RUFFED GROUSE NATALITY, CHICK SURVIVAL, AND BROOD MICRO-HABITAT SELECTION IN THE SOUTHERN APPALACHIANS

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(ABSTRACT)

Natality characteristics were calculated for 3 regions in the southern Appalachians (Ridge and Valley, Alleghany Plateau, and Ohio River Valley). I report data collected in the first 2 years of a long term ($\geq$ 6 years) study conducted by the Appalachian Cooperative Grouse Research Project (ACGRP). Nesting rate, pooled over all regions, was 83.6% in 1997 and 79.7% in 1998. In the 2-year period, the Alleghany Plateau reported the highest nesting rate (97.6%) while the Ohio River Valley reported the lowest rate (54.2%). Overall hen success rates were 81.5% in 1997 and 56.9% in 1998. Yearling hen success rates were as high or higher than adults. Adult hen success was 85.7% in 1997 and 48.5% in 1998; yearling hen success was 86.7% in 1997 and 82.3% in 1998. Additionally, I found a lower renest rate (6% over 2 years) in the southern Appalachians than previous studies have reported. The mean first-nest clutch size in the southern Appalachian region was considerably lower (9.5, years and regions pooled) than that reported for other portions of ruffed grouse range. Recommendations are given on how ACGRP natality data collection may be improved in upcoming years.

Ruffed grouse chick survival estimates were calculated from data collected in the first 2 years of a long term ACGRP study as well as data collected separate from ACGRP protocol. First-week chick survival estimates ranged from 0.18 to 0.32 in 1997 and 0.45 to 0.48 in 1998. Late brood season survivorship values (0.11-0.13 at week 5, 0.07 at week 10) were considerably lower in the southern Appalachians than those reported from more northern portions of ruffed grouse range. Additionally, the mean number of chicks per brood in July was lower in the southern Appalachians than that reported in the Great Lakes region during July and August. Recommendations are given on how ACGRP chick count data collection may be improved in upcoming years.

I compared micro-habitat characteristics at known brood locations with randomly selected locations to determine which characteristics are selected by ruffed grouse hens and broods in the southern Appalachians. In the first half of the brood season (weeks 1-6) hens and

broods selected sites with tall, complete, vegetative ground cover. Additionally, broods selected forested sites with a well-developed canopy, rather than areas affected by large canopy gaps or openings. Higher ground cover at brood sites may have been due to a lack of midstory structure. The abundance of arthropods, fruit, and forage at brood flush sites was higher during the first few weeks of the brood season; this was possibly due to flush sites being located in open, mid-age or mature forest. Several authors have speculated that as the chicks' diet shifts from primarily arthropods to fruit and forage at approximately 3 weeks of age, the habitat selected by hens and their broods may change to accommodate this dietary shift. In my study, a change in habitat selection did not occur between weeks 3 and 4 as expected but after week 6 and may indicate the chicks' dietary shift occurs later than some have predicted.

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PREACE AND RESEARCH JUSTIFICATION

The range of the ruffed grouse (*Bonasa umbellus*) extends east from Alaska to central and southern Canada, and south to the central Rocky Mountains and southern Appalachian Mountains. Throughout southern Canada and the Great Lakes region, ruffed grouse densities are higher than at the extreme portions of its range (Bump et al. 1947). Many authors have attributed ruffed grouse success in this region to its close association with aspen (*Populus* spp.) (Gullion and Svoboda 1972, Gullion 1977, Kubisiak et al. 1980, Kubisiak 1985). As a result of its abundance and popularity as a game bird, much research has been conducted on ruffed grouse ecology in the Great Lakes region.

In the southern portions of its range, ruffed grouse hunting is popular, though population densities are lower than in the North. Aspen, an important food source during winter and spring in the North, is uncommon or nonexistent in many portions of the southern ruffed grouse range. Apart from this, the factors limiting ruffed grouse populations in the southern range are not well understood. Public concern over declining grouse populations in the southern Appalachians has heightened the need for research. In Virginia, researchers concluded ruffed grouse populations have stabilized at a low density following a decline in 1992 (Norman and Steffen 1995). In southern Ohio, low grouse abundance has been attributed to the maturing of abandoned farmland and associated woodlots (Swanson and Stoll 1995). Similarly, maturing forests were the suggested cause of declining grouse habitat in West Virginia (Allen 1995).

In 1996, the Appalachian Cooperative Grouse Research Project (ACGRP) was formed to investigate ruffed grouse population ecology in the Appalachian region. At its conception, the ACGRP was a consortium of 5 states – Virginia, West Virginia, Kentucky, Ohio, and Maryland, and 8 research sites were distributed among these states. Sites in Pennsylvania (1998), North Carolina (1999), and a third in Virginia (1998) were later added. The objectives of the ACGRP were to 1) understand the population ecology of ruffed grouse in the region, 2) determine the additive or compensatory impact of hunting, 3) determine the additive or compensatory impact of late-season hunting, and 4) develop population models integrating natural and hunting mortality, habitat availability and suitability, and other identified influences on ruffed grouse (Norman 1996).

My project was designed to investigate one aspect of ruffed grouse population ecology in the southern Appalachians, specifically, natality, chick survival, and brood micro-habitat selection. These topics have been studied by many authors in northern states and southern Canada (Bump et al. 1947, Berner and Geysel 1969, Cringan 1970, Porath and Vohs 1972, Godfrey 1975, Kubisiak 1978, Maxon 1978, Small et al. 1996, Larson 1998). In the southern Appalachians, however, relatively little work has been done to describe brood habitat or estimate natality characteristics and chick survival rates.

The objectives of this project were

1) to estimate natality characteristics for ruffed grouse hens in the southern Appalachians
2) to determine the timing and extent of ruffed grouse chick mortality in the southern Appalachians
3) to determine if brood habitat selection occurs and, if so, whether the criteria for selection changes over the brood period
4) to determine if ACGRP data were being collected in the correct format and at the correct time so that they are usable in analyses to accomplish the objectives of the long-term ACGRP study.

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STUDY AREA

In 1997, data were collected at 8 study sites in 5 states (Ohio, Maryland, West Virginia, Virginia, and Kentucky), and in 1998 a ninth site was added in Virginia (Table 0.1). During the 2 years of the study, all sites provided natality and chick survival data, but brood habitat data were collected at only 3 of these sites (VA/2, VA/3, WV/2). The 9 study sites are distributed within the Ridge and Valley and Alleghany Plateau physiographic provinces, subregions of the Southern Appalachian Hardwood Forest region (Fenneman 1938, Smith 1995). Forests in this region underwent major harvests during the late 19th and early 20th centuries and are primarily second-growth (Smith 1995). The present species composition has been shaped by disturbance events such as wildfire, chestnut blight, Dutch elm disease, selective forest-stand harvesting, and gypsy moth infestation (Smith 1995).

A wide geographic distribution of study sites offered an opportunity to determine if regional variation existed among grouse populations in the southern Appalachians. For this purpose, study areas were grouped into the following regions: Ridge and Valley, Alleghany Plateau, and Ohio River Valley. Though the Ohio River Valley sites are located in the extreme western portion of the Alleghany Plateau Province, they differ in topography, land cover characteristics, and ownership from other sites in that region and were considered a separate, third region.

Ridge and Valley Region

Four study areas were located in the Ridge and Valley region: VA/1, VA/2, VA/3, and WV/2 (Table 0.1). This region is characterized by long, southwest-to-northeast tending ridges and interrupted, shorter ridges and hills (Fenneman 1938). Ridgetops and mountain summit elevations generally range from 900 to 1,500 m. The major forest type of this region is the Oak-Chestnut (*Quercus-Castanea*) community, though the oak-chestnut association no longer exsists (Braun 1974). Tree species common in valleys include American beech (*Fagus grandifolia*), eastern hemlock (*Tsuga canadensis*), tulip poplar (*Liriodendron tulipifera*), northern red oak (*Quercus rubra*), white oak (*Q. alba*), red maple (*Acer rubrum*), sugar maple (*A. saccharum*), basswood (*Tilia americana*), hickory (*Carya* spp.), and black gum (*Nyssa sylvatica*) (Braun 1974). Slopes and ridgetops are characterized by chestnut oak (*Quercus prinus*), red oak, black oak (*Q. velutina*), bear oak (*Q. ilicifolia*), and sweet birch (*Betula lenta*) (Braun 1974). Virginia pine (*Pinus virginiana*) and pitch pine (*P. rigida*) are commonly found on dry slopes in this region (Harlow et al. 1996). Major shrubs include witch hazel (*Hamamelis virginiana*), mountain laurel (*Kalmia latifolia*), rhododendron (*Rhododendron* spp.), and azalea (*Azalea* spp.) (Braun 1974). Common understory species include striped maple (*Acer pensylvanicum*) and service-berry (*Amelanchier arborea*). In the southern portion of the Oak-Chestnut region, mixed-mesophytic coves are common and include beech, hemlock, buckeye (*Aesculus* spp.), basswood, and bitternut hickory (*Carya cordiformis*) (Braun 1974).

All study areas in the Ridge and Valley region are characterized by large tracts of contiguous forest, interspersed with regenerating hardwood clearcuts, clearings maintained for wildlife, or both. The VA/1 study area is located in Augusta County, Virginia, within a portion of the Jefferson-George Washington National Forest. The site is approximately 2,000 ha in size and managed by the U. S. Forest Service. The VA/2 study site is located in Botetourt County, Virginia. This site is approximately 6,000 ha and owned by Westvaco Corporation. The VA/3 study site is located at the Clinch Mountain Wildlife Management Area in Smyth and Washington Counties, Virginia. It is approximately 10,000 ha in size and managed by the Virginia Department of Game and Inland Fisheries (VDGIF). The WV/1 study site is located in Greenbrier County, West Virginia. This site is located on Westvaco Corporation property and is approximately 2,400 ha in size.

Alleghany Plateau Region

Three study sites are located in the Alleghany Plateau region: MD/1, WV/1, and KY/1 (Table 0.1). The Alleghany Plateau is an expansive region that is generally higher on its eastern margin than in the west (Fenneman 1938). In the east, mountains and ridges rise to 1,000-1,350 m; in the western portion of the region elevations above 350 m are uncommon and relief is $\leq$ 300 m (Fenneman 1938). The major forest type of this region is the mixed mesophytic community, typified by a variety of dominant trees, including American beech, tulip poplar, basswood, sugar maple, buckeye, red oak, white oak, and hemlock (Braun 1974:40). Other important canopy species include sweet birch, black cherry (*Prunus serotina*), cucumber tree (*Magnolia acuminata*), white ash (*Fraxinus americana*), red maple, black gum, and the hickories. Important understory trees in this community include flowering dogwood (*Cornus florida*), sourwood (*Oxydendrum arboreum*), striped maple, redbud (*Cercis canadensis*), ironwood (*Carpinus caroliniana*), hop hornbeam (*Ostrya virginiana*), and service-berry. Common shrubs of this community include witch hazel and spicebush (*Lindera benozin*) (Braun 1974:40-43).

All study sites in the Alleghany Plateau region are generally characterized by large tracts of contiguous forest, interspersed with regenerating hardwood clearcuts, clearings maintained for wildlife, or both. At MD/1, grouse were trapped at Garrett State Forest (approximately 3,240 ha) and Mount Nebo Wildlife Management Area (approximately 730 ha), Garrett County, Maryland. In addition to these sites, radio-collared grouse were located at Swallow Falls State Park (approximately 120 ha), Herrington State Park (approximately 140 ha), and privately owned property immediately adjacent to these sites. WV/1 is located at the Westvaco Wildlife and Ecosystem Research Forest, in Randolph County, West Virginia. This site is approximately 3,400 ha and owned by Westvaco Corporation. KY/1 is located at Yatesville Lake Wildlife Management Area, in Lawrence County, Kentucky. This site is approximately 6,100 ha and owned by the U. S. Army Corps of Engineers but managed by the Kentucky Department of Fish and Wildlife Resources.

Ohio River Valley Region

Two study sites occur in this region: OH/1 and OH/2 (Table 0.1). The Ohio River Valley region is located at the extreme western portion of the Alleghany Plateau physiographic province and is characterized by generally level plain and low hills, most under 300 m in elevation (Fenneman 1938). The major forest type in this region is mixed mesophytic and is described above (Braun 1974). Both sites are managed by the Ohio Division of Wildlife; OH/1 is located at the Woodbury Wildlife Management Area (approximately 7,700 ha) in Coshocton County, Ohio and OH/2 is located at the Waterloo Wildlife Management Area (approximately 600 ha) in Athens County, Ohio. Additionally, grouse were trapped and tracked at the Zaleski State Forest (approximately 11,000 ha), adjacent to the OH/2 site. The Zaleski State Forest is managed by the Ohio Division of Forestry. The Ohio River Valley sites are characterized by highly fragmented land cover and offer a variety of habitats including mature forest, regenerating forest, agriculture, and development. Additionally, Ohio River Valley sites are fragmented by land ownership; the study areas include various public- and privately-owned properties.

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Table 0.1. Study sites involved with the ACGRP study, 1997-1998.

