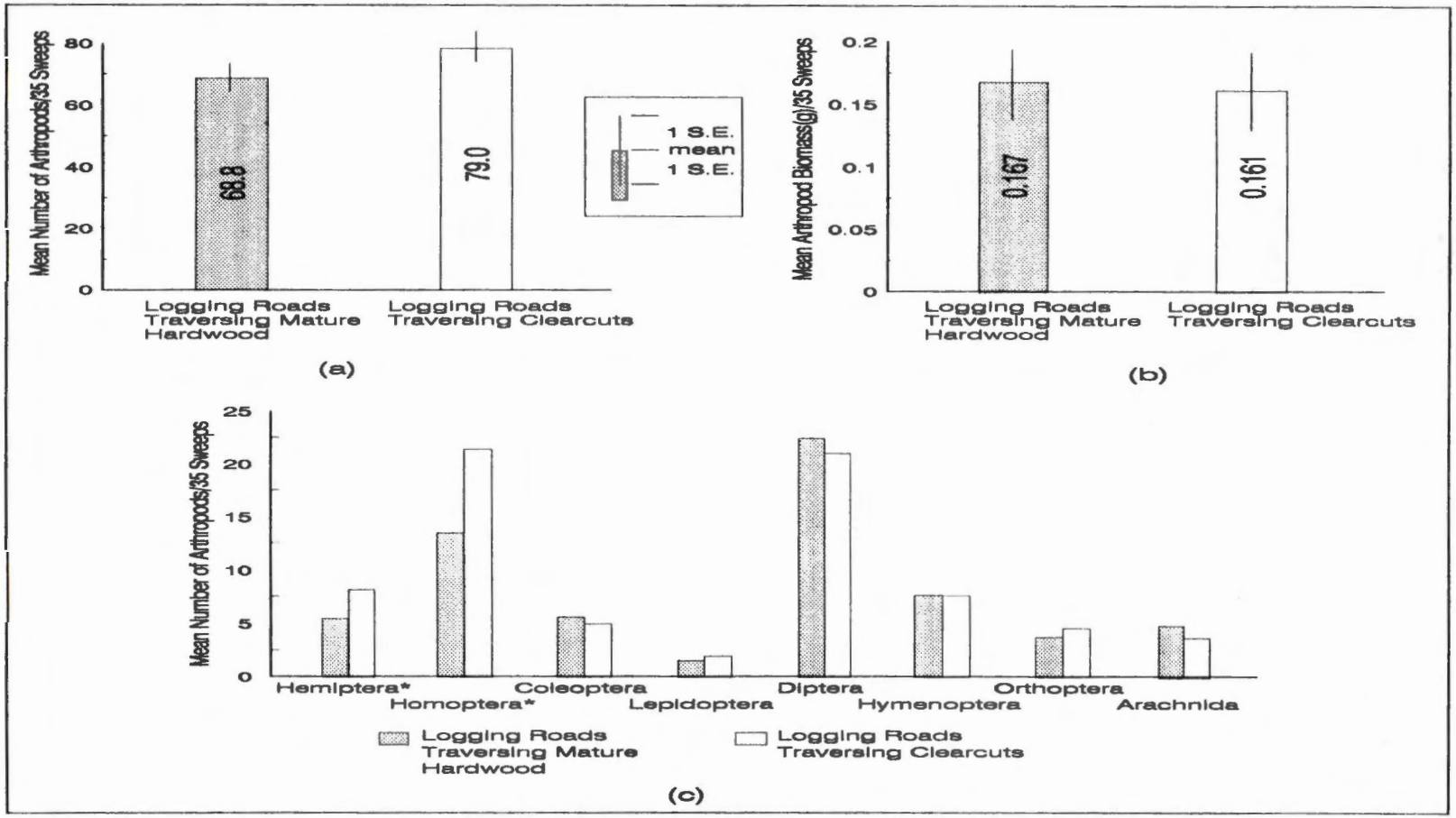

Figure 10. Characteristics of arthropod communities collected from unmanaged logging roads traversing mature hardwood and unmanaged logging roads traversing clearcuts: (a) abundance, (b) biomass, (c) taxonomic structure, June 1990-91, Cherokee National Forest, Tennessee. * Significant difference between road classifications ($P \leq 0.02$).