Site	Years of Involvement	Location
Ridge and Valley Region		
VA/1	1998	Augusta County, VA
VA/2	1997/1998	Botetourt County, VA
VA/3	1997/1998	Smyth and Washington counties, VA
WV/2	1997/1998	Greenbrier County, WV
Alleghany Plateau Region		
MD/1	1997/1998	Garrett County, MD
WV/1	1997/1998	Randolph County, WV
KY/1	1997/1998	Lawrence County, KY
Ohio River Valley Region		
OH/1	1997/1998	Coshocton County, OH
OH/2	1997/1998	Athens County, OH

CHAPTER 1

RUFFED GROUSE NATALITY IN THE SOUTHERN APPALACHIANS: A 2-YEAR SUMMARY OF THE *APPALACHIAN COOPERATIVE GROUSE RESEARCH PROJECT*

Understanding natality, or the number of young that are born or hatched into a population, is important for those wishing to manage wildlife populations. Although estimates of ruffed grouse natality characteristics are available for many portions of the species' range, few data exist for the southern Appalachians. Ruffed grouse densities are lower here than in the core of its range (Bump et al. 1947), and identifying differences in natality characteristics between these 2 regions may help explain why grouse populations in the southern Appalachians are lower. The objective of this report is to calculate natality characteristics from data collected in the southern Appalachians. This chapter summarizes the first 2 years of data from our long-term ($\geq$ 6 years) cooperative research project.

Data were collected by cooperators working with the Appalachian Cooperative Grouse Research Project (ACGRP) during 1997 and 1998. These data are presented here to summarize the efforts to date and provide a review of data collection procedures. Large cooperative projects involving many data collectors in several states must contend with the challenge of standardizing methodology and communicating procedural changes effectively. In light of this, a secondary objective of this report is to determine if natality data were being collected in the correct format and at the correct time so that they are usable in analyses to accomplish the objectives of the long-term ACGRP study.

METHODS

Study Sites

All study sites involved in the ACGRP during spring-summer 1997 and/or 1998 provided data for this report (Table 0.1).

Trapping

Ruffed grouse hens were captured each fall and spring during 1996-1998. Typically, 2 lily-pad traps were used, joined by a chicken-wire drift-fence (Gullion 1965). Traps were located in areas accessible by roads where grouse had been previously seen or in areas deemed suitable habitat.

Sex and age-class (juvenile or adult) were determined for each captured bird using methodology described by Davis (1969) and Roussel and Ouellet (1975). A necklace-style 10-

11 g radio-transmitter (Advanced Telemetry Systems, Isanti, MS) was fitted around the neck of each captured bird, with the weight of the unit resting on the region of the crop. Transmitters were equipped with an 8-hour mortality mode (rapid pulse signal), operated in the 150-152 Mhz range, and had a life expectancy $\geq$ 1 year. Most birds were released within 15 m of the trap site and < 1/2 hour after being removed from the trap.

Monitoring

Prior to the nesting season (i.e., before approximately April 1), each radio-tagged hen was monitored at least twice each week by field personnel. A 3-element Yagi or "H-type" antenna and portable receiver (Advanced Telemetry Systems, Isanti, MS; Telonics, Inc., Mesa, AZ) were used to monitor hens from fixed telemetry stations located by a global positioning system (GPS) unit (Corvallis MicroTechnology, Inc., Corvallis, OR). Observers plotted 3-5 fixes in the field on U. S. Geological Survey 7.5 minute topographic maps and identified the 3 azimuths with best agreement.

Hens with transmitters emitting a mortality signal were recovered as quickly as possible after detection of the mortality mode. Most mortalities were recovered within 3 days and the cause of death could be determined. The cause of each mortality was determined by the condition and location of the carcass, as well as the presence of relevant field signs (predator feces, raptor pellets, tracks, etc.). If the hen was nesting, an attempt was made to find the nest and the condition of the nest and eggs were noted.

Hens were assumed to have begun nesting when 4-5 estimated locations were consistently within approximately 100 m of each other. Hatch date was estimated to be 41 days after nesting was assumed to have begun; this accounts for a 17-day egg-laying period and 24-day incubation. Incubating hens were located from a distance using binoculars or triangulated using radio-telemetry from marked locations 10-30 m from the nest. When incubating hens were inadvertently flushed from nests, the clutch size was noted and the nest location flagged several meters from the nest. During the estimated last week of incubation, most hens were located more than twice each week, some as much as daily, to detect the day the hen and brood left the nest. After hatch, eggshell fragments were examined to determine clutch size, and the number of unhatched eggs was noted.

Data Analysis

Nesting rate (proportion of hens nesting), hen success rate (proportion of hens with nests hatching ≥ 1 chick), hatching success rate (proportion of eggs hatching from successful nests), mean first-nest clutch size, and mean first-nest hatch day were calculated for each region (Alleghany Plateau, Ohio River Valley, Ridge and Valley) in the ACGRP study. Researchers at several study sites had difficulty trapping sufficient ruffed grouse hens for calculation of reliable natality characteristics. Therefore, averaging mean values across study sites in each region often produced regional results biased by the equal weight inappropriately given to sites with low sample sizes. To minimize the bias caused by sites with disproportionally low samples, results for each region were calculated from values pooled across all sites in that region (i.e., all data from separate study sites combined as if from 1 site) for this report.

For the purposes of this report, birds captured in the fall or early spring immediately prior to the nesting season and classified as juveniles at that time are referred to as "yearlings." All other captured birds were classified as adults. To determine if hen age affects natality, natality characteristics were calculated separately for adult (> 1 year of age at nesting season) and yearling (< 1 year of age at nesting season) age classes.

Nesting, hen success, and hatching success rates were compared by year, region, and age-class using Z-tests. Mean clutch size and hatch date of first nests were compared by year, region, and age-class using 2-sample *t*-tests.

A secondary objective of this report was to determine if natality data were being collected in the correct format and at the correct time so that they are usable in analyses to accomplish the objectives of the long-term ACGRP project. When large amounts of field data are being collected in a short period of time by many busy cooperators, the possibility exists that a portion of these data is not collected or is improperly reported. This often results in lost data, a reduction of sample size, and, hence, reduced power in statistical analysis. This 2-year review provided an excellent opportunity to determine which natality characteristics were most affected by lost data and to recommend how ACGRP collection procedures may be improved to alleviate these problems in the future. To determine which characteristics have been affected by lost data, I calculated the proportion of potential data that was actually collected and used to calculate each natality characteristic. Recommendations also are given to improve data collection.

RESULTS

One hundred and thirty-six radio-collared hens entered the 1997 (n=67) and 1998 (n=69) nesting seasons across all 3 regions (Table 1.1). In 1997 and 1998 combined, 41 hens were radio-collared in the Alleghany Plateau region, 24 in the Ohio River Valley region, and 71 in the Ridge and Valley region (Table 1.1).

Natality Characteristics

Nesting rate, pooled over all regions, was 83.6% in 1997 and 79.7% in 1998 (Table 1.1). There were no differences between the 1997 and 1998 nesting rates within regions (Z = 0.97-1.31, *P* = 0.19-0.327); however, overall differences existed between regions. The Alleghany Plateau had nesting rates that were higher over the 2-year period than the Ohio River Valley (Z = 4.36, *P* = < 0.001) and Ridge and Valley (Z = 2.45, *P* = 0.01) regions. Also, the Ohio River Valley region's nesting rates were lower than the Ridge and Valley's rates (Z = 2.68, *P* = 0.01) in the 2-year period. There were no differences in nesting rates between age-classes in 1997 (Z = 0.80, *P* = 0.43) or 1998 (Z = 1.48, *P* = 0.14) (Table 1.2).

Hen success rate, pooled over all regions, was 81.5% in 1997 and 56.9% in 1998 (Table 1.1). In 1997 and 1998, hen success was consistent in the Alleghany Plateau region (Z = 0.14, *P* = 0.89); however, both the Ohio River Valley (Z = 2.13, *P* = 0.03) and the Ridge and Valley (Z = 2.72, *P* = 0.006) regions experienced declines in hen success between 1997 and 1998 (Table 1.1). Hen success rates among yearlings and adults were similar (Z = 0.09, *P* = 0.92) in 1997 (Table 1.2). In 1998, however, adult hen success rates were lower (Z = 2.31, *P* = 0.02) than yearling rates.

Lower hen success in 1998 was attributed to a high incidence of hen predation (12.0%, regions pooled) and nest depredation (23.5%, regions pooled) (Table 1.3). Nest depredation rates increased between 1997 and 1998 in the Ohio River Valley (Z = 1.96, *P* = 0.05) and Ridge and Valley (Z = 2.24, *P* = 0.03) regions but not in the Alleghany Plateau (Z = 1.51, *P* = 0.13). Nest depredation rates were similar between age-classes in 1997 (Z = 0.56, *P* = 0.58) and 1998 (Z = 0.49, *P* = 0.62) (Table 1.4). In 1998, however, the incidence of hen predation was higher (Z = 1.86, *P* = 0.06) among adults. In the 2 years of this study, only 4 nests appeared to have been abandoned, and all of these were nests of adult hens.

Pooled aver all 3 regions, hatching success was 95.5% in 1997 and 92.5% in 1998 (Table 1.5) Hatching success was consistent within all regions (Z = 0.48-1.58, *P* = 0.11-0.63) between

1997 and 1998. Hatching success rates were similar between age-classes in 1997 (Z = 0.31, P = 0.76) and higher for yearlings (Z = 1.69, P = 0.09) in 1998 (Table 1.6). Mean first-nest clutch size, pooled over all regions, was 9.6 in 1997 and 9.3 in 1998 (Table 1.5). Although mean clutch sizes were similar in the Ohio River Valley (t = 1.14, 9 df, P = 0.28) and Ridge and Valley (t = 1.46, 24 df, P = 0.16) regions between 1997 and 1998, mean clutch size increased in the Alleghany Plateau region (t = 1.93, 21 df, P = 0.07) during this period. However, in the 2-year period no region appeared to have a consistently higher mean clutch size than other regions. Clutch sizes were similar between age classes in 1997 (t = 1.31, 26 df, P = 0.20) and 1998 (t = 0.07, 30 df, P = 0.20) (Table 1.6).

The 2-year mean first-nest hatch date, pooled over all regions was May 25 (Table 1.7). Hatch dates were consistent between 1997 and 1998 in the Ohio River Valley (t = 0.22, 5 df, P = 0.84) and Ridge and Valley (t = 0.05, 24 df, P = 0.96) regions, but in the Alleghany Plateau the mean hatch date was later in 1997 than 1998 (t = 2.00, 11 df, P = 0.07). Overall, hatch dates were similar among age-classes (t = 0.14, 60 df, P = 0.89) (Table 1.8). First-nest hatch dates ranged from May 10th - June 19th in 1997 and May 12th - June 7th in 1998 (Figure 1.1). Only 2 renests were reported over the 2-year period and both were successful. In 1997, a renest hatched July 1 in West Virginia, and in 1998 a renest hatched on June 6 in Ohio.

Data Collection

In 1997, nearly all of the potential data for the calculation of nesting rates and hen success were actually collected and used (Table 1.9). However, only 58% of the potential data for the calculation of hatching success and clutch size were actually collected by cooperators in 1997. In 1998, there was little change in the amount of potential nesting rate and hen success data collected, and the percent of potential data for hatching success and mean clutch size calculation increased considerably (Table 1.9).

DISCUSSION

Natality Characteristics

Although nearly all hens attempted to nest in the Alleghany Plateau in 1997 and 1998, the nesting rates in the other 2 regions, particularly those in the Ohio River Valley, were lower than nesting rates other authors have reported. However, results from the Ohio River Valley may have been affected by a low sample size in both years. Most authors have reported nearly all ruffed grouse hens in their studies attempted a first nest (Bergerud 1988:580). In one study in

Minnesota, all 15 radio-tracked hens nested (Maxson 1978). In Wisconsin, Small et al. (1996) reported all 23 hens in their study initiated a first clutch. Bump et al. (1947) speculated nesting rates ranged from 75 to 100% in any given year, but could not verify this with data. Bergerud (1988:581) speculated that all females should breed because the lifespan of grouse is too short to make a nesting delay beneficial.

In our study, the overall 1997 hen success rate (81.5%, regions pooled) was considerably higher than rates reported elsewhere. In New York, 58% of over 5,400 nests were successful and all of these were believed to be first nests (Bump et al. 1947). In Wisconsin, 59% of 22 first nests were successful (Maxson 1978). In another Wisconsin study, 10 of 21 hens (48%) had a successful first nest (Small et al. 1996). Although these studies report first nest success and I report hen success (combining first-nest and renest data), I believe my results are comparable because only one hen was known to renest in the present study during 1997. Therefore, the results of this study primarily (53 of 54 hens) represent first nest success.

Despite higher rates in 1997, our 1998 data do not support the conclusion that hen success rates are consistently higher in the southern Appalachians than in more northern portions of ruffed grouse range. In 1998, our regionally pooled hen success rate was similar to rates reported in New York and Wisconsin. Therefore, our 1997 rates may reflect a year of higher than average hen success in the Ohio River Valley and Ridge and Valley regions. However, it is also possible that our observed hen success in the southern Appalachians is usually higher than that in more northern areas and 1998 was a below average year. Data from ongoing ACGRP research should clarify this in future years.

Annual variation in nest success rates (or in the case of this report, hen success) has been observed in grouse by other authors (Bergerud 1988: 599). After reviewing several studies on all species of North American grouse, Bergerud (1988:609) suggested nest success declines when the proportion of yearlings in a population increases. He argued that nest success would be higher in a population with fewer yearlings because they are inexperienced nesters and, therefore, less successful (Bergerud 1988: 599). In our study, yearlings had hen success rates as high or higher than adult hens during both 1997 and 1998. Therefore, my results give no evidence that yearlings are less capable of completing nests successfully.