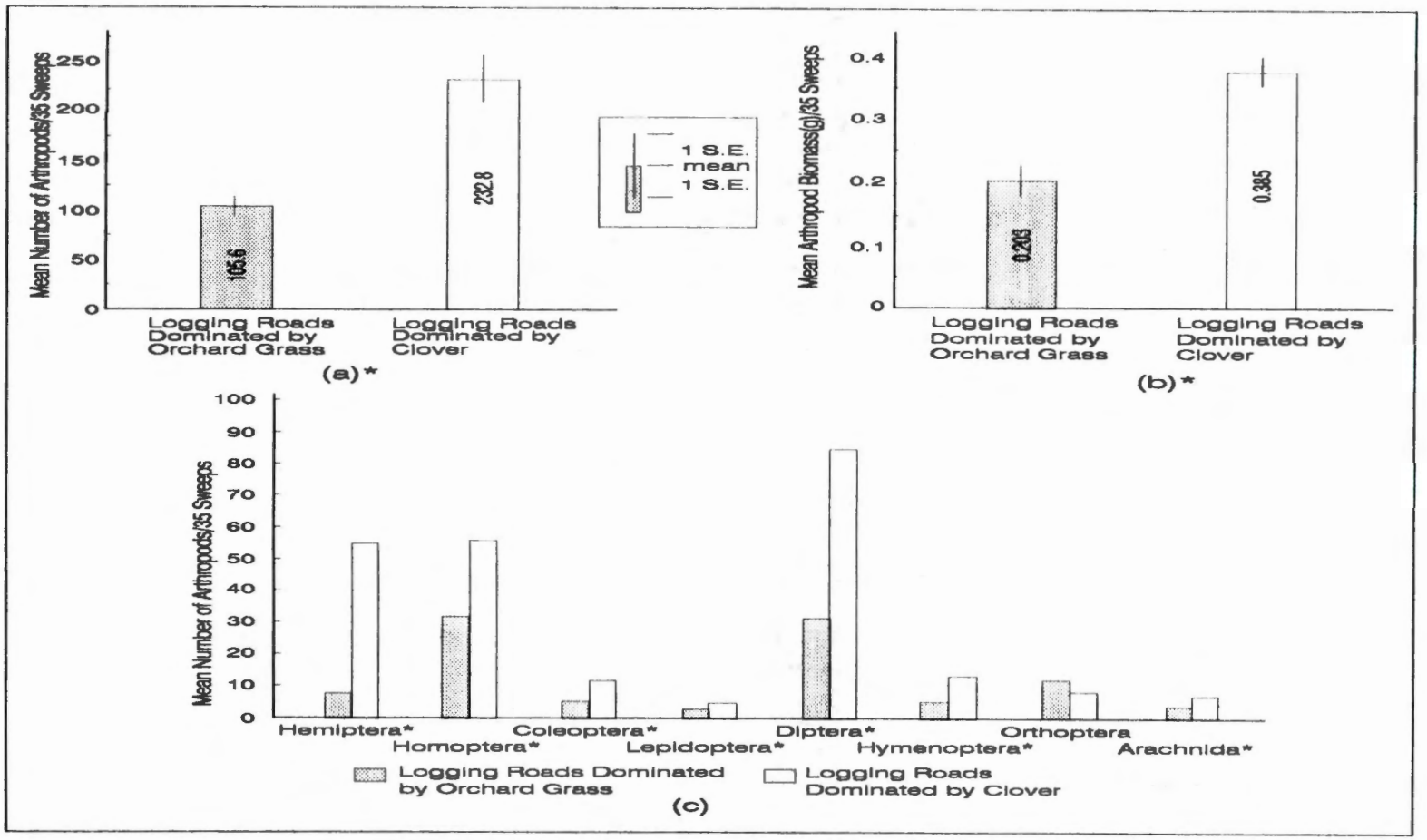

Figure 11. Characteristics of arthropod communities collected from managed logging roads planted to orchard grass and managed logging roads planted to clover: (a) abundance, (b) biomass, (c) taxonomic structure, June 1990-91, Cherokee National Forest, Tennessee. * Significant difference between road classifications ($P \leq 0.03$).

dominated by clover also contained more arthropod biomass than those on which orchard grass was the primary vegetative member ($P \leq 0.0001$) (Figure 11b). Numbers of orthopterons were not significantly different between road types (Figure 11c). In every other taxon analyzed logging roads planted to clover were more heavily populated than those dominated by orchard grass ($P \leq 0.03$).

CHAPTER V

DISCUSSION

I. Arthropod Abundance

i. Effect of Habitat on Arthropod Populations

Ruffed grouse chicks feed heavily on insects, especially during their first month of life, and areas producing abundant supplies of insects are an important element of brood habitat (Kimmel and Samuel 1984). Managed logging roads and mature hardwood were the most productive habitats for arthropods. Although mean abundance appeared higher on managed logging roads no significant difference in arthropod numbers was determined between these habitats.

Areas containing large quantities of herbaceous vegetation, such as managed openings, are most productive for insects (Carpenter 1936, Grace 1942). The comparatively large abundance of arthropods in mature hardwoods was probably related to their dense layer of herbaceous ground cover. This is supported by Healy (1985) who reported that arthropods were numerous in forested sites only where succulent ground cover was found in quantity.

Unmanaged logging roads, due to the nearly complete loss of planted grasses and clovers, did not produce numbers of arthropods comparable to managed roads. No significant differences among unmanaged logging roads and forested sites were determined except during 1990 when arthropods were less abundant in class I clearcuts. Unless forest openings are planted to and maintained in herbaceous species they may not produce more insects than forested areas.

Although medium and large sized arthropods occurred infrequently on habitats sampled, there is evidence that grouse chicks show some selection toward larger arthropods as food items (Spidso 1980). Spidso (1980) felt that larger than average arthropods are more easily seen and captured than smaller ones. Due to their lack of abundance, however, larger arthropods cannot be considered a dependable food resource to chicks (Spidso 1980). Healy (1985) found no evidence that wild turkey poults can compensate for low feeding rates by selecting large items.

The chicks of some species of grouse, including red grouse (*Lagopus l. scoticus*) (Savory 1977) and willow grouse (*Lagopus lagopus*) (Spidso 1980), select arthropod prey items from different taxa in proportion to their availability. Kimmel and Samuel (1984), however, found that ruffed grouse chicks feed selectively, taking some types of arthropods more than expected and some less. Those universally preferred are

the hymenopterons, coleopterons, and lepidopterons (Darrow 1939, Bump et al. 1947, Stewart 1956, King 1969, and Kimmel and Samuel 1984). Other groups of importance include homoptera (Stewart 1956, King 1969, and Kimmel and Samuel 1984), and diptera (Kimmel and Samuel 1984). Although ruffed grouse chicks from different areas generally preferred the same types of arthropods, it is apparent that some variation in selection does occur. These variations are likely linked to availability of preferred arthropods and are local in nature.

Results indicated the types of arthropods universally favored as food for ruffed grouse chicks were most abundant on managed logging roads and in mature hardwood with herbaceous ground cover. Hymenopterons were found in greatest numbers in mature hardwood. Similarly Whittaker (1952) and Stuen and Spidso (1988) found hymenopterons abundant in rich mature forests.

Insects from the order Lepidoptera were most abundant on managed logging roads and in mature hardwood. Whittaker (1952) found largest numbers of lepidopterons in rich mesic forests. However, few differences in lepidopteron numbers among habitats were found by Steun and Spidso (1988). Lepidopteron abundance may vary greatly among years in the same area (Spidso 1980). This fact may account for inconsistencies between results of this study and others.

Managed logging roads were the most productive habitat for beetles. Coleopteron numbers did not vary significantly among other habitats. In the Great Smoky Mountains, coleopterons were reported abundant in forest openings (Whittaker 1952). However, Healy and Nenno (1983) reported coleopterons not abundant in managed openings. It is unclear why these discrepancies are present.

Homopterons, also preferred by ruffed grouse chicks, were most plentiful on logging roads, especially managed ones. Likewise, Healy (1985) found homopterons most abundant in clearings.

Dipterons were most abundant on managed logging roads and mature hardwood. These insects were similarly found abundant in rich mature forests and forest openings by Whittaker (1952). Dipterons are reported as important forage for ruffed grouse chicks only by Kimmel and Samuel (1984). However, dipterons are important as food items for other species of grouse chicks (Savory 1977, Spidso 1980, Spidso and Stuen 1988). Since dipterons are among the most active of insects (Spidso 1980), and thus harder for the chicks to capture, it is possible that they are only utilized as forage when the supply of more easily captured prey is limited.

Arachnids, although not a primary component of the diet of ruffed grouse chicks, were regularly identified in food habit studies (Bump et al. 1947 and Kimmel and Samuel 1984).

This suggests that arachnids may be of local importance to chicks. Arachnids were most prevalent in mature hardwood and class III clearcuts. Wild turkey poults generally had higher feeding rates on arachnids in mature timber than in clearings (Healy 1985).