Bergerud (1988: 594) also suggested that annual variation in nest success may be due to varying nest predation rates. Furthermore, he believed grouse in the southern latitudes of North

America appear to be limited by predation of nests and hens because there is a higher diversity and abundance of nest predators and the proportion of nests destroyed by predators is greater than in northern latitudes. In our study, predation rates did vary between 1997 and 1998. In 1997, hen success was considerably higher than that previously reported, and this was due to a low incidence of hen predation (5.7%, regions pooled) and nest depredation (9.3%, regions pooled). In 1998, increased hen predation (12.0%, regions pooled) and nest depredation (23.5%, regions pooled) was reflected by a drop in hen success. Pooled over all regions and years, the nest depredation rate in our study (16.2%) is still lower than those reported elsewhere. In New York, Bump et al. (1947) reported an average 34% of nests were lost to predators over 13 years. In central Pennsylvania, 22% of artificial nests were disturbed by predators (Yahner et al. 1993). In previous studies done on the same site in central Pennsylvania, nest disturbance by predators ranged from 32-42% (Yahner et al. 1993). In an artificial nest study done in western Virginia, Hewitt (1994) reported predation rates of nearly 20% after 20 days of exposure. Hewitt (1994) suggested that nest predation is not a limiting factor in the southern Appalachians because 1) nest predation rates are low in this region, 2) he found no evidence that the diversity or abundance of nest predators is greater in the south, and 3) grouse densities appear too low in the southern Appalachians for density-dependent nest predation to occur. Our 1997 data provide evidence for Hewitt's (1994) contention that nest predation rates are low in the southern Appalachians; however, considering our 1998 results I would suggest rates are lower or at least as low as rates reported in northern studies.

Researchers in New York suggest that annual variation in wild turkey (*Meleagris gallopavo*) nest success may be related to the amount of precipitation during the incubation period (Roberts et al. 1995). Roberts et al. (1995) observed high nest success during years with below average precipitation during peak incubation. They suggested that predators found more incubating hens and nests during wet weather because moisture may increase a predator's ability to detect and locate incubating hens (Roberts et al. 1995). In our study, hen success was considerably lower in 1998 than 1997 and precipitation amounts in April and May were higher in 1998 than 1997 at most study sites (Appendix A). During May, when most ruffed grouse hens in our study were incubating, the mean precipitation amount in 1997 and 1998 remained consistent among the sites in the Alleghany Plateau region, where nest predation rates remained relatively unchanged between 1997 and 1998 (Appendix A). In the other 2 regions, where nest predation rates increased in 1998, mean May precipitation amounts also increased in 1998, though the increase in the Ohio Valley region appears marginal (Appendix A). Our results weakly support the hypothesis presented by Roberts et al. (1995); however, research in the coming years of the ACGRP study should provide a clearer understanding of the relationship between hen success and precipitation amounts during the incubation period.

Annual variation in hen success may also be attributed to variation in hen condition prior to reproduction. In southwestern Virginia, Servello and Kirkpatrick (1988) found that ruffed grouse hens collected in a spring following a fall of exceptional oak mast (acorn) production tended to have the highest pre-breeding carcass fat levels and dietary metabolizable energy among hens collected over 3 years. In our study, hen success was highest in 1997, a spring that followed a good fall production of acorns (Martin 1998). White oak acorns are particularly important to ruffed grouse (Servello and Kirkpatrick 1989) and 1996 production levels in western Virginia were among the highest recorded in 40 years (Martin 1998). Conversely, acorn production in the fall of 1997 was among the lowest recorded in western Virginia in 40 years, particularly for white oak acorns, and hen success rates in the spring of 1998 were considerably lower than 1997 rates. It is impossible to draw conclusions from 2 years of data; however, these trends may suggest that ruffed grouse hen success in the southern Appalachian region is affected by the previous year's acorn production. In future years, research is needed to determine if such a relationship exists.

Our 2-year renest rate of 6% (2 renests of 33 failed first-nests) is lower than any rate reported in the literature. In Wisconsin, Small et al. (1996) reported 5 of 9 hens (56%) that lost their initial clutch renested. In a review of studies in Minnesota and New York, Bergerud (1988:598) reported 22-26% of hens with first-nest failures renested. The low rate reported here, however, may be an artifact of our sampling procedure; very few first nests were located before late incubation and if some first nests failed before they were located, the renest may have been incorrectly classified as a first nest attempt rather than a renest. This may explain why the distribution of first-nest hatch dates in 1997 is similar to that of 1998 except for 3 nests hatching after June 12 in 1997 (Figure 1.1). The earliest known renest hatch date in our project was June 6; therefore, it is possible that nests hatching after June 12 are also renests. If these 3 renests were misclassified as first-nests, our overall renest rate could be as high as 15% (5 renests of 33 failed first-nests). However, even if our renest rate increased to 15% it would still be lower than that reported in other studies. In future years, ACGRP data should provide more accurate renesting rates as cooperators make better attempts to locate first-nests early.

Our hatching success rates indicate nearly all incubated eggs in successful nests hatch, a conclusion similar to those of previous studies. In southern Ontario, the 6-year mean hatching success rate was 90% (Cringan 1970). In New York, only 2.6% of nearly 5,700 eggs did not hatch during an 11-year period (Bump et al. 1947: 365). In that same study egg infertility ranged from 1 to 7% annually (Bump et al. 1947: 365).

First-nest mean clutch size varied by region in 1997 and 1998, but no region was consistently different compared to the others in the 2 years. Clutch size pooled over the 3 regions was 9.6 in 1997 and 9.3 in 1998. Our results suggest hens in the southern Appalachians have smaller clutches than hens in more northern portions of ruffed grouse range. In New York, Bump et al. (1947) report the 11-year mean clutch size for nearly 1,500 first-nest clutches was 11.5. In southern Ontario, the mean clutch size of 45 first-nest clutches was 11.4 (Cringan 1970). In the Great Lakes region, the mean clutch size of first-nests was 11.1 in Minnesota (Maxson 1978), 10.3 in Wisconsin (Small et al. 1996), and 12.7 in northern Michigan (Larson 1998).

Latitudinal variation in a species' clutch size has been observed in other avian studies (Lack 1967, Bergerud 1988). Lack (1967:22) suggested that the clutch size of each species has been adapted by natural selection to correspond with the largest number of young that can be provided food. In Galliformes, Lack (1968:200) suggested that since the hen is not providing food for the chicks after hatch, clutch size is related to the amount of food available to the hen prior to egg-laying. Furthermore, he asserts that regional clutch-size variation within a species may be affected by the same principal; specifically, regional differences in the availability of food may influence conspecific clutch-size (Lack 1967: 32). Bergerud (1988:584), however, does not believe this principal can be applied to North American grouse species. He contends that it does not adequately explain regional clutch size differences in conspecific populations eating similar foods. The winter diet of southern Appalachian ruffed grouse, however, differs considerably from the diet of northern ruffed grouse (Stafford and Dimmick 1979, Servello and Kirkpatrick 1987). Research in the southern Appalachians suggests grouse populations in this region may be limited by winter foods (Servello and Kirkpatrick 1987, Hewitt 1994). In the southern Appalachians, many foods common in grouse winter diets have low protein levels and high tannin levels that make protein unavailable for digestion (Servello and Kirkpatrick 1987, Hewitt 1994). Although Bergerud (1988:582) suggested hen condition has no bearing on clutch size, Beckerton and Middleton (1982) found that decreases in the dietary protein level of ruffed grouse diets resulted in decreases in clutch size. Given that southern Appalachian ruffed grouse consume winter foods with low protein levels, the effect of low protein on ruffed grouse clutch sizes, and the small mean clutch size reported in our study, further research is recommended to determine if low-quality winter diets affect clutch sizes in the southern Appalachians.

The date of first-nest hatch was fairly consistent among regions and years; most first-nests hatched in the fourth week of May (Figure 1.1). Our overall mean hatch date, May 25, is approximately 1-2 weeks earlier than those reported in northern studies, which may be a result of an earlier vegetation green-up in the southern Appalachians. In Wisconsin, peak first-nest hatch most often occurs in the first week of June but peaks have been reported as late as June 10 (Maxson 1978). In southern Ontario, Cringan (1970) reported most nests hatched in the last week of May or first week in June during his 6 year study. Bump et al. (1947) reported peak hatch dates in New York that were similar to Cringan's (1970).

Data Collection

After reviewing the 1997 and 1998 reproduction data and compiling the natality characteristics reported earlier, I have identified 2 issues of concern and recommend procedures to improve ACGRP data collection. These issues are (1) identifying first-nest attempts early and determining the cause of first-nest failures, and (2) determining incubating clutch size and the number of eggs hatching.

1. Identifying first nest attempts early and determining the cause of first nest failures.

Nests must be found soon after incubation begins to ensure any first-nest failure is documented and the cause is determined. In this study, renesting rates were lower than had been reported from previous studies. To ensure that this is a characteristic of the southern Appalachian population and not an artifact of our sampling procedures, I recommend verifying first-nest attempts by visually locating the nest during early incubation.

Presently, most nests are visually located during late incubation for fear of flushing the hen from the nest early in the nesting period and causing abandonment. During previous reproduction seasons, however, some cooperators report repeatedly visiting nest sites without causing abandonment (Tom Allen, West Virginia Department of Natural Resources, pers. comm.). Repeatedly flushing hens from nests is not recommended, but it seems from our past experience that hens may tolerate visits by observers more than we had first assumed. I recommend visiting each nest site twice during the nesting period: once during early incubation to initially locate the nest and again during late incubation to determine clutch size.

Most first nests in the southern Appalachians hatch around May 25. Egg-laying begins approximately 41 days before the hatch date (Bump et al. 1947) and, therefore, usually commences in mid-April. The onset of egg-laying may be observed during this period by a concentration of telemetry locations indicating a reduction in movement (Maxon 1978). To detect a reduction in hen movement, I recommend triangulating each hen accurately at least twice each week starting in the third week of March or April 1, at the latest. Egg-laying lasts for approximately 15-17 days, and during this period the hen visits the nest only to deposit eggs (Bump et al. 1947). After egg-laying, incubation begins and the hen spends as much as 95% of the day on the nest (Maxson 1977), presenting the first opportunity to reliably locate the hen on the nest. To locate nests during early incubation, hens on nests should be visually located approximately 18-20 days after egg-laying is suspected to have begun. Telemetry locations during incubation should be consistent and the radio signal should not vary since the hen moves little while on the nest (Bump et al. 1947).

Though there is little evidence to suggest hens will abandon nest attempts if disturbed during incubation, I recommend care be taken to ensure the hen is not flushed from the nest during the early-incubation visit. Two individuals, each equipped with a receiver, antenna, and flagging tape, should carefully circle the nesting hen until both are within sight of one another and 180 degrees apart. The nest can then be found from a distance, using binoculars, or if cover is particularly dense and the observers are close to one another, the location can be estimated. If the location is estimated (i.e. the hen is not seen on the nest), then the site should be revisited within a few days to ensure the hen is still in the same general area and nesting. An estimated location should attempt to pinpoint the nest in an area as small as possible; an observer not involved with the first visit may have to find the nest once the hen leaves, and this is often extremely difficult even within moderate cover and a small area. Before leaving the nesting site, each observer should label flagging tape with the approximate distance and azimuth to the nest and attach to nearby trees. If, during routine telemetry, the hen is located away from the nest site, the nest can be found by referring to the labeled flagging.

2. Determining incubating clutch size and the number of eggs hatching

Determining the number of eggs hatching is an important component of reproductive success. We must identify how many eggs could potentially hatch (clutch size at incubation) and how many, if any, hatch. This information contributes to characteristics such as clutch size, hatching success, hatch date, and chick survival.

To determine the clutch size at incubation, nest sites must be visited during this period to flush the hen from the nest and to count the eggs. Incubation lasts approximately 23-24 days (Bump et al. 1947). Since the nest site was visited in the first few days of incubation to locate the nest, the second visit should be approximately 18-20 days after the first visit, depending on how late into incubation the first visit was conducted. During the late-incubation visit the hen can be flushed from the nest and the eggs quickly counted. If this procedure is done once, quickly, there is little evidence to suggest the hen will abandon the nest (Bump et al. 1947). To ensure the observer's presence does not attract predators to the nest, knee-high rubber boots should be worn to the nest to eliminate scent. Also, all flagging should be kept well away from the nest. Previous research on ground-nesting birds has suggested predatory mammals follow the scent left behind by observer's boots and clothing (Steen and Unander 1985) and that flagging attracts avian predators to nests (Picozzi 1975).

Nests must be visited immediately after the hen and brood leave the nest to determine the number of eggs that hatch. During the last week of incubation, hens should be located more than twice each week – preferably daily. If possible, a telemetry station or other location should be used that is very near (within 100 m) to the nest without disturbing the hen. Telemetry locations taken from a close distance will be a more reliable indication if the hen is away from the nest. Once the hen is located away from the nest it should be checked immediately to determine the number of eggs hatched.

CONCLUSIONS

Natality Characteristics

The major objective of this chapter was to calculate preliminary (after 2-years) ruffed grouse natality characteristics for 3 regions in the southern Appalachians.

(1) Overall nesting rate (81.6%) and hatching success rate (94.0%) were similar to rates reported from studies done in the more northern portions of ruffed grouse range.

(2) Overall hen success rate (69.2%) in the southern Appalachians appears to be as high or slightly higher than that reported in more northern ruffed grouse populations. Additionally, yearlings had hen success rates as high or higher than adults in our study. These results differ from most reports in other regions that indicated adults usually have higher hen success than yearlings. More research is recommended to determine why annual variation in hen success exists and what effect it may have on recruitment.

(3) We found a lower renest rate (6.0%) in the southern Appalachians than those reported from other portions of ruffed grouse range. However, some renesting may have been mistaken for first nest attempts.