Orthopterons and hemipterons occurred in greatest abundance on managed logging roads. These insects are of little importance to foraging ruffed grouse chicks (Darrow 1939, Bump et al. 1947, Stewart 1956, King 1969, and Kimmel and Samuel 1984). Orthopterons were prominent, though, in the diets of wild turkey poults (Blackburn et al. 1975, Hurst and Stringer 1975) and were fed on extensively by ruffed grouse in September (Judd 1905 in Bump et al. 1947). Wild turkey poults and mature grouse may be able to utilize orthopterons, which are generally larger than other arthropods, to a greater degree than grouse chicks. Hemipterons though apparently not readily taken by ruffed grouse chicks are important to other species of grouse chicks and to wild turkey poults (Hurst and Stringer 1975, Savory 1977, Spidso 1980, Healy 1985, Spidso and Stuen 1988). It is unclear why ruffed grouse chicks rarely feed on this group of insects.

ii. Effect of Weather on Arthropod Populations

Differences in insect abundance among years may influence annual productivity of ruffed grouse populations. Southwood and Cross (1969) reported 89.5% of the variation in breeding success of partridge (*Perdix perdix*) could be accounted for by variations in arthropod abundance. During the present investigation arthropods were more abundant in 1991 than in 1990. Weather conditions may have played an important role in this difference.

High mortality of insects during very cold periods of winter is probably the primary factor controlling insect populations in temperate latitudes (Uvarov 1931). The period of extreme cold during late December 1989 where daily minimum temperatures fell near -15°C could have played a factor in lower arthropod abundance during 1990. No cold periods of this magnitude occurred during the winter of 1990-91.

Low measurements of precipitation may result in outbreaks of insects (Uvarov 1931). During early 1991 rainfall at a site near the study area was 21 cm lower than that recorded during the same period in 1990 (National Oceanic and Atmospheric Administration 1990,1991). This along with the mild winter of 1990-91 created favorable conditions for an increase in the arthropod population.

Weather, by influencing the growth stage of vegetation, may affect insect populations to a greater extent than it does directly (Grace 1942). Average daily temperature was 2.75°C higher in 1991 than in 1990 during the early growing season (April and May) (National Oceanic and Atmospheric Administration 1990,1991). This, along with several consecutive days during late May 1991 on which the daily maximum temperature was near 30°C, may have increased the insect population above June 1990 levels by causing insect hatches to occur earlier than normal and providing a more favorable stage of vegetation for them to feed on.

Weather may affect the collection rate of arthropods. At a mountain weather station near the study area, measurable precipitation fell each day from 13-28 June 1991 (National Oceanic and Atmospheric Administration 1991). During this period it was rare to find the vegetation completely dry. Bump et al. (1947) noted sweep net samples taken during wet weather contained 25% fewer insects than those taken under dry conditions. This was a factor in reduced arthropod abundance during the latter part of June 1991.

Precipitation affects insects by causing them to become less active and seek shelter (Uvarov 1931), making them less accessible to ruffed grouse chicks. Chicks, primarily during the early brooding period, are placed under stress during periods of precipitation, especially when it occurs for

several consecutive days (Bump et al. 1947). When weather events like this develop, as was the case during the last half of June 1991, ruffed grouse chicks are not only placed under increased metabolic stress but their chief source of food, insects, becomes harder to find.

iii. Weekly Variation of Arthropod Populations

Weekly variation in the arthropod population during June also occurred. During 1990, abundance was lowest during week 1 and peaked during week 4. The vegetative stage may have been more favorable during late rather than early June due to the climatic factors discussed. Arthropod production during June 1991 peaked during the early portion of the month. This would favor survival of ruffed grouse chicks since they typically hatch in late May and early June in the southeast (Epperson 1988).

Differences in arthropod abundance among weeks within habitats were also present. Possible explanations for these variations include inclement weather, local hatches of insects, and disturbance of the vegetation. During week 3 1990 on managed logging roads, samples were taken on a damp, foggy day. The decrease in arthropod abundance from week 2 was probably a result of these weather conditions. Similar reductions occurred on class II and III clearcuts during

weeks 3 and 4, 1991. Declines in arthropod abundance from weeks 1 and 2 were presumably caused by the frequent showers during the latter half of June described previously. Reduced feeding opportunities to grouse chicks are probably affected as much by light showers as by heavy rain. A brief shower can cause vegetation to remain wet for as long a period as after a heavy downpour. This was also noted by Bump et al. (1947).

Local hatches of insects probably played a role in variation in abundance among weeks within habitats. An example of a local hatch occurred on managed logging roads, where fleahoppers (Miridae) became very numerous during the last week in June of both 1990 and 1991.

In 1991 unmanaged logging roads were mowed before sampling occurred during week 4. A decrease in arthropod abundance from weeks 2 and 3 to week 4 was evident. Mowing may reduce arthropod numbers for at least a few weeks (Hurst and Owen 1980). The decline in arthropod abundance observed during week 4 was likely caused by mowing.

Availability of the coloepterons, lepidopterons, and homopterons did not vary among weeks. Numbers of these insects were stable during June, and this may explain some of the preference shown to them by grouse chicks. The abundance of arachnids, dipterons, hymenopterons and other taxa varies over time. Fluctuations in abundance of these arthropods

may force the chicks to switch to alternate food sources and/or spend more time foraging.

iv. Effect of Forest Succession on Arthropod Populations

Since ruffed grouse are early successional species the quantity of insects produced in this stage of forest development is important to wildlife managers. Insect abundance is generally lower in young clearcuts (≤ 3 years) than in mature forest (Seastedt and Crossley 1981, Healy and Nenno 1983, Stuen and Spidso 1988). Class I clearcuts (mean age=2.5 years) were poor producers of arthropods during 1990, but during 1991 were not significantly different from any other habitat except managed logging roads. A lack of palatable herbaceous vegetation available to arthropods in recently harvested stands offers an explanation for reduction in arthropod abundance. Although arthropod numbers are initially suppressed in new clearcuts they should begin to rebound as the density of woody stems becomes less and herbaceous vegetation begins to reappear at ground level. Since sunlight is able to reach the forest floor in this habitat, the structure of the arthropod community is more comparable to that found on logging roads than in other forested habitats.

Arthropod numbers in older clearcuts (classes II and III) were lower than those in mature hardwood, except in 1990 when no significant difference between class III clearcuts and mature hardwood was established. Older clearcuts with large quantities of herbaceous vegetation at ground level appeared as productive for insects as mature hardwood. But not all sites on which older clearcuts were located produced continuous herbaceous ground cover. This likely accounted for differences in arthropod abundance between this age class of clearcuts and mature forests.

Availability of insects is only one habitat component important to broods. Protective cover is also necessary. Areas of high stem density provide chicks with this habitat type (Bump et al. 1947, Kubisiak 1978, and Thompson et al. 1987). In the southeastern deciduous forest, borders of logging roads, overgrown fields, evergreen shrub thickets, and clearcuts provide areas of high stem density. Recently harvested sites in the 2-4 year class do not usually provide this habitat type as slash from timber removal may impede travel by the chicks (Kubisiak 1978, Barber et al. 1989). Chicks may exchange areas of good habitat for sites with poorer cover where insects are abundant if both are not closely situated (Godfrey 1975). Since habitats providing highest insect populations are not those providing the best cover, interspersion of a diversity of vegetative communities

is important to broods. By providing areas of high stem density near habitats productive for insects the essentials of brood habitat should be met.

v. Effect of Management on Arthropod Populations

Numerous differences in arthropod populations were observed between logging roads dominated by clover and those on which orchard grass was the primary component. Both arthropod abundance and biomass were approximately 2 times higher on logging roads planted to clover than on logging roads dominated by orchard grass. Clover not only furnishes higher arthropod numbers and biomass but contains more of the arthropods favored as food by grouse chicks. All taxa except orthopterons were more abundant in clover. Orchard grass, although not producing the amount of arthropods as clover, is nonetheless attractive to a large quantity of invertebrates.

Most openings managed for wildlife commonly are planted to orchard grass and/or clover, rationalized by an assumption that these plantings increase the supply of food to game birds (Krusac and Michael 1979). However, few studies have measured their arthropod production. Insects were 25 times more abundant in clearings dominated by orchard grass than under the forest canopy (Martin and McGinnes 1975). Healy (1985) found wild turkey poult feeding rates (pecks/minute)

highest in a clearing on which orchard grass was predominant. Openings planted to clover were not sampled in either study. Grace (1942) reported that clover provided habitat to about 200 species of insects. Of habitats sampled by Nenno and Lindzey (1979), those dominated by clover endured the highest feeding rates of wild turkey poults.

Another quality that makes clover appealing to grouse chicks is its vegetative structure. Ground cover should not be so dense as to inhibit the travel of chicks (Barber et al. 1989). Lush stands of orchard grass are typically dense and wild turkey poults have trouble moving through the grass to feed (Healy 1981). Since ruffed grouse chicks are smaller than turkey poults it is reasonable to assume that they would have trouble moving through dense orchard grass. Clover stands characteristically are less dense and shorter than orchard grass and should hinder foraging chicks' movements less. Grouse readily feed on clover (Hungerford 1957, Gullion 1989) and it provides food to chicks when plant material becomes the principal component of their diet.

Arthropod abundance and biomass were not significantly different between unmanaged logging roads traversing mature hardwoods and unmanaged logging roads crossing clearcuts. Availability of homopterons and hemipterons was higher in those dissecting clearcuts. Although some minor differences in arthropods populations between these road habitats were

evident they are most likely of little significance to foraging grouse chicks.

Logging roads may also serve another function to grouse chicks, especially in areas of steep, rugged terrain. Broods prefer level topography, and avoid use of steep slopes (Bump et al. 1947, Stewart 1956, Porath and Vons 1972). Young wild turkey poults lose balance and exhibit difficulty in moving on slopes greater than 30% (Rodgers 1985). Logging roads may be attractive to chicks, not only because of their high populations of insects, but also because their level surface allows chicks to forage as efficiently as possible.

II. Arthropod Biomass

Managed logging roads produced significantly more arthropod biomass than any other habitat, including mature hardwood from which it did not differ significantly in arthropod abundance. Some of this may be related to differences between the types of insects that live on managed logging roads and mature forests. Homopterons and orthropterons occurred frequently on managed logging roads but were infrequent members of the arthropod community in mature hardwood . These insects were replaced in mature hardwood by smaller species from the orders Diptera and Hymenoptera.

Arthropods of large mass are not given special emphasis in an analysis of total abundance. But in an analysis of biomass arthropods of greater size affect the ranking of a habitat more than smaller arthropods do. Consequently arthropod biomass may be a more important factor than abundance in determining the value of a habitat to foraging grouse chicks.

CHAPTER VI

MANAGEMENT IMPLICATIONS

Increasing insect production as well as green forage for wildlife can be accomplished by planting logging roads and log landings to clover or orchard grass and can achieve desirable results in 1 growing season. For example, during fall 1990, an unmanaged logging road was planted to clover. Sampling of this road during June 1991 revealed an approximate 300% increase over June 1990 in both arthropod abundance and biomass (Figure 12). While clover is highly productive for insects and provides good vegetative structure to chicks, it is harder to maintain than orchard grass (Krusac and Michael 1979). Maintenance of plantings includes both periodic use of fertilizer and lime and mowing during the growing season (Healy and Nenno 1983). Mowing reduces arthropod abundance (Hurst and Owen 1980). If mowing is postponed until at least a month after the peak of the hatch chicks should have maximum numbers of arthropods available during the period that they are most dependent on them as a food source. Renewal of the cover crop, based on site characteristics and encroachment of undesirable species must be performed periodically.