(4) Overall mean first-nest clutch size (9.5) in the southern Appalachian region was considerably lower than what has been reported from studies done in the central and northern portions of ruffed grouse range. More research is recommended to determine why regional variations in clutch size exist and what effect it may have on recruitment.

(5) Our overall mean hatch date, May 25, is approximately 1-2 weeks earlier than those reported in the more northern studies. This may be a result of an earlier vegetation green-up in the southern Appalachians.

Data Collection

A secondary objective of this chapter was to determine if natality data were being collected in the correct format and at the correct time so that they are usable in analyses to accomplish the objectives of the long-term ACGRP study. I have highlighted 2 issues of concern and given recommendations on how these may be corrected or improved in upcoming years. Locating nests sites during early incubation will increase the probability a first-nest failure is reported and the cause determined. Visiting nest sites during late incubation and soon after hatch will help determine clutch size, hatching success, and chick survival. These recommendations contribute to the ACGRP by strengthening existing sampling protocol and defining new and improved procedures.

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Table 1.1. Nesting and hen success rates (%) of ruffed grouse in 3 regions of the southern Appalachians, 1997-1998.

	1997				1998				Years Pooled			
		Nesting		Hen		Nesting		Hen		Nesting		Hen
Region[a]	n[b]	Rate[c]	n[d]	Success[e]	n	Rate	n	Success	n	Rate	n	Success
AP	22	100.0	21	66.7	19	94.7	16	68.8	41	97.6	37	67.7
ORV	10	70.0	7	100.0	14	42.9	6	50.0	24	54.2	13	75.0
RV	35	77.1	26	88.5	36	86.1	29	55.1	71	81.7	55	71.8
Pooled	67	83.6	54	81.5	69	79.7	51	56.9	136	81.6	105	69.2

[a] AP: Alleghany Plateau, ORV: Ohio River Valley, RV: Ridge and Valley

[b] total number of radio-tracked hens

[c] proportion of hens attempting a first nest

[d] number of hens cooperators reported to have nested

[e] proportion of hens with nests producing $\geq$1 live chick

Table 1.2. Nesting and hen success rates (%) of adult and yearling ruffed grouse in the southern Appalachians, 1997-1998.

	1997				1998				Years Pooled			
		Nesting		Hen		Nesting		Hen		Nesting		Hen
Age Class	n[a]	Rate[b]	n[c]	Success[d]	n	Rate	n	Success	n	Rate	n	Success
Adult	40	87.5	35	85.7	36	94.4	33	48.5	76	90.8	68	67.6
Yearling	18	94.4	15	86.7	22	81.8	17	82.3	40	87.5	32	84.3

[a] total number of known-age radio-tracked hens

[b] proportion of hens attempting a first nest

[c] number of hens cooperators reported to have nested

[d] proportion of hens with nests producing $\geq$1 live chick

Table 1.3. Proportion of ruffed grouse hens killed on nests, nests depredated, and nests abandoned in 3 regions of the southern Appalachians, 1997-1998.

	1997			1998			Years Pooled		
Region [a]	Hen Killed[b]	Nest Depredated[c]	Nest Abandoned[d]	Hen Killed	Nest Depredated	Nest Abandoned	Hen Killed	Nest Depredated	Nest Abandoned
AP	2/20	3/21	1/21	3/15	0/15	1/15	5/35	3/36	2/36
ORV	0/7	0/7	0/7	1/6	3/7	0/7	1/13	3/14	0/14
RV	1/26	2/26	0/26	2/29	9/29	3/29	3/55	11/55	3/55
Pooled (%)	5.7	9.3	1.8	12.0	23.5	7.8	8.7	16.2	4.7

[a] AP: Alleghany Plateau, ORV: Ohio River Valley, RV: Ridge and Valley

[b] hens killed on nests / number of nests of known outcome

[c] number of depredated nests (nest disturbed by predators, but hen survived) / number of nests of known outcome

[d] number of permanently deserted nests found with no signs of depredation / number of nests of known outcome

Table 1.4. Proportion of adult and yearling ruffed grouse hens killed on nests, nests depredated, and nests abandoned in the southern Appalachians, 1997-1998.

	1997			1998			Years Pooled (%)		
Age Class	Hen Killed[a]	Nest Depredated[b]	Nest Abandoned[c]	Hen Killed	Nest Depredated	Nest Abandoned	Hen Killed	Nest Depredated	Nest Abandoned
Adult	2/35	4/36	0/36	6/33	7/33	4/33	11.7	15.9	6.0
Yearling	1/15	1/15	0/15	0/17	5/18	0/18	4.5	18.1	0

[a] hens killed on nests / number of nests of known outcome

[b] number of depredated nests (nest disturbed by predators, but hen survived) / number of nests of known outcome

[c] number of permanently deserted nests found with no signs of depredation / number of nests of known outcome

Table 1.5. Hatching success rate (%) and mean first-nest clutch size of ruffed grouse in 3 regions of the southern Appalachians, 1997-1998.

	1997					1998					Years Pooled				
		Hatching		Mean			Hatching		Mean			Hatching		Mean	
Region[a]	n[b]	Success[c]	n[d]	Clutch	SE	n	Success	n	Clutch	SE	n	Success	n	Clutch	SE
AP	94	95.7	12	8.7	0.7	103	94.2	11	10.5	0.6	197	94.9	23	9.5	0.5
ORV	56	94.6	5	11.2	0.9	18	100.0	6	9.5	1.1	74	95.9	11	10.3	0.8
RV	92	95.7	11	9.9	0.6	119	89.9	15	8.5	0.8	211	92.4	26	9.1	0.5
Pooled	242	95.5	28	9.6	0.4	240	92.5	32	9.3	0.5	482	94.0	60	9.5	0.3

[a] AP: Alleghany Plateau, ORV: Ohio River Valley, RV: Ridge and Valley

[b] number of eggs in successful clutches (from nests hatching ≥ 1 live chick)

[c] proportion of eggs hatching from successful clutches

[d] number of incubating clutches reported by cooperators

Table 1.6. Hatching success rate (%) and mean first-nest clutch size of adult and yearling ruffed grouse in the southern Appalachians, 1997-1998.

	1997					1998					Years Pooled				
Age Class	n[a]	Hatching Success[b]	n[c]	Mean Clutch	SE	n	Hatching Success	n	Mean Clutch	SE	n	Hatching Success	n	Mean Clutch	SE
Adult	188	95.2	23	9.3	0.5	124	93.5	19	9.3	0.7	312	94.5	42	9.3	0.4
Yearling	54	96.2	5	10.8	1.0	105	98.1	13	9.4	0.7	159	97.5	18	9.8	0.6

[a] number of eggs in successful clutches (from nests hatching ≥ 1 live chick)

[b] proportion of eggs hatching from successful clutches

[c] number of incubating clutches reported by cooperators

Table 1.7. Mean first-nest hatch dates of ruffed grouse in 3 regions of the southern Appalachians, 1997-1998.

	1997			1998			Years Pooled		
		Mean Hatch			Mean Hatch			Mean Hatch	
Region[a]	n[b]	Day	SD[c]	n	Day	SD	n	Day	SD
AP	10	June 2	11.3	11	May 24	4.9	21	May 28	9.6
ORV	6	May 21	9.4	3	May 26	10.9	9	May 23	9.6
RV	20	May 24	11.0	16	May 24	11.1	36	May 24	8.4
Pooled	36	May 26	11.9	30	May 25	4.8	66	May 25	9.1

[a] AP: Alleghany Plateau, ORV: Ohio River Valley, RV: Ridge and Valley

[b] number of first-nests from which hatch dates were reported by cooperators

[c] standard deviation

Table 1.8. Mean first-nest hatch dates of adult and yearling ruffed grouse in the southern Appalachians, 1997-1998.

	1997			1998			Years Pooled		
Age Class	n[a]	Mean Hatch Day	SD	n	Mean Hatch Day	SD	n	Mean Hatch Day	SD
Adult	25	May 25	12.4	16	May 24	3.1	41	May 25	9.8
Yearling	10	May 26	9.4	14	May 24	6.4	24	May 25	7.7

[a] number of first-nests from which hatch dates were reported by cooperators

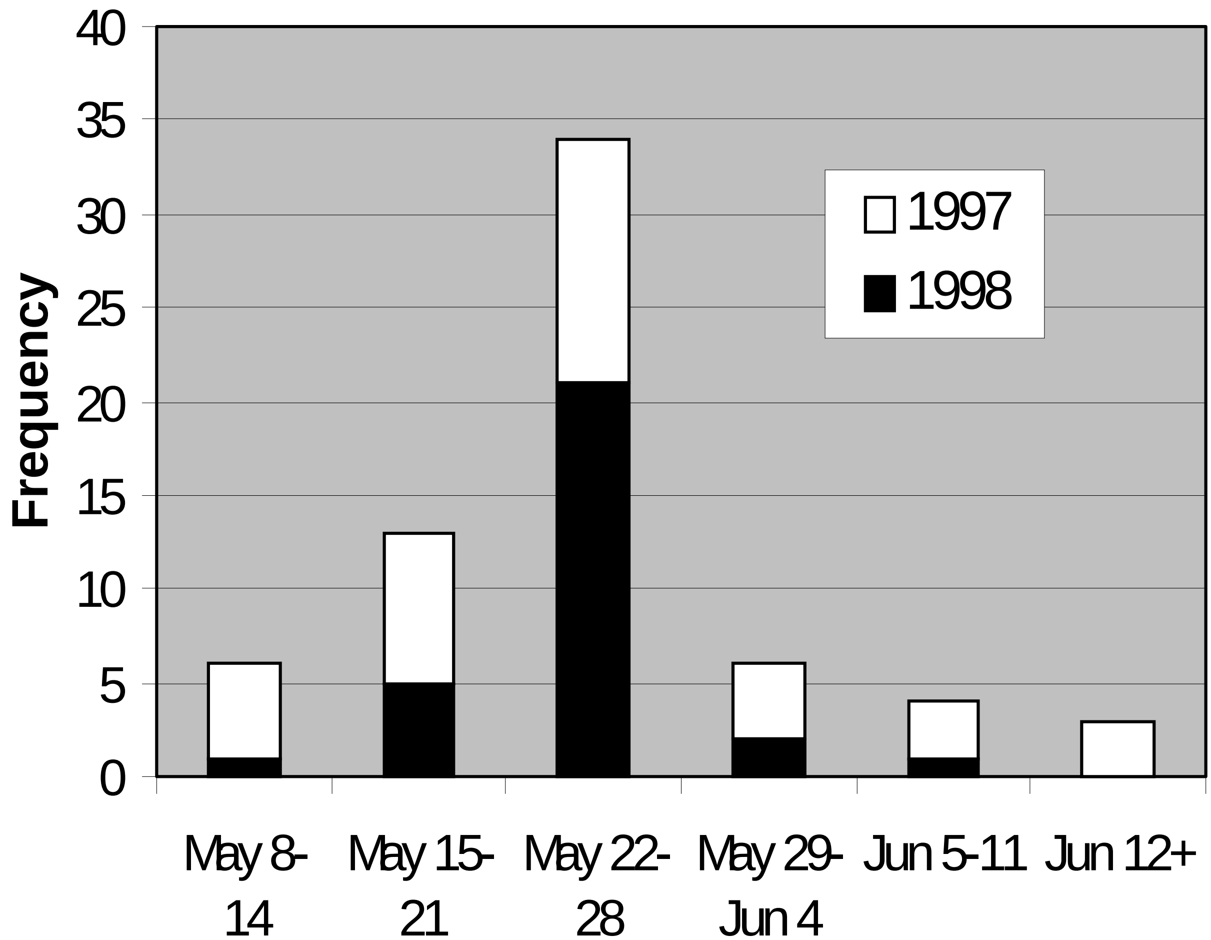

Figure 1.1. Distribution of ruffed grouse first-nest hatch dates in the southern Appalachians, 1997-1998. Data pooled from 8 study areas in 1997 and 9 areas in 1998.

Table 1.9. Percent of potential data that was actually collected and used to calculate natality characteristics of ruffed grouse hens in the southern Appalachians, 1997-1998.

	Nest Attempt		Nest Outcome[a]		No. Eggs at Incubation[b]		No. Eggs Hatched[c]		Hatch Date	
Year	No. Hens Available	% Data Collected	No. Nests	% Data Collected	No. Succ. Nests[d]	% Data Collected	No. Succ. Nests	% Data Collected	No. Succ. Nests	% Data Collected
1997	67	100	55	98	43	58	43	58	43	84
1998	69	100	55	93	30	87	30	87	30	100

[a] used to calculate hen success, a successful outcome would be a nest hatching $\geq$ 1 chick

[b] used to calculate mean clutch size and hatch success

[c] used to calculate hatch success

[d] number of successful nests (nests hatching $\geq$ 1 live chick)

CHAPTER 2

RUFFED GROUSE CHICK SURVIVAL IN THE SOUTHERN APPALACHIANS

Producing young that survive and reach sexual maturity is crucial for a sustained population. However, for many species, including ruffed grouse, the period between being born or hatched and the first breeding season is often the most hazardous in an individual's life. In many grouse populations, the survival rate the chicks is considerably lower than the adult survival rate, with most mortality occurring in the first 2-weeks after hatch (Bump et al. 1947, Bergerud 1988).