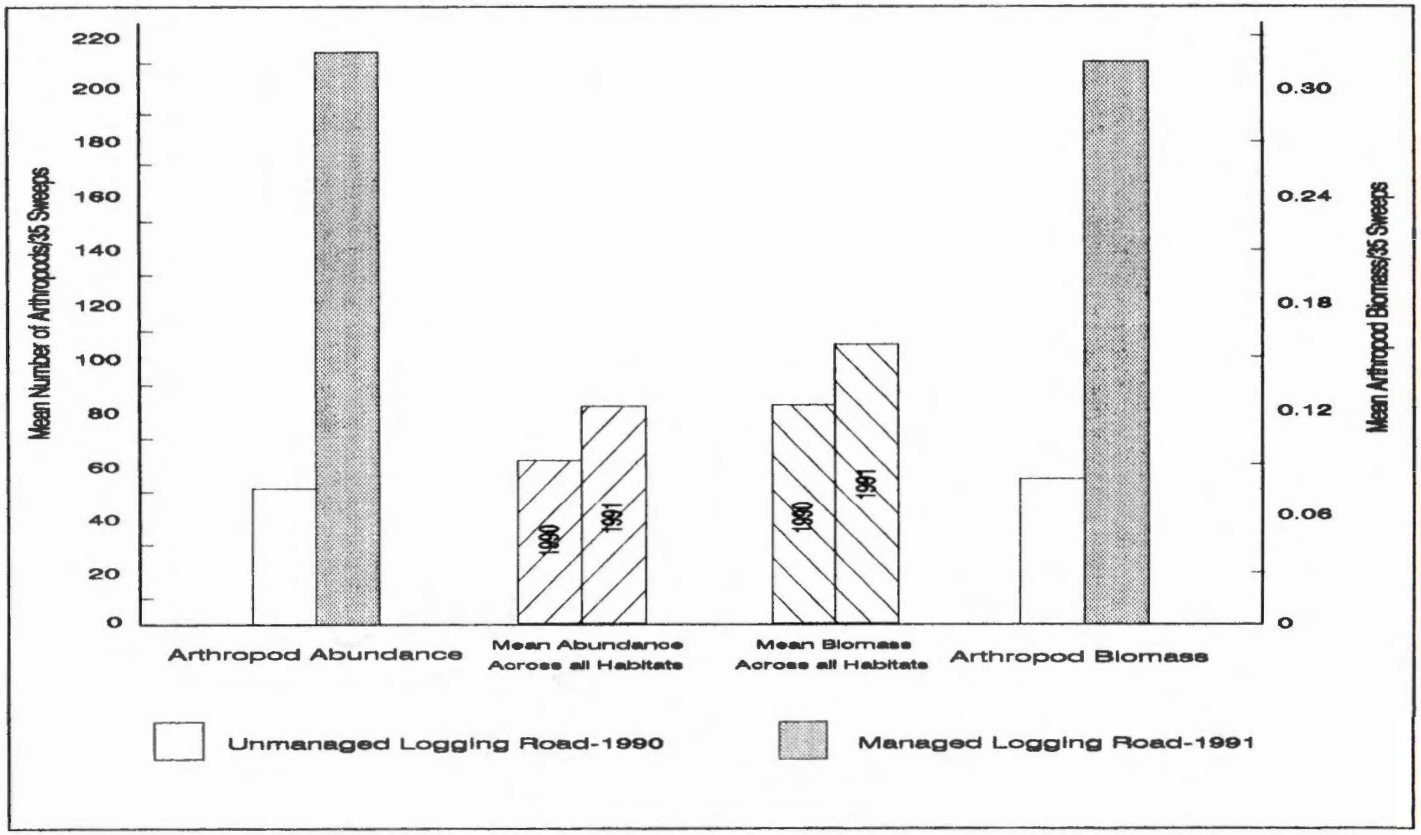

Figure 12. Comparison of mean arthropod abundance and biomass on a logging road converted from unmanaged to managed, June 1990-91, Cherokee National Forest, Tennessee.

High use of logging roads by chicks may result in increased predation (Gullion 1989). Establishing a soft edge near road borders providing chicks quick access to cover may help reduce their susceptibility to predation. Gating logging roads should reduce vehicle damage to wildlife plantings, and alleviate excessive human disturbance of wildlife, including poaching (Bailey et al. 1981).

Logging roads traversing areas of timber harvest provide grouse chicks with their preferred cover type in close proximity to excellent "insect catching grounds". Strategic location of clearcuts can also be beneficial to grouse broods. Forested sites containing good supplies of insects are those which contain abundant ground vegetation (Healy 1985). Stands with northerly aspects are those most likely to produce high quality herbaceous foliage (Pack et al. 1980). Consideration of slope when determining stands to be harvested is another management alternative. Both young ruffed grouse chicks and wild turkey poults tend to avoid steep sections within their range (Bump et. al 1947, Porath and Vons 1978, Rogers 1985). A management area providing good interspersion and juxtapositioning of a diversity of habitats is one most conducive to the production of ruffed grouse.

Literature Cited

LITERATURE CITED

Ahrens, C.D. 1988. Meteorology today: an introduction to weather, climate, and the environment. West Publishing Company, St. Paul, MN. 583 pp.

Bailey, R.W., J.R. Davis, J.E. Frampton, J.V. Gwynn, and J. Shugars. 1981. Habitat requirements of the wild turkey in the southeast piedmont. Pages 14-23 *in* P.T. Bromley and R.L. Carlton, eds. Proc. Symp. Habitat Requirements and Habitat Manage. for the Wild Turkey in the Southeast. Va. Wild Turkey Fed., Richmond.

Barber, H.L., R. Chambers, R. Kirkpatrick, J. Kubisiak, F.A. Servello, S.K. Stafford, D.F. Stauffer, and F.R. Thompson, III. 1989. Cover. Pages 294-319 *in* S. Atwater and J. Schnell, eds. Ruffed grouse. Stackpole Books, Harrisburg, PA. 370 pp.

Berner A., and L.W Gysel. 1969. Habitat analysis and management considerations for ruffed grouse for a multiple use area in Michigan. J. Wildl. Manage. 33:769-778.

Blackburn, W.E., J.P. Kirk, and J.E. Kennamer. 1975. Availability and utilization of summer foods by eastern wild turkey broods in Lee County, Alabama. Proc. Natl. Wild Turkey Symp. 3:86-96.

Blouin, D.C., and A.M. Saxton. 1990. General Linear Mixed Models (GLMM) Version 1.0 User's Manual. Dept. of Experimental Statistics. Louisiana State Univ. and Agric. and Mechanical College. Baton Rouge, LA. 24 pp.

Borror, D.J., D.M. De Long, and L.A. Triplehorn. 1981. An introduction to the study of insects. Saunders College Publishing, Philadelphia, PA. 827 pp.

Boyd, R.A. 1990. Population density and habitat utilization of ruffed grouse in the southern Appalachians. Master's Thesis, The Univ. of Tennessee, Knoxville. 95pp.

Bump, G., R.W. Darrow, F.C. Edminster, and W.F. Crissey. 1947. The ruffed grouse: life history, propagation, management. New York State Conserv. Dept. 915 pp.

Carpenter, J.R. 1936. Quantitative community studies of land animals. J. An. Ecol. 5:231-245.

Cole, J.C., and R.W. Dimmick. 1991. Distribution of ruffed grouse south of the range of quaking aspen. Proc. Annu. Conf. Southeast. Assoc. Fish and Wildl. Agencies. In Press.

Darrow, R.W. 1939. Seasonal food preferences of adult and of young grouse in New York State. Trans. North Am. Wildl. Conf. 4:583-590.

DeLong, D.M. 1932. Some problems encountered in the estimation of insect populations by the sweeping method. Ann. Ent. Soc. Amer. 25:13-17.

Epperson, R.G., Jr. 1988. Population status, movements and habitat utilization of ruffed grouse on the Catoosa Wildlife Management Area, Cumberland County Tennessee. Master's Thesis, The Univ. of Tennessee, Knoxville. 108pp.