Despite its importance, few good estimates of ruffed grouse chick survival exist in the literature because of the difficulty in observing the number of chicks hatched and then documenting chick attrition in each brood accurately throughout the brood season. However, several authors report estimates of the number of chicks per hen during the late brood season as an index to chick production success. State game agencies often report the proportion of juveniles harvested in the annual fall grouse hunting season to approximate chick survival. This index is a measure of recruitment, and includes juveniles that immigrated into a population. However, assuming that the number of young born into a population is an important component of recruitment, this index provides additional evidence of reproductive success. A review of these indices from various portions of ruffed grouse range have caused many to conclude that the species' reproductive success, or more accurately, recruitment, is lowest in the southern portion of its range (Davis and Stoll 1973, Harris 1981, Kalla and Dimmick 1995). Therefore, low reproductive success and/or recruitment may be contributing to low population densities in the southern Appalachians, a region where grouse densities are lower than other portions of the species' range (Bump et al. 1947). The objective of this study was to determine the extent of ruffed grouse chick survival within the southern Appalachian region. Given the lack of chick survival estimates in the southern Appalachians, this information will benefit those wishing to evaluate factors affecting ruffed grouse densities and population trends in this region.

Much of the data used in this study was collected by cooperators working with the Appalachian Cooperative Grouse Research Project (ACGRP) during 1997 and 1998. It is presented here to summarize the regional data collected to date and provide a review of our data collection procedures. Large cooperative projects involving many data collectors in several states must contend with the challenge of standardizing methodology and communicating procedural changes effectively. In light of this, a secondary objective of this chapter was to determine if brood data at ACGRP sites were being collected at the correct time (i.e. 7, 21, 35 days) so that they were usable in analysis to accomplish the objectives of the ACGRP study.

METHODS

Study Sites

All study sites involved in the ACGRP during spring-summer 1997 and/or 1998 provided data for this study (Table 0.1).

Trapping

Ruffed grouse hens were captured each fall and spring during 1996-1998. Typically, 2 lily-pad traps were used, joined by a chicken-wire drift-fence (Gullion 1965). Traps were located in areas accessible by roads where grouse had been previously seen or in areas deemed suitable habitat.

Sex and age-class (juvenile or adult) were determined for each captured bird using the methodology previously described by Davis (1969) and Roussel and Ouellet (1975). A necklace-style 10-11 g radio-transmitter (Advanced Telemetry Systems, Isanti, MS) was fitted around the neck of each captured bird, with the weight of the unit resting on the region of the crop. Transmitters were equipped with an 8-hour mortality mode (rapid pulse signal), operated in the 150-152 Mhz range, and had a life expectancy $\geq$ 1 year. Most birds were released within 15 m of the trap site and < 1/2 hour after being removed from the trap.

Monitoring

Prior to nesting (i.e., before approximately April 1), each radio-tagged hen was monitored at least twice each week by field personnel. A 3-element Yagi or “H-type” antenna and portable receiver (Advanced Telemetry Systems, Isanti, MS and Telonics, Inc., Mesa, AZ) were used to monitor hens from fixed telemetry stations located by a global positioning system (GPS) unit (Corvallis MicroTechnology, Inc., Corvallis, OR). Observers plotted 3-5 fixes in the field on U. S. Geologic Survey 7.5 minute topographic maps and identified the 3 azimuths with best agreement.

After mid-April, hens were assumed to have begun nesting when their estimated locations were consistently within approximately 100 m of each other. Hatch date was estimated to be 41 days after nesting was assumed to have begun (accounting for a 17 day egg laying period and 24 day incubation). Most nests were visited during the estimated last week of incubation to determine clutch size and to visually locate the nest. When hens were inadvertently flushed from incubating nests, the clutch size was noted and the nest location flagged several meters from the nest. During the last week of incubation most hens were located more than twice each week, some as much as daily, to detect the day the hen and brood left the nest. After hatch, eggshell fragments were examined to determine clutch size and the number of unhatched eggs was noted.

Brood Size Estimation

In 1997 an intensive brood-flush schedule ("intensive counts") was followed at the VA/2, VA/3, and WV/2 study sites. Following nest departure, hens with broods were located twice each week though triangulation and visual observation for habitat analysis at brood locations. After triangulating the hen and determining the general location, observers followed the signal of the hen's radio-transmitter to locate and flush the brood and make an ocular estimation of brood size. Though broods were flushed and counted twice each week, only the last count of each week was used in survival estimate calculation. In 1997, a less-intensive brood-flush schedule ("ACGRP counts") was followed at the WV/1, Ohio, Maryland, and Kentucky study sites. At these sites, broods were flushed and ocular estimations of brood size were made at the end of weeks 1, 3, and 5 post-hatch, i.e. at 7, 21, and 35 days ($\pm$ 2 days). In 1998, the intensive schedule (locations and flush counts twice each week) was followed at VA/2, VA/3, and for 2 broods at WV/2. Concurrently, in 1998, the less-intensive ACGRP schedule (end of weeks 1, 3, and 5) was followed at VA/1, WV/1, Ohio, Maryland, and Kentucky sites, and for 5 broods at the WV/2 site.

The intensive counts were the original sampling schedule of this thesis project. ACGRP counts were concurrently being conducted in 1997 and 1998 throughout the southern Appalachian region on study sites operated by ACGRP personnel. ACGRP flush counts and survival estimates are presented here for 2 reasons: 1) to give a more complete representation of chick survival in the southern Appalachian region, and 2) to use for comparison with the intensive counts done twice each week to determine if the more frequent flushes of the intensive schedule reduce chick survival.

Data Analysis

Researchers at several study sites had difficulty trapping sufficient samples of ruffed grouse hens for calculation of reliable brood survival estimates. Calculating survival estimates at each study site and then averaging across study sites would have biased results because of the equal weight that would have been given to sites with low sample sizes. To minimize the bias caused by sites with disproportionally low samples, results were calculated from values pooled across all sites. In other words, flush count data from all sites were combined and survival estimates were calculated as if all broods had come from the same study site. I recognize that pooling sites within the large southern Appalachian region also has limitations; variation inherent to particular study sites will be lost in the pooling of data. However, I concluded pooling data, rather than averaging estimates, would give the most accurate presentation of survival data. Because many sites have as few as 1 or 2 hens available each year, reliable comparisons among study sites could not be made. However, an ocular examination of the flush count data indicated chick survival was fairly consistent throughout the regions sampled.

Brood survival (S_t) was calculated for each observation period (weekly for intensive counts; weeks 1, 1-3, and 3-5 post-hatch for ACGRP counts) using a modified version of the Kaplan-Meier product limit estimator (Flint et al. 1995). One assumption of this method is that all broods are observed on the same schedule (Flint et al. 1995). This means that all broods on the intensive schedule must have a reliable count at the end of each 7-day period ($\pm$ 2 days) post-hatch to calculate weekly survival estimates. For ACGRP counts, a reliable count must be reported at the end of weeks 1, 3, 5 post-hatch, i.e. 7, 21, and 35 days ($\pm$ 2 days). Counts that could be used for Kaplan-Meier survival estimation were restricted to $\pm$ 2 days of the appropriate day. Survival estimates were generated using formulas presented by Flint et al. (1995) in Microsoft Excel spreadsheets.

ACGRP counts done > 2 days before or after the scheduled day were censored from survival estimate calculation. Censoring is used in survival estimate calculation when the fate of the individual (or, in this case, individuals) is not known during the period of observation (Pollock et al. 1989). In the case of this study, the counts that are not done on the correct day will not accurately reflect chick attrition within the period of interest, and, therefore, the fate of all of the chicks in a brood are not known for that period. Using these counts would have biased estimates since chick survival is not constant throughout the brood period, especially during the first few weeks following hatch. Including counts done even a few days before or after 7, 21, or 35 days post-hatch would not accurately represent survival at these intervals. As a result, for many ACGRP broods one or more flush counts have been censored from chick survival estimates and data are not available for all 3 periods (i.e., at 7, 21, 35 days).

Survivorship values, or the proportion of chicks surviving over time, were calculated from both intensive and ACGRP survival estimates (S_t). Survivorship values, S(t), are the estimates of survival from hatch to time t. These values were calculated as the product of the individual period survival estimates (S_t) to t (Flint et al. 1995). For instance, using ACGRP schedule data, survivorship from hatch to week 5 (S[5]) would be the product of survival from hatch to the end of week 1 (S_1), weeks 1-3 (S_3), and weeks 3-5 (S_5), or: $S(5) = S_1*S_3*S_5$.

The original version of the Kaplan-Meier method assumes survival among members of the same brood is independent and no brood mixing occurs (Flint et al. 1995). Several authors have noted these assumptions are violated by brooding birds, particularly waterfowl (Flint et al. 1995). The modified approach used here does not assume survival is independent among members of the same brood and, additionally, allows for brood mixing. In determining survival estimates, chicks are considered independent sampling units and standard errors are calculated by treating broods as clusters (Flint et al. 1995).

Additionally, to use ACGRP schedule data that were censored from Kaplan-Meier survival estimates, regression models were used to determine the relationship between the proportion of chicks hatched in a brood that are counted at flush counts and brood age. Regression models were calculated using all ACGRP data, regardless of the day it was sampled. Survivorship curves were created from the proportion of chicks, estimated by the regression model, that survive to the end of each week of the ACGRP observation period (i.e., hatch to end of weeks 1, 3, and 5).

The mean number of chicks per successful hen (a hen with nests that hatch $\geq$ 1 chick) was calculated for weeks 1, 3, and 5 by combining broods sampled in the intensive and ACGRP schedules. Because ACGRP and intensively sampled broods appeared to have similar survival estimates, I combined the flush counts from these sampling schedules to calculate a region-wide mean. This method of calculation accounts for whole brood loss because broods that have lost all chicks are included in mean calculations and a value of “0” was entered for that flush count. In contrast, most previous studies obtained flush count data by randomly flushing broods of hens not radio-instrumented. This method does not account for whole brood loss because only hens with chicks are counted and hens that lost their entire brood cannot be distinguished from males and unsuccessful hens. To compare our results with the results of these studies, I also calculated the mean number of chicks per surviving brood ($\geq$ 1 chick alive) for weeks 1, 3, and 5 using combined data from all broods sampled in the intensive and ACGRP schedules. This method does not account for whole brood loss because only flush counts resulting in $\geq$ 1 chicks are used in calculations. Additionally, the mean number of chicks per hen entering the nesting season (at April 1) was calculated as the product of mean chicks per successful hen and ACGRP nesting and hen success rates. ACGRP Nesting and hen success rates are reported in Chapter 1.

To determine if chick survival was similar throughout the southern Appalachian region, the mean number of chicks per successful hen, hen entering the nesting season, and surviving brood were calculated for 3 regions in the southern Appalachians (Ridge and Valley, Alleghany Plateau, and Ohio River Valley). No statistical analysis was done to determine if the mean number of chicks differed significantly among regions. Preliminary data from the first 2 years of the long-term ACGRP project is used here to help detect possible trends in regional variation that may be addressed in future research. In future years, once more data have been collected and sample sizes increase, regional comparisons using statistical analysis will be made to determine if differences exist between regions in the southern Appalachians. Data were pooled over 1997 and 1998 because of small samples of broods within regions, particularly the Ohio River Valley. Although pooling increased sample sizes in 2 regions, the Ohio River Valley still did not have an adequate sample or complete brood data for reliable Kaplan-Meier survival estimates. Because reliable survival estimates cannot be calculated for the regions, I assumed the regional mean number of chicks at each week adequately reflects chick survival.

A secondary objective of this chapter was to determine if brood-flush count data at ACGRP sites were being collected at the correct time (i.e. 7, 21, 35 days) so that they were usable in analysis to accomplish the objectives of the ACGRP study. To determine which collection procedures have been most affected by lost data, I calculated the proportion of potential data that was collected and actually used to calculate survival estimates. Recommendations are also given to improve data collection.

RESULTS

In 1997, 14 hens with broods were sampled following the ACGRP schedule and 20 were sampled following the intensive schedule. In 1998, 14 hens with broods were sampled following the ACGRP schedule and 8 were sampled following the intensive schedule. Because broods were not always sampled on the day appropriate to the sampling schedule (and were consequently censored) or the counts were unreliable, the number of broods counted vary by observation period, particularly for the ACGRP schedule.

Chick Survival

In 1997 and 1998, intensive schedule survival rates were lowest in the first week following hatch (Table 2.1). Whole brood loss was high during the first week after hatch (5 of 12 broods [42%], years pooled) and contributed to low first-week survival. After week 1, rates are consistent and higher in both years (> 0.68) (Table 2.1). ACGRP schedule survival rates illustrate a trend similar to those of the intensive schedule: lowest in week 1 and consistently higher during the observation periods that follow (Table 2.2). First-week whole brood loss was also high among ACGRP sampled broods (8 of 22 broods [36%], years pooled). Compared to the intensive schedule, lower survival rates in the ACGRP schedule periods after week 1 are due to combining 2 weeks into each observation period (i.e., “1-3 weeks”). If the intensive schedule’s survival rates in weeks 2 and 3 were combined, 0.68*0.89 (Table 2.1), the result (0.61) would be similar to that of the ACGRP schedule for weeks 2-3 (0.63).

Survivorship values, or the proportion of hatchlings surviving over time, were calculated from 3 sources of data (intensive schedule Kaplan-Meier survival estimates, ACGRP schedule Kaplan-Meier survival estimates, and total ACGRP data). Regression models were calculated from all ACGRP data (i.e., usable and unusable in Kaplan-Meier survival estimates) to determine the relationship between the proportion of chicks hatched that are counted at flush counts and brood age. Scatterplots of the proportion of surviving chicks observed in each brood and the age of the brood indicated a curvilinear pattern fitted these data best, thus a polynomial regression model ($y=B_o+B_1x+B_2x^2+\varepsilon$) was used. For 1997, 1998, and data pooled over years, R^2 values ranged from 0.12-0.18 (Table 2.3), indicating that 12-18% of the variability in the proportion of surviving chicks estimated in each brood can be explained by the age of the brood.