Erikstad, K.E. and T.K. Spidso. 1982. The influence of weather on food intake, insect prey selection and feeding behavior in willow grouse in northern Norway. Ornis Scand. 13:176-182.

Godfrey, G.A. 1975. Home range characteristics of ruffed grouse broods in Minnesota. J. Wildl. Manage. 39:287-298.

Grace, R.A. 1942. The relationship of insect population with normal conditions of weather and vegetation in two test areas in Milwaukee county during the summer months. Master's Thesis, Marquette University. 40pp.

Gudlin, M.J., and R.W. Dimmick. 1984. Habitat utilization by ruffed grouse transplanted from Wisconsin to west Tennessee. Pages 75-88 *in* W.L. Robinson, ed. Ruffed Grouse Management: State of the Art in the Early 1980's. The North Central Section of the Wildlife Society, and The Ruffed Grouse Society.

Gullion, G.W. 1977. Forest manipulation for ruffed grouse. Trans. North Am. Wildl. Nat. Resour. Conf. 42:449-458.

_____. 1989. Managing the woods for the birds' sake. Pages 334-349 *in* S. Atwater and J. Schnell, eds. Ruffed grouse. Stackpole Books, Harrisburg, PA. 370 pp.

_____, and F.J. Svoboda. 1972. Aspen - the basic habitat resource for ruffed grouse. Pages 113-119 *in* U.S. For. Serv. Gen. Tech. Rep. NC-1.

Hale, P.E., A.S. Johnson, and J.L. Landers. 1982. Characteristics of ruffed grouse drumming sites in Georgia. J. Wildl. Manage. 46:115-123.

Healy, W.M. 1981. Habitat requirements of wild turkeys in the southeastern mountains. Pages 24-34 *in* P.T. Bromley and R.L. Carlton, eds. Proc. Symp. Habitat Requirements and Habitat Manage. for the Wild Turkey in the Southeast. Va. Wild Turkey Fed., Richmond.

_____. 1985. Turkey poult feeding activity, invertebrate abundance, and vegetation structure. J. Wildl. Manage. 49:466-472.

_____, and E.S. Nenno. 1983. Minimum maintenance versus intensive management of clearings for wild turkeys. Wildl. Soc. Bull. 11:113-120.

Hillhouse, T.L., and H.N. Pitre. 1974. Comparison of sampling techniques to obtain measurements of insect populations on soybeans. J. Econ. Entomol. 67:411-414.

Hungerford, K.E. 1957. Evaluating ruffed grouse foods for habitat improvement. Trans. N. Am. Wildl. Conf. 22:381-395.

Hurst, G.A., and B.D. Stringer, Jr. 1975. Food habits of wild turkey poults in Mississippi. Proc. Natl. Wild Turkey Symp. 3:76-85.

_____, and C.N. Owen. 1980. Effects of mowing on arthropod density and biomass as related to wild turkey brood habitat. Proc. Nat. Wild Turkey Symp. 4:225-232

Jones, L.F. 1979. Evaluation of a ruffed grouse restoration attempt on the western highland rim in Tennessee. M.S. Thesis. The University of Tennessee, Knoxville. 64 pp.

Judd, S.D. 1905. The grouse and wild turkeys of the United States and their economic value. USDA Biol. Survey Bull. 24.

Kalla, P.I., and R.W. Dimmick. 1987. Evaluation of a ruffed grouse reintroduction in Tennessee. Proc. Annu. Conf. Southeast. Assoc. Fish and Wildl. Agencies 41:365-372.

Kimmel, R.O., and D.E. Samuel. 1984. Implications of ruffed grouse brood habitat studies in West Virginia. Pages 89-108 *in* W.L. Robinson, ed. Ruffed Grouse Management: State of the Art in the Early 1980's. The North Central Section of the Wildlife Society, and The Ruffed Grouse Society.

King, R.D. 1969. Spring and summer foods of ruffed grouse on Vancouver Island. J. Wildl. Manage. 33:440-442.

Krusac, D.C., and E.D. Michael. 1979. Management of wildlife food plots: a regional comparison. Trans. Northeast Sect. Wildl. Soc. 36:88-96.

Kubisiak, J.F. 1978. Brood characteristics and summer habitats of ruffed grouse in central Wisconsin. Wis. Dept. of Nat. Resc., Tech. Bull. 108. Madison.

Longwitz, R.J. 1985. Some aspects of the ecology of ruffed grouse un unmanaged hardwood forests of the Cumberland Plateau, Tennessee. M.S. Thesis. The University of Tennessee, Knoxville. 114 pp.

Martin, D.D., and B.S. McGinnes. 1975. Insect availability and use by turkeys in forest clearings. Proc. Nat. Wild Turkey Symp. 3:70-75.

National Oceanic and Atmospheric Administration. 1990. Climatological data annual survey, Tennessee. U.S. Dept. of Comm., Asheville, N.C.

National Oceanic and Atmospheric Administration. 1991. Climatological data annual survey, Tennessee. U.S. Dept. of Comm., Asheville, N.C.

Nenno, E.S., and J.S. Lindzey. 1979. Wild turkey poult feeding activity in old field, agricultural clearings, and forest communities. Trans. Northeast Sect. Wildl. Soc. 36:97-109.

Norman, G.W., and R.L. Kirkpatrick. 1984. Foods, nutrition, and condition of ruffed grouse in southwestern Virginia. J. Wildl. Manage. 48:183-187.

Pack, J.C., R.P. Burkert, W.K. Igo, and D.J. Pybus. 1980. Habitat utilized by wild turkey broods within oak-hickory forests in West Virginia. Proc. Natl. Wild Turkey Symp. 4:213-224.

Pelren, E.C. 1991. Daily movement and habitat utilization of ruffed grouse in the Cherokee National Forest. M.S. Thesis. The University of Tennessee, Knoxville. 87 pp.

Porath, W.R., and P.A. Vons, Jr. 1972. Population ecology of ruffed grouse in northeastern Iowa. J. Wildl. Manage. 36:793-802.

Savory, C.J. 1977. The food of red grouse chicks (*Lagopus l. scoticus*). Ibis 119:1-9.

Seastedt, T.R., and D.A. Crossley, Jr. 1981. Microarthropod response following cable logging and clear-cutting in the southern Appalachians. Ecology 62:126-135.

Seehorn, M.E., R.F. Harlow, and M.T. Mengak. 1981. Foods of ruffed grouse from three location in the southern Appalachian Mountains. Proc. Ann. Conf. S.E. Assoc. Fish and Wildl. Agencies 35:216-224.