All 3 methods (intensive schedule Kaplan-Meier, ACGRP schedule Kaplan-Meier, and ACGRP regression analysis) illustrate similar trends in survivorship at 1, 3, and 5 weeks (Figure 2.1). In 1997, 1998, and years pooled, the sharpest decline in survivorship occurred during the first week, then a gradual decrease in survivorship occurred between weeks 1 and 5. Though ACGRP schedule survivorship values (regression estimated and Kaplan-Meier) seem slightly higher than intensive schedule Kaplan-Meier values for weeks 1 and 3 in 1997, this trend was not consistent in 1998. Survivorship values among all 3 methods appear similar at week 5 in both years, and for the 2-year period survivorship at week 5 ranged between 0.11 and 0.13, depending on the method. Survivorship to weeks 13 (1997) and 10 (1998) were calculated using intensive schedule data (Figure 2.2). In 1997, survivorship at week 13 was 0.04, and in 1998, survivorship to week 10 was 0.11 (Figure 2.2).

By week 5, successful hens had an average 1.1 chick in 1997 and 2.1 chicks in 1998 (Table 2.4). At week 5, the mean number of chicks per hen entering the nesting season was 0.7 in 1997 and 1.0 in 1998. By week 5, the average surviving brood had 2.6 chicks in 1997 and 3.6 chicks in 1998. The mean number of chicks per successful hen and surviving brood at week 5 appeared to be highest in the Ohio River Valley region (Table 2.5). However, the Ohio River Valley's result was likely affected by small sample size. Considering the other 2 regions, the mean number of chicks in surviving broods appeared similar, though the mean number of chicks per successful hen appeared lower in the Alleghany Plateau region (0.9) compared to the Ridge and Valley (1.6). The mean number of chicks per hen entering the nesting season appeared to be similar among all 3 regions in this study (Table 2.5).

Data Collection

A second objective of this preliminary report was to determine if brood-flush count data at ACGRP sites were being collected at the correct time (i.e. 7, 21, 35 days) so that they were usable in analysis to accomplish the objectives of the long-term ACGRP project. Because intensive-schedule broods were located on ACGRP study sites, their brood data were included in this inquiry. In 1997, approximately half of the possible data that could have been collected for number of eggs hatching and flush counts were collected and usable in calculating survival estimates (Table 2.6). Though the percent of possible data collected for number of eggs hatching increased in 1998, the percent of flush counts used in survival estimations did not greatly improve over 1997 (Table 2.6). In both 1997 and 1998, a large portion of the reported data (ACGRP and intensive schedules) could not be used for Kaplan-Meier analysis because the counts were not within 2 days of 7, 21, or 35 days post-hatch (Table 2.7).

DISCUSSION

Chick Survival

Survivorship to week 5 post-hatch, pooled over 1997 and 1998, ranged from 0.11 to 0.13, depending on the data source (intensive or ACGRP schedule). At week 10, survivorship was

0.07, from data pooled over 1997 and 1998. Survival estimates reported here are considerably lower than those previously reported from other portions of ruffed grouse range. In New York, a 13-year average of chick survivorship to approximately 8-10 weeks of age was 0.37 (Bump et al. 1947). In Alberta, chick survivorship to week 12 was 0.51 (Rusch and Keith 1971). However, the survival estimates in these studies are based on flushes of hens with surviving broods and do not account for hens that lost their entire brood earlier in the summer (Bump et al. 1947, Rusch and Keith 1971). In northern Michigan, Larson (1998) was able to account for whole brood loss by radio-tagging grouse chicks and reported a chick survivorship of 0.32 at approximately 12 weeks.

Survival estimates were lowest in the first week after hatch, primarily due to a high incidence of whole brood loss. The results of our study indicate that approximately one-third of broods are lost in the first week in the southern Appalachians. In the 13-year New York study, Bump et al. (1947:316) report first-week whole brood loss averaged 10 to 15%. In Alberta, Rusch and Keith (1971) did not determine the frequency of whole brood loss but believed it was uncommon during the 2 brood seasons studied. The high incidence of first-week whole brood loss may be unique to the southern Appalachian region and deserves further study.

Based on my results, by early July (5 weeks of age) the average surviving grouse brood in the southern Appalachians would consist of 3 chicks. Compared to determining survival estimates of chicks from radio-tagged hens with broods, determining average brood size from randomly flushed hens late in summer is easier and less time consuming. This explains why more average brood size estimates occur in the literature than survival estimates. Based on the number of chicks counted in 13 5-week-old broods, Harris (1981) found the 2-year average number of chicks per brood in northern Georgia to be 5.3. His results are higher than ours, but low sample size may have affected his results. In the Great Lakes region, mean late-summer chick counts are considerably higher than those reported in the southern Appalachians. In Wisconsin, Dorney and Kabat (1960) reported 6-7 chicks per brood from 367 broods flushed during July and August, 1950 to 1953, a period during which grouse populations were believed to be high. During low population years (1954-1957), an average of nearly 8 chicks per brood were counted from 288 broods flushed in July and August (Dorney and Kabat 1960). A second study in Wisconsin by Kubusiak (1978) reported an average of nearly 7 chicks per brood in 182 broods flushed in July and August from 1967-1975, a period of low grouse populations.

Compared to the findings of studies conducted in the Great Lakes region, our results suggest production success is considerably lower in grouse populations of the southern Appalachians. My conclusion is consistent with reported age ratios of hunter harvested grouse from state game agencies within the southern Appalachians. Assuming the annual fall grouse harvest provides a random, unbiased, representative sample, age ratios from harvest reports provide an index to the relative proportion of juveniles in the fall and winter grouse population. In Virginia, the 24-year mean proportion of juveniles in the annual harvest was 40% (Norman et al. 1997). Harris (1981) reported a 10-year mean juvenile proportion of 40% in West Virginia. Juveniles comprised 39% of a hunter harvest sample in a Tennessee study (Kalla and Dimmick 1995). In southeastern Ohio, juveniles comprised 53.3% of a 9-year harvest (Davis and Stoll 1973). Kentucky's mean juvenile proportion is higher than many other southern Appalachian states. In one 10-year period the mean proportion of juveniles was 49.5% and in a recent 8-year period the mean proportion was 59.7% (Sole 1995). In comparison, states in the Great Lakes region and southern Canada report considerably higher proportions of juveniles. In Wisconsin, a 5-year mean proportion was 76.6% (Dorney 1963). In Alberta, a 2-year average proportion of juveniles in samples shot and trapped from August to April was 80% (Rusch and Keith 1971).

Though not an objective of this study from the outset, I was able to compare chick survival estimates calculated from data obtained by 2 similar methods with different sampling schedules. My results indicate that intensive brood flushes (i.e., twice each week) have no greater effect on the survival of chicks than flushing on a less intensive schedule (i.e., once per week at 1, 3, and 5 weeks post-hatch). Survivorship trends were similar for both methods, and the survival estimation for hatch to week 5 was similar in each of the years sampled. My conclusions agree with Cotter and Gratto (1995) who studied the effect of frequent flush counts on rock ptarmigan (*Lagopus mutus*) chicks. They found no difference in chick survival between broods counted every 3-4 days and those counted every 6-9 days (Cotter and Gratto 1995). Additionally, Hubbard et al. (1999) concluded brood flushes have no significant effect on wild turkey (*Meleagris gallopavo*) poult survival. They found no difference between the survival of flush counted poults and poults monitored using radio-telemetry (Hubbard et al. 1999).

In our study, the greatest difference between the methods occurred during week 1 in 1997; the intensively flushed broods had considerably lower survival than broods on the ACGRP schedule. However, this difference was not apparent in 1998, and because of this inconsistency, I believe the difference in week 1, 1997, survival was not due to the more frequent flushes. This comparison cannot account for variation in chick survival between study sites because each method was conducted at different sites. It is possible that some study sites characteristically have higher chick survival than others; although, in the course of this 2-year study that phenomenon was not consistently apparent.

Data Collection

Collecting brood size counts proved to be the most difficult challenge of this study, and this difficulty is reflected in the quantity of data available for survival estimation. It was the intention of the ACGRP to calculate chick survival estimates using a modified Kaplan-Meier product limit estimator. Two assumptions of this method include 1) all adult females are observed on the same equally spaced schedule, and 2) individuals in each brood under study can be accurately counted at each observation (Flint et al. 1995). ACGRP flush count results from 1997 and 1998 show that field personnel often violated assumption 1. The results of this report indicate that a high proportion of flush counts that were to be conducted at 7, 21, and 35 days post-hatch were done > 2 days before or after the correct date. This violates assumption 1 and biases survival estimates since the number of chicks counted in these instances did not reliably reflect the number of chicks at 7, 21, or 35 days post-hatch. Nearly one-third of the data collected were censored and could not be used to calculate Kaplan-Meier chick survival estimates for 1997 and 1998. This resulted in greatly lowered sample sizes and greater estimate variability. If the Kaplan-Meier survival estimator is to be used effectively in future brood seasons, all ACGRP cooperators must conduct flush counts within 2 days of 7, 21, or, 35 days post-hatch to ensure all available data can be used for chick survival estimates.

Ruffed grouse chicks, particularly in the first few weeks after hatch, are notoriously difficult to find and brood-size counts often may be unreliable. In some instances, cooperators report minimum counts (e.g., “we saw more than 6”) when their confidence in the count is low. For this reason I believe assumption 2 of the Kaplan-Meier estimator also may be violated, and, as a result, our estimates can only be minimum estimates. It would be unrealistic to suggest all future counts be of completely high confidence; however, I recommend ensuring each count reported is as reliable as possible. If an unsatisfactory count occurs, another count should be attempted within 2 days of 7, 21, or 35 days post-hatch. Additionally, I recommend repeated counts do not occur on the same day, particularly for broods with young (< 5 weeks) chicks.

Repeated flushes within 1 day may increase chick stress and the opportunity for observer-influenced mortality. Also, counts done within a few hours of one another may be inaccurate because hens may have not completely collected the entire brood after the first flush.

Because of the difficulty in sampling on a strict Kaplan-Meier schedule, regression analysis may be a more appropriate method of estimating chick survival for ACGRP personnel. My results indicate regression analysis yields survivorship results similar to Kaplan-Meier estimates and provides greater sampling flexibility. Field personnel could be required to conduct counts within specified weeks after brood-hatch, rather than within a restrictive, periodic 3-day interval.

CONCLUSIONS AND RECOMMENDATIONS FOR FUTURE RESEARCH

Chick Survival

The primary objective of this study was to determine the extent of ruffed grouse chick survival within the southern Appalachian region.

(1) Survivorship values from 2-years of study are considerably lower (0.11-0.13 at week 5, 0.07 at week 10) than those previously reported in the literature. By week 5, the mean number of chicks per hen entering the nesting season was 0.7 in 1997 and 1.0 in 1998. Additionally, the mean number of chicks per surviving brood in July is far lower in the southern Appalachians than those reported in the Great Lakes region in July and August.

(2) Lower chick survival and, consequently, production success in the southern Appalachians probably accounts for the historically low densities of ruffed grouse in this region. Future research into the causes of high chick mortality and low production success should focus on the first 2 weeks after hatch. Whole brood loss was considerable in this study and the extent of this mortality may be unique to the southern Appalachians. I would recommend monitoring ruffed grouse chick survival over several years in this region. As in any short-term study, the low survival rates reported here may not represent long-term trends. The results from our 2-year study may represent abnormally low years of chicks survival, although we have no evidence to support this.

(3) As a result of sampling broods on 2 schedules differing in flush intensity, I suggest chick survival was not affected by the number of times the brood is flushed. I found little difference between the survivorship of broods flushed intensively (twice each week) and broods flushed approximately 3 times in 5 weeks. Counting chicks in flushed broods is an

efficient sampling technique, and if done repeatedly, I believe flush counts produce reliable estimations of chick attrition. However, these schedules were followed on separate study sites in a large region. Some sites may have had inherently different survival from the others that could have biased results. Future research should isolate the variation that may exist on the different study sites. I recommend flushing broods on the same site using schedules differing only in flush intensity.

Data Collection

A secondary objective of this report was to determine if count data at ACGRP sites were being collected at the correct time (i.e. 7, 21, 35 days) so that they were usable in analysis to accomplish the objectives of the long-term ACGRP project. In the first 2 years of the ACGRP investigation, a large portion of flush count data were censored and could not used in Kaplan-Meier chick survival estimation because counts were often done > 2 days before or after the date prescribed by ACGRP protocol. However, I was able to calculate regression models using all ACGRP flush count data to estimate of the number of chicks per brood from flush counts of known-age broods. I recommend sampling all broods on a weekly or biweekly schedule for Kaplan-Meier estimation. However, sampling for regression analysis is less time-consuming and may be more appropriate for ACGRP cooperators.

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Table 2.1. Weekly survival estimates of ruffed grouse chicks sampled twice each week on the intensive schedule. Data collected from 3 sites in the southern Appalachians, 1997-1998.

	1997				1998				Years Pooled			
Week	Broods[a]	n[b]	S[c]	SE[d]	Broods	n	S	SE	Broods	n	S	SE
1	8	77	0.18	0.09	4	33	0.45	0.15	12	110	0.26	0.07
2	10	28	0.68	0.17	5	21	0.71	0.13	15	49	0.69	0.10
3	11	28	0.89	0.07	8	27	0.89	0.13	19	55	0.89	0.04
4	11	41	0.68	0.16	6	23	0.91	0.08	17	64	0.76	0.04
5	10	28	0.96	0.08	5	21	0.90	0.07	15	49	0.90	0.04
6	9	25	0.88	0.08	5	19	0.74	0.10	14	44	0.82	0.05
7	8	20	1.20	0.12	3	8	0.88	0.81	11	28	1.11	0.03
8	7	22	0.91	0.06	3	7	1.00	0.00	10	29	0.93	0.02
9	5	17	0.88	0.07	3	7	0.71	0.20	8	24	0.83	0.05
10	6	18	0.83	0.09	2	3	1.00	0.00	8	21	0.86	0.08
11	5	4	1.00	0.00					5	4	1.00	0.00
12	2	4	0.75	0.25					2	4	0.75	0.25
13	2	3	1.00	0.00					2	3	1.00	0.00

[a] number of broods

[b] number of chicks

[c] estimation of survival from beginning to end of week

[d] standard error

Table 2.2. Survival estimates of ruffed grouse chicks sampled on the Appalachian Cooperative Grouse Research Project (ACGRP) schedule. Data collected from 5 sites in 1997 and 7 sites in 1998 in the southern Appalachians, 1997-1998.

	1997				1998				Years Pooled			
Period	Broods[a]	n[b]	S[c]	SE[d]	Broods	n	S	SE	Broods	n	S	SE
Hatch-Week 1[e]	13	117	0.28	0.08	9	70	0.48	0.16	22	187	0.36	0.07
Week 1-Week 3	7	27	0.63	0.22	5	31	0.58	0.20	12	58	0.60	0.06
Week 3-Week 5	5	15	0.47	0.25	6	25	0.68	0.20	11	40	0.60	0.06

[a] number of broods

[b] number of chicks

[c] estimation of survival from beginning to end of period

[d] standard error

[e] survival estimated from hatch to end of week 1

Table 2.3. Coefficient of determination (R^2), intercept (B_o), and slopes (B_1 and B_2) used to determine the relationship between the proportion of chicks hatched that are counted at flush counts and brood age. Data used in regression analysis collected at 8 sites in 1997 and 9 sites in 1998 in the southern Appalachians.

Year	n	R^2	B_o	B_1	B_2
1997	41	0.12	0.3755	-0.0084	0.000005
1998	45	0.18	0.6146	-0.0192	0.0002
Pooled	86	0.14	0.5067	-0.0145	0.0001

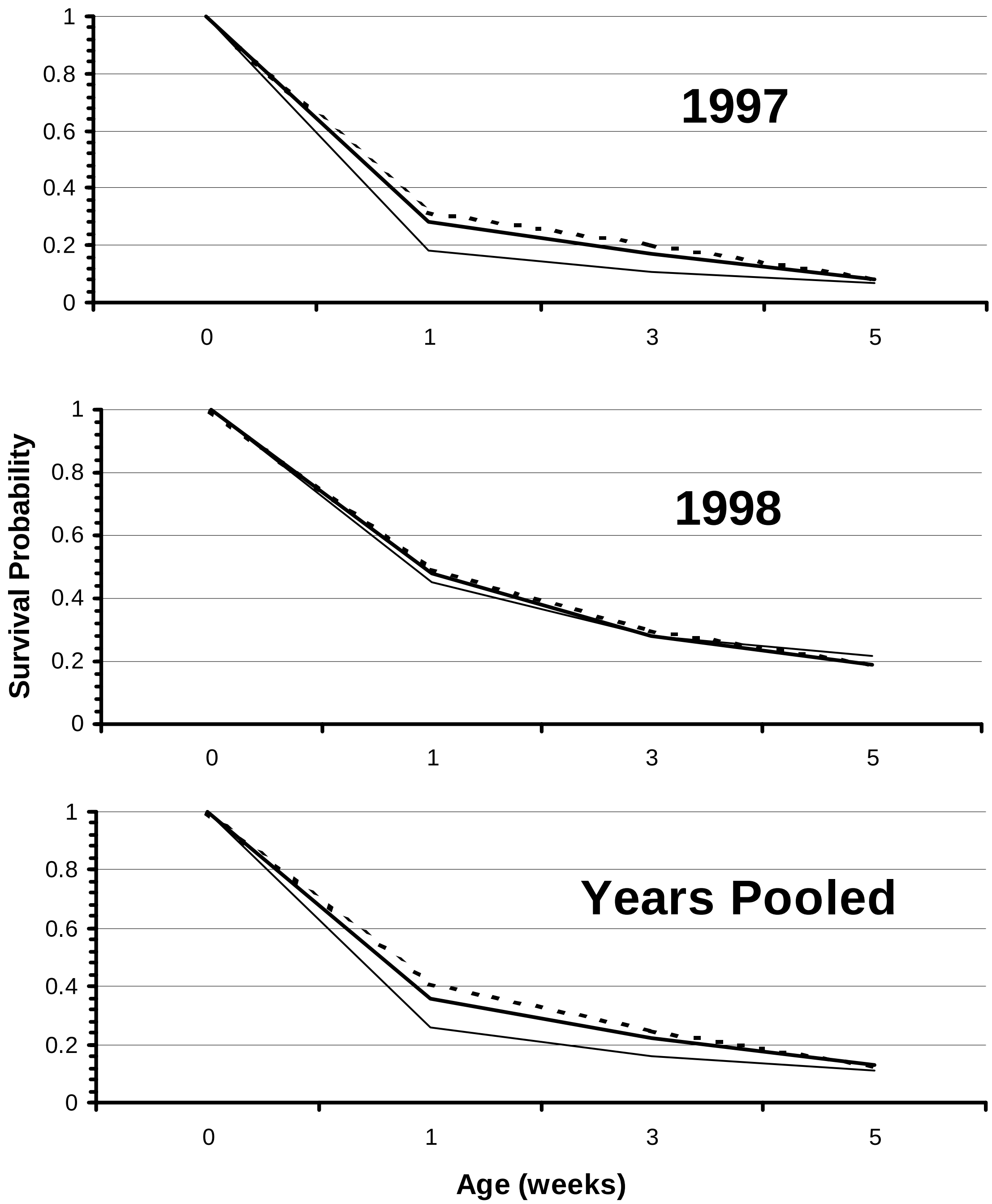

Figure 2.1. Survivorship of ruffed grouse chicks in the southern Appalachians, 1997-1998, using data sampled from intensive schedule and ACGRP schedule broods. Survivorship of intensively scheduled broods (—)was calculated using a Kaplan-Meier estimator. ACGRP schedule Kaplan-Meier estimates (▬) were calculated from flush counts done 7, 21, and 35 days (± 2 days) post-hatch, and regression analysis (▪▪▪) includes all ACGRP schedule flush counts.

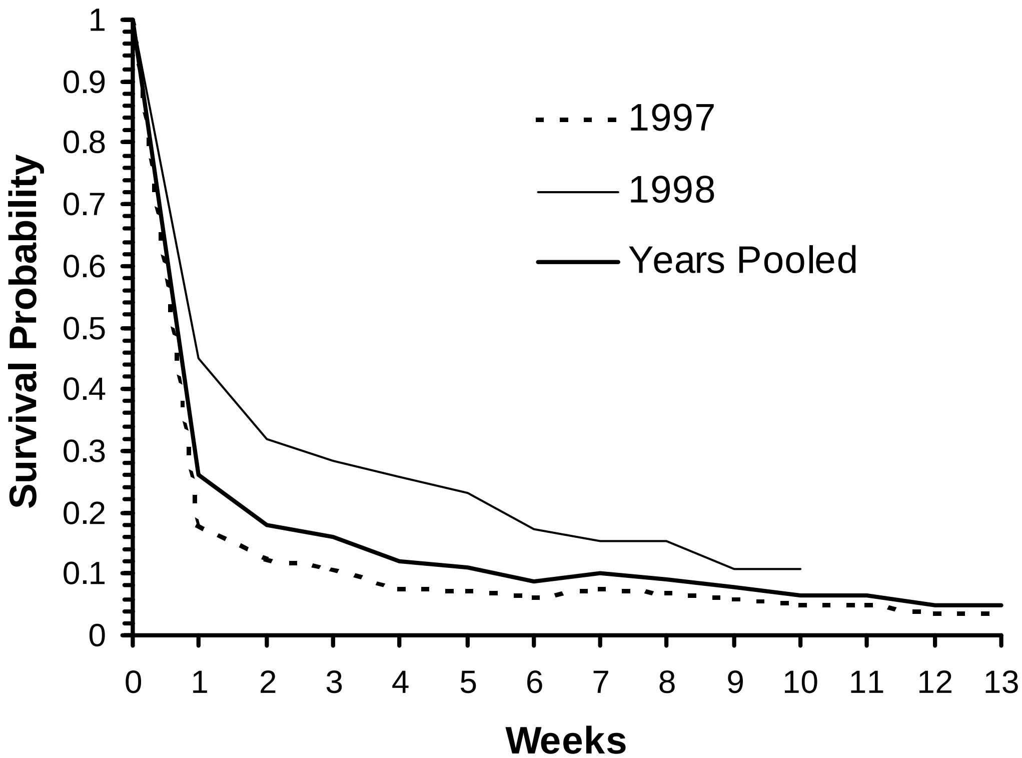

Figure 2.2. Survivorship of ruffed grouse chicks in the southern Appalachians, 1997-1998, using data sampled from intensive schedule broods.

Table 2.4. Mean number of ruffed grouse chicks alive at weeks 1, 3, and 5. Mean number of chicks per successful hen includes broods that lost all chicks. Mean number of chicks per surviving brood includes only broods with $\geq$ 1 living chick(s). Mean number of chicks per hen entering the nesting season is the product of mean chicks per successful hens, ACGRP nesting rates, and ACGRP hen success rates. Data collected at 8 sites in 1997 and 9 sites in 1998 in the southern Appalachians.

		Successful Hen				Surviving Brood				Mean Chicks Per Hen
Year	Week	Broods [a]	n [b]	Mean [c]	SE [d]	Broods	n	Mean	SE	Entering the Nesting Season
1997	1	26	68	2.6	0.5	17	68	4.0	0.5	1.8
	3	31	64	2.1	0.4	17	64	3.8	0.5	1.4
	5	30	34	1.1	0.3	13	34	2.6	0.4	0.7
1998	1	14	55	3.9	0.9	11	55	5.0	0.9	1.8
	3	18	49	2.7	0.6	12	49	4.1	0.7	1.2
	5	17	36	2.1	0.7	10	36	3.6	0.9	1.0
Years Pooled	1	40	123	3.1	0.4	28	123	4.4	0.4	1.7
	3	49	112	2.3	0.4	29	112	3.9	0.4	1.3
	5	48	70	1.5	0.3	23	70	3.0	0.4	0.8

[a] number of broods

[b] number of chicks

[c] mean number of chicks per brood at the end of each week

[d] standard error

Table 2.5. Mean number of ruffed grouse chicks alive at weeks 1, 3, and 5 in 3 regions of the southern Appalachians, 1997-1998. Mean number of chicks per successful hen includes broods that lost all chicks. Mean number of chicks per surviving brood includes only broods with $\geq$ 1 living chick(s). Mean number of chicks per hen entering the nesting season is the product of mean chicks per successful hens, ACGRP nesting rates, and ACGRP hen success rates. 1997 data collected at 3 sites in the Ridge and Valley region, 3 sites in the Alleghany Plateau region, and 2 sites in the Ohio River Valley region. 1998 data collected at 4 sites in the Ridge and Valley region, 3 sites in the Alleghany Plateau region, and 2 sites in the Ohio River Valley region. Data pooled over years.

		Successful Hen				Surviving Brood				Mean Chicks Per Hen
Region	Week	Broods [a]	n [b]	Mean [c]	SE [d]	Broods	n	Mean	SE	Entering the Nesting Season
Alleghany Plateau	1	14	47	3.4	0.9	10	47	4.7	0.9	2.2
	3	16	35	2.2	0.6	10	35	3.5	0.6	1.54
	5	14	13	0.9	0.5	10	13	2.6	1.0	0.6
Ohio River Valley	1	4	14	3.5	2.1	2	14	7.0	1.0	1.4
	3	3	8	2.7	2.7	1	8	8.0	0.0	1.1
	5	3	7	2.3	2.3	1	7	7.0	0.0	0.9
Ridge and Valley	1	22	62	2.8	0.5	16	62	3.9	0.5	1.6
	3	30	69	2.3	0.5	18	69	3.8	0.5	1.3
	5	31	50	1.6	0.4	17	50	2.9	0.5	0.9

[a] number of broods

[b] number of chicks

[c] mean number of chicks per brood at the end of each week

[d] standard error

Table 2.6. Proportion of successful nests from which ACGRP cooperators collected data usable in chick survival estimate calculation, 1997-1998.

Year	Successful Nests	Hatching Data Collected (%)	Flush Count Data Collected		
			Week 1 (%)	Week 3 (%)	Week 5 (%)
1997	43	58	49	56	56
1998	30	87	43	60	70

Table 2.7. Number of discarded week 1, 3, and 5 ruffed grouse flush counts and the reasons why they were not included in survival estimate calculations, 1997-1998.

	Counts > 2 Days of 7, 21, 35 Days Post-Hatch			No Counts Reported			Other[a]		
Year	Week 1	Week 3	Week 5	Week 1	Week 3	Week 5	Week 1	Week 3	Week 5
1997	9	16	12	9	3	1	4	0	6
1998	15	9	6	2	3	1	0	0	2

[a] includes vague counts and instances where only 1 reliable count was available for a brood (cannot contribute to survival estimate calculation)

CHAPTER 3

RUFFED GROUSE BROOD MICRO-HABITAT SELECTION IN THE SOUTHERN APPALACHIANS

Brood habitat is an important, perhaps critical, part of ruffed grouse habitat. Berner and Geysel (1969) described brood cover as the single most important component of grouse habitat. Brood habitat provides cover and forage for broods and their hens, as well as other nonbrooding adults. Sharp (1963) believed the short life-span of ruffed grouse (2-4 years) made recruitment and the quality of the brood range even more critical to a sustained population. In Virginia, Stewart (1956) suggested the presence or absence of appropriate brood habitat may be a major limiting factor to ruffed grouse populations.