Servello, F.A., and R.L. Kirkpatrick. 1987. Regional variation in the nutritional ecology of ruffed grouse. J. Wildl. Manage. 51:749-770.

Southwood, T.R.E., and D.J. Cross. 1969. The ecology of the partridge, III. Breeding success and the abundance of insects in natural habitats. J. An. Ecol. 38:497-509.

Spidso, T.K. 1980. Food selection by willow grouse (*Lagopus lagopus*) chicks in northern Norway. Ornis Scand. 11:99-105.

_____, T.K., and O.H. Stuen. 1988. Food selection by capercaillie chicks in southern Norway. Can. J. Zool. 66:279-283.

Stafford, S.K., and R.W. Dimmick. 1979. Autumn and winter foods of ruffed grouse in the southern Appalachians. J. Wildl. Manage. 43:121-127.

Stewart, R.E. 1956. Ecological study of ruffed grouse broods in Virginia. Auk 73:33-41.

Stuen, O.H., and T.K. Spidso. 1988. Invertebrate abundance in different forest habitats as animal food available to capercaillie (*Tetrao urogallus*) chicks. Scand. J. For. Res. 3: 527-532.

Taylor, D.A. 1976. An analysis of some physical characteristics of ruffed grouse (*Bonasa umbellus*) drumming sites and logs in middle and eastern Tennessee. TWRA Tech. Rept. 75-25. 72pp.

Thompson, F.R., D.S. Freiling, and E.K. Fritzell. 1987. Drumming, nesting, and brood habitats of ruffed grouse in an oak-hickory forest. J. Wildl. Manage. 51:568-575.

USDA Forest Service. 1976. Cherokee National Forest timber management plan. Final environmental impact statement. USDA RS-R8 ADM-76-16. Cleveland, TN. 199 pp.

_____. 1985. Final land and resource management plan. Cherokee National Forest. Cleveland, TN.

Uvarov, B.P. 1931. Insects and Climate. Entomological Society of London, London, England. 247pp.

White, D.W., and R.W. Dimmick. 1978. Survival and habitat use of northern ruffed grouse introduced into west Tennessee. Proc. Ann. Conf. S.E. Assoc. Fish and Wildl. Agencies 32:1-7.

Whittaker, R.H. 1952. A study of summer foliage insect communities in the Great Smoky Mountains. Ecol. Monogr. 22:1-44.

APPENDIX

Table 4. Stand characteristics of clearcuts and mature hardwood plots, Tellico Ranger District, Cherokee National Forest, Monroe Co., Tennessee, 1990.

Stand	Compart.	Habitat Type	Forest Type	Stand Cond. Class	Under.	Year of Harvest	Area (ha)
11	70	1	56	13	5	1989	13
13	70	1	56	13	5	1988	12
16	70	1	81	13	5	1988	14
05	81	2	56	13	1	1982	4
09	81	2	56	13	1	1982	7
15	417	2	56	13	1	1979	13
06	81	3	56	13a	1	1977	16
08	417	3	56	13a	1	1975	10
14	80	3	81	11	1	1965	12
02	70	4	53	10	4	1918	50
07	81	4	56	10	4	1915	117
12	79	4	56	12	4	1928	18

Habitat Type
1 class I clearcut
2 class II clearcut
3 class III clearcut
4 mature hardwood

Forest Type
53 white oak-northern red oak-hickory
56 yellow poplar-white oak-northern red oak
81 sugar maple-beech-yellow birch

Understory
Herbaceous
1 forbs and vines
Trees
4 midstory species and/or good browse
5 regeneration overstory species

Stand Condition Class
10 mature sawtimber
11 immature poletimber
12 immature sawtimber
13 seedling and sapling adequately stocked
13a seedling and sapling adequately stocked, with some immature poletimber

Table 5. Comparison of arthropod abundance by week within habitat, June 1990-91, Cherokee National Forest, Tennessee.

Classification	Mean Number of Arthropods per 35 Sweeps ± S.E. (Logarithmic Scale)	
1990 (Habitat*Week)		
Class I Clearcuts*1-7 June	3.28 ± 0.22	A[a]
Class I Clearcuts*8-14 June	3.45 ± 0.21	A
Class I Clearcuts*15-21 June	3.43 ± 0.21	A
Class I Clearcuts*22-30 June	3.42 ± 0.21	A
Class II Clearcuts*1-7 June	3.63 ± 0.22	A
Class II Clearcuts*8-14 June	3.76 ± 0.21	A
Class II Clearcuts*15-21 June	3.84 ± 0.21	A
Class II Clearcuts*22-30 June	3.98 ± 0.21	B
Class III Clearcuts*1-7 June	3.80 ± 0.25	A
Class III Clearcuts*8-14 June	4.13 ± 0.21	B
Class III Clearcuts*15-21 June	4.09 ± 0.21	AB
Class III Clearcuts*22-30 June	4.38 ± 0.21	C
Mature Hardwood*1-7 June	4.41 ± 0.22	A
Mature Hardwood*8-14 June	4.48 ± 0.21	A
Mature Hardwood*15-21 June	4.38 ± 0.23	A
Mature Hardwood*22-30 June	4.51 ± 0.21	A
Unmanaged Logging Roads*1-7 June	4.32 ± 0.22	B
Unmanaged Logging Roads*8-14 June	4.00 ± 0.21	A
Unmanaged Logging Roads*15-21 June	4.24 ± 0.24	AB
Unmanaged Logging Roads*22-30 June	4.21 ± 0.21	AB
Managed Logging Roads*8-14 June	4.92 ± 0.18	B
Managed Logging Roads*15-21 June	4.14 ± 0.18	A
Managed Logging Roads*22-30 June	5.44 ± 0.18	B
1991 (Habitat*Week)		
Class I Clearcuts*1-7 June	4.04 ± 0.25	A
Class I Clearcuts*8-14 June	4.26 ± 0.25	A
Class I Clearcuts*15-21 June	4.32 ± 0.25	A
Class I Clearcuts*22-30 June	4.24 ± 0.27	A
Class II Clearcuts*1-7 June	4.33 ± 0.25	A
Class II Clearcuts*8-14 June	4.21 ± 0.25	AB
Class II Clearcuts*15-21 June	3.84 ± 0.32	BC
Class II Clearcuts*22-30 June	3.63 ± 0.27	C

Table 5. (cont.)