The 2 most commonly reported characteristics of brood cover are high stem densities in regenerating stands (Porath and Vohs 1972, Gullion 1977, Kubisiak 1978, Freiling 1985, Stauffer and Peterson 1985, Harris 1981) and moderately-dense herbaceous ground cover (Bump et al. 1947, Sharp 1963, Berner and Geysel 1969, Porath and Vohs 1972, Gullion 1977, Kubisiak 1978, Freiling 1985, Harris 1981). Though brood cover has been thoroughly described throughout most of ruffed grouse range, few authors have investigated brood habitat in the southern Appalachians. In northern Georgia, Harris' (1981) results were similar to what had been reported from other portions of ruffed grouse range; he found broods selected regenerating, upland and cove hardwood sapling and poletimber stands. A study in North Carolina, however, reported 15 broods were found in mature oak-pignut hickory stands (Hein 1970).

Food availability is also an important component of brood habitat. Several authors have emphasized the importance of available, high-quality foods on brood ranges (Bump et al. 1947, Kimmel and Samuel 1978, Bergerud 1988, Hollifield and Dimmick 1995). Bergerud (1988) suggested food abundance within good cover is necessary for chicks to successfully survive the first 2 weeks of life. In the first several weeks after hatch, a diet consisting of approximately 30% protein is required by chicks for rapid tissue growth (Bump et al. 1947). Protein-rich diets allow developing chicks to double in weight within the first week (Bump et al. 1947). Insects and other arthropods are high in protein and constitute > 90 % of the chick's diet in the first 3 weeks post-hatch (Stewart 1956, Kimmel and Samuel 1984, Hollifield and Dimmick 1995). After a chick's third week, fruit and green leaves constitute an increasing portion of the diet, and by the eighth week, vegetation and fruit are consumed more than arthropods (Kimmel and Samuel 1978).

Habitat offering a high abundance of arthropods may not offer an abundance of suitable plant foods. Therefore, older broods that primarily consume fruits and vegetation may select habitat with different characteristics than the habitat chosen by younger, arthropod-consuming broods. In Minnesota, Godfrey (1975) noted brood ranges shifted after a preliminary pattern had been established early in the brood season. He believed this shift was the result of a change in dietary needs. In western Virginia, Stewart (1956) noted an abrupt change in the habitat preferences of broods by July. In early summer, broods were found in moist coves and ravines; in late summer, broods were found in dry, forested, mountain slopes in the vicinity of blueberry (*Vaccinium* spp.) patches (Stewart 1956). Also during this study, Stewart (1956) analyzed the crop and stomach contents of 29 chicks and found their diet to be dominated by fleshy fruits duing July and August. In New York, Bump et al. (1947) found similar results after examining 540 chick stomachs. During 1 summer, 73% of chick stomachs contained the remains of raspberry and blackberry fruit (*Rubus* spp.) (Bump et al. 1947).

The objectives of this study were to determine if brood habitat selection occurs and, if so, whether the criteria for selection change over the brood period. Few studies have attempted to determine which habitat characteristics, including cover and food availability, are important to broods in the southern Appalachians. In my study, selection criteria include numerous micro-scale vegetative cover characteristics, as well as food (vegetative and arthropod) availability. Although many authors have suggested habitat shifts occur during the brood season, I know of no study that attempted to quantitatively detect these shifts in the southern Appalachians. To determine if selection changes over time, I identified habitat components that were selected by grouse broods weekly and during 3 periods of chick development: early (hatch-3 weeks), middle (4-6 weeks), and late (7-9 weeks).

METHODS

Study Sites

Habitat data were collected at VA/2, VA/3, and WV/2 study sites during the summers of 1997 and 1998 (Table 0.1). The VA/2 study site is owned by Westvaco Corporation and intensively managed for timber production. This study site is characterized by regenerating hardwood clearcuts interspersed among large tracts of contiguous mature forest. The VA/3 study site is managed by Virginia Department of Game and Inland Fisheries and characterized by large tracts of contiguous forest cover interspersed with clearings maintained for wildlife and several regenerating hardwood clearcuts. The WV/2 site is located on property owned by Westvaco Corporation and is intensively managed for timber production and similar in character to the VA/2 study site.

Trapping

Ruffed grouse hens were captured each fall and spring during 1996-1998. Typically, 2 lily-pad traps were used, joined by a chicken-wire drift-fence (Gullion 1965). Traps were located in areas accessible by roads where grouse had been seen previously seen or in areas deemed suitable habitat.

Sex and age-class (juvenile or adult) were determined for each captured bird using the methodology previously described by Davis (1969) and Roussel and Ouellet (1975). A necklace-style 10-11 g radio-transmitter (Advanced Telemetry Systems, Isanti, MS) was fitted around the neck of each captured bird, with the weight of the unit resting on the crop. Transmitters were mortality sensing, operated in the 150-152 Mhz range, and had a life expectancy of at least 1 year. Each captured bird was weighed and fitted with a uniquely numbered aluminum leg band for identification. Most birds were released within 15 m of the trap site and < 1/2 hour after being removed from the trap.

Monitoring

Prior to nesting (i.e., before approximately April 1), each radio-tagged hen was monitored at least twice each week by field personnel. A 3-element Yagi or "H-type" antenna and portable receiver (Advanced Telemetry Systems, Isanti, MS and Telonics, Inc., Mesa, AZ) were used to monitor hens from fixed telemetry stations located by a global positioning system (GPS) unit (Corvallis MicroTechnology, Inc., Corvallis, OR). Observers plotted 3-5 fixes in the field on U. S. Geologic Survey 7.5 minute topographic maps and identified the 3 azimuths with best agreement.

After mid-April, hens were assumed to have begun nesting when their estimated locations were consistently within approximately 100 m of each other. Hatch date was estimated to be 41 days after nesting was assumed to have begun (accounting for a 17 day egg laying period and 24 day incubation). Most nests were visited during the estimated last week of incubation to determine clutch size and to visually locate the nest. During the last week of incubation most hens were located more than twice each week, some as much as daily, to detect the day the hen and brood left the nest.

Following nest departure, hens with broods were located twice each week though triangulation and visual observation. After triangulating the hen and determining the general location, observers followed the signal of the hen's radio-transmitter to locate and flush the brood. The location where the brood flushed was marked with flagging tape labeled with a plot identification code and entered into a GPS unit.

One assumption of this study is that personnel approaching the brood do not influence where the brood is first observed. To determine if the hen was moving as personnel approached, the hen's radio-transmitter signal was continually monitored. A varying signal indicated the hen was moving, since movement often causes the signal to vary. Previous research on ruffed grouse activity concluded varying signal strength was a good indicator of movement (Hewitt and Kirkpatrick 1997). If the hen and brood were believed to be moving away from approaching observers, personnel would attempt to confine them by quickly separating into 2 groups and approaching the brood from different directions. However, the success of this technique often was determined by the topography and vegetation density. Thick cover on steep slopes made quick approaches difficult and if the brood was believed to have moved a considerable distance (i.e., >20 m) as personnel approached, the flush and habitat sampling were postponed until at least the following day.

Habitat Sampling

Habitat was sampled at each brood-flush location and a randomly-located paired site 100 m from the flush site. Habitat was always measured at locations where the brood flushed, even in cases where the hen flushed several meters from the brood. During the course of this study it was found that some broods regularly remained motionless while the hen moved – in effect "leading" observers away from the brood. In these instances, vegetation where the hen was first located was extensively searched by some observers while others quickly followed the hen to induce a flush.

Often, the hen would flush and fly a considerable distance (> 50m) and the brood would scatter into nearby cover. Habitat sampling was conducted on the randomly selected plot (random site) first to allow the hen to return to the brood. Once the random plot was sampled (approximately 45 minutes to 1-1/2 hours), observers returned to the brood flush site (brood site) and sampled vegetation there.

Habitat was sampled within a 0.04 ha plot (11.3 m radius) centered where the brood was first observed and a plot 100 m from the brood site. In 1997, random sites were located 100 m in the opposite direction the brood flushed to ensure the brood was not disturbed while sampling at the random site. In 1998, plot selection was made more random by using randomly chosen azimuths. Over 100 random azimuths were generated using Microsoft Excel computer software and used in the order they were generated. If the random azimuth fell in the exact direction the brood flushed, a second azimuth was chosen from the list.

In the 0.04 ha plot, 4 11.3-m transects radiated from the plot center in each of the cardinal directions. Transects were delineated by a measuring tape stretched to 11.3 m and marked at 2 m intervals. Stem density of shrubs and saplings, and percent tree, ground, and dead woody cover (slash) were measured along each transect (Noon 1981). Trees were defined as any woody stem > 8 cm dbh and > 2 m tall, saplings as woody-stemmed plants < 8 cm dbh and > 0.5 m tall, shrubs as multiple-stemmed woody plants < 3 cm dbh and > 0.5 m tall, ground cover as any live cover (woody or herbaceous) < 0.5 m high, and slash as dead woody material ≥ 15 cm above the ground or ≥ 15 cm dbh.

Percent canopy, ground, and slash cover were measured by recording the presence ("hit") or absence of each item at 2 m increments along each transect (Noon 1981). Ground or slash cover was present if the material intersected the measuring tape at 2 m intervals. Canopy cover was present if green, leafy material (conifer or deciduous) crossed > 2 m above the measuring tape at 2 m intervals. Canopy above the transect was isolated using a 1.5 inch diameter tube with 2 perpendicular pieces of monofilament line at 1 end to serve as cross-hairs. Only canopy centered within the intersection of the sighting tube cross-hairs were counted as a hit for the location. Percent cover for each type of cover is the sum of hits for that type over all 20 plot locations multiplied by 5. To determine ground cover and slash height, the highest intersecting item < 0.5 m at each location was measured. Average ground and slash cover height over the entire plot was determined by dividing the total height of all hits by 20, the number of 2 m intervals on all 4 transects.

To measure stem density of shrubs and saplings, observers walked transects with a 2 m pole at breast height, parallel to the ground and perpendicular to the transect (Noon 1981). Each shrub and sapling stem encountered was tallied, taking care not to double count where transects met.

Within the 0.04 ha plot the number of all trees > 8 cm dbh was counted (Noon 1981). A tally of trees by species was recorded within the following 4 size classes: 8-20 cm, 21-40 cm, 41-60 cm, and > 60 cm. Species names were in accordance with Gray's Manual of Botany (Fernald 1950). Basal area was also measured from the center of the 0.04 ha plot.

To characterize herbaceous cover 3 1-m^2 quadrats were centered 12.3 m from the 0.04 ha plot center at azimuths of 0°, 120°, and 240°. Data were obtained from each plot to estimate fruit and green leafy forage abundance. Within each 1-m^2 quadrat the total number of fruits (soft and hard mast, forb and grass seed) were counted, and representative samples of each were collected to determine dry mass. Forbs were defined as broad-leaved herbaceous plants, excluding ferns, grasses, sedges, and mosses. Fruit samples were initially air dried and later dried to a constant weight in a microwave oven at study site locations and Virginia Polytechnic Institute & State University (VPI&SU). Total dry mass of fruit in each plot was calculated by multiplying fruit count by sample dry mass.

Green leaf samples used to estimate forage dry mass were collected using a rank-set sampling approach (Banker 1994). At each brood site, the 3 1-m^2 quadrats were ranked on the basis of total estimated volume (1-m x 1-m x 0.5-m) of forbs, deciduous woody plants, and grasses/sedges. At the first brood plot, the quadrat with the highest ("high") estimated volume ranking was clipped to remove all green leaves within the quadrat to a height of 0.5 m. At the second brood plot, the quadrat with the second highest estimated total volume ("medium") was clipped, and at the third brood plot the quadrat with the lowest ("low") estimated total volume was clipped. Clipped vegetation was separated into the following categories: forbs, deciduous woody plants, and grasses/sedges. In all 3 quadrats an ocular estimation of the volume contributed by each category was made. To determine dry mass of the clipped sample, clipped leaves were initially air dried, then dried to a constant weight in a microwave oven and weighed at study sites and VPI & SU. If oven-drying could not be accomplished soon after clipping, samples were stored, below freezing, in a freezer at VPI & SU. Regression analysis for each estimator allowed the development of models that predicted the dry mass in each of the unclipped quadrats based on the volume estimates and the clipped-quadrat dry mass results.

No attempt was made to sample only fruit and forage species ruffed grouse hens and chicks prefer. Ruffed grouse have been shown to consume a wide variety of plant species and parts, especially in the summer (Bump et al. 1947, Korschgen 1966, Kimmel and Samuel 1978, Stoll et al. 1980). Though grouse diets have been studied extensively, few studies have thoroughly investigated summer food preference because of the difficulty in obtaining crop and/or stomach samples from juveniles and adults outside of the hunting season. Additionally, studies that rely on fecal droppings are unable to identify all herbaceous species, a major contributor to the summer diet (Korschgen 1966, Stoll et al. 1980). The most comprehensive list of summer foods was published by Bump et al. (1947), which named 414 plant species known to be consumed by grouse in New York. In addition to most of these species, many more occur in the southern Appalachian region. Because it would be impractical in the scope of this study to sample only known summer foods, our fruit and forage samples provide a crude