Classification	Mean Number of Arthropods per 35 Sweeps ± S.E. (Logarithmic Scale)	
Class III Clearcuts*1-7 June	4.19 ± 0.25	B
Class III Clearcuts*8-14 June	4.23 ± 0.25	B
Class III Clearcuts*15-21 June	3.69 ± 0.27	B
Class III Clearcuts*22-30 June	3.79 ± 0.25	A
Mature Hardwood*1-7 June	4.62 ± 0.25	AB
Mature Hardwood*8-14 June	4.72 ± 0.25	B
Mature Hardwood*15-21 June	4.40 ± 0.25	A
Mature Hardwood*22-30 June	4.87 ± 0.27	B
Unmanaged Logging Roads*1-7 June	4.43 ± 0.25	AB
Unmanaged Logging Roads*8-14 June	4.57 ± 0.25	B
Unmanaged Logging Roads*15-21 June	4.61 ± 0.25	B
Unmanaged Logging Roads*22-30 June	4.24 ± 0.25	A
Managed Logging Roads*1-7 June	4.96 ± 0.22	A
Managed Logging Roads*8-14 June	5.11 ± 0.22	AB
Managed Logging Roads*15-21 June	4.95 ± 0.22	A
Managed Logging Roads*22-30 June	5.24 ± 0.22	B

[a] Means in each block not followed by same capital letter are significantly different ($P \leq 0.10$)

Table 6. Common names of arthropods in taxa analyzed.

Common Name	Scientific Taxa
harvestmen, spiders, and mites	Arachnida
beetles	Coleoptera
flies	Diptera
true bugs	Hemiptera
aphids, hoppers, and leafhoppers	Homoptera
ants, bees, sawflies, and wasps	Hymenoptera
moths and butterflies	Lepidoptera
crickets, grasshoppers, katydids, mantids, and walking sticks	Orthoptera

Table 7. Comparison of arthropod biomass by week within habitat, June 1990-91, Cherokee National Forest, Tennessee.

(Habitat*Week)	Mean Arthropod Biomass (g) per 35 Sweeps ± S.E.	
Class I Clearcuts*1-7 June	0.100 ± 0.039	A[a]
Class I Clearcuts*8-14 June	0.079 ± 0.038	A
Class I Clearcuts*15-21 June	0.089 ± 0.039	A
Class I Clearcuts*22-30 June	0.084 ± 0.040	A
Class II Clearcuts*1-7 June	0.106 ± 0.040	A
Class II Clearcuts*8-14 June	0.066 ± 0.038	A
Class II Clearcuts*15-21 June	0.068 ± 0.041	A
Class II Clearcuts*22-30 June	0.095 ± 0.040	A
Class III Clearcuts*1-7 June	0.136 ± 0.041	ABC
Class III Clearcuts*8-14 June	0.154 ± 0.039	C
Class III Clearcuts*15-21 June	0.104 ± 0.040	A
Class III Clearcuts*22-30 June	0.109 ± 0.038	AB
Mature Hardwood*1-7 June	0.169 ± 0.039	BC
Mature Hardwood*8-14 June	0.160 ± 0.039	B
Mature Hardwood*15-21 June	0.111 ± 0.040	A
Mature Hardwood*22-30 June	0.139 ± 0.040	AB
Unmanaged Logging Roads*1-7 June	0.246 ± 0.040	B
Unmanaged Logging Roads*8-14 June	0.132 ± 0.039	A
Unmanaged Logging Roads*15-21 June	0.148 ± 0.040	A
Unmanaged Logging Roads*22-30 June	0.110 ± 0.039	A
Managed Logging Roads*1-7 June	0.241 ± 0.037	A
Managed Logging Roads*8-14 June	0.207 ± 0.034	A
Managed Logging Roads*15-21 June	0.201 ± 0.034	A
Managed Logging Roads*22-30 June	0.328 ± 0.034	B

[a] Means in each block not followed by same capital letter are significantly different (P≤0.10)

Table 8. Mean arthropod abundance and biomass on unmanaged logging roads traversing mature hardwood, unmanaged logging roads traversing clearcuts, managed logging roads dominated by orchard grass, and managed logging roads dominated by clover, June 1990-91, Cherokee National Forest, Tennessee.

	Mean Arthropod Abundance ± S.E. per 35 Sweeps (Logarithmic Scale)	Mean Arthropod Biomass (g) per 35 Sweeps
Unmanaged logging roads traversing mature hardwood	4.26 ± 0.06	0.167 ± 0.030
Unmanaged logging roads traversing clearcuts	4.38 ± 0.06	0.161 ± 0.034
Managed logging roads dominated by orchard grass	4.67 ± 0.08	0.385 ± 0.022
Managed logging roads dominated by clover	5.22 ± 0.10	0.203 ± 0.018

Table 9. Mean arthropod abundance within taxa on unmanaged logging roads traversing mature hardwood, unmanaged logging roads traversing clearcuts, managed logging roads dominated by orchard grass, and managed logging roads dominated by clover, June 1990-91, Cherokee National Forest, Tennessee.

Classification	Mean Number of Arthropods per 35 Sweeps ± S.E. (Square Root Scale)
Unmanaged logging roads traversing mature hardwood	
Hemiptera	2.53 ± 0.14
Homoptera	3.81 ± 0.24
Coleoptera	2.42 ± 0.15
Lepidoptera	1.55 ± 0.07
Diptera	4.85 ± 0.23
Hymenoptera	2.96 ± 0.15
Orthoptera	2.16 ± 0.16
Arachnida	2.43 ± 0.11
Unmanaged logging roads traversing clearcuts	
Hemiptera	3.01 ± 0.16
Homoptera	4.74 ± 0.26
Coleoptera	2.63 ± 0.16
Lepidoptera	1.69 ± 0.08
Diptera	4.70 ± 0.25
Hymenoptera	2.95 ± 0.16
Orthoptera	2.35 ± 0.18
Arachnida	2.18 ± 0.13
Managed logging roads dominated by orchard grass	
Hemiptera	3.16 ± 0.43
Homoptera	5.66 ± 0.34
Coleoptera	2.69 ± 0.18
Lepidoptera	1.84 ± 0.08
Diptera	5.73 ± 0.39
Hymenoptera	2.78 ± 0.16
Orthoptera	3.57 ± 0.22
Arachnida	2.09 ± 0.15

Table 9. (cont.)

Classification	Mean Number of Arthropods per 35 Sweeps ± S.E. (Square Root Scale)
Managed logging roads dominated by clover	
Hemiptera	7.42 ± 0.54
Homoptera	7.53 ± 0.42
Coleoptera	3.47 ± 0.23
Lepidoptera	2.12 ± 0.10
Diptera	9.29 ± 0.49
Hymenoptera	3.71 ± 0.20
Orthoptera	3.10 ± 0.28
Arachnida	2.99 ± 0.20

VITA

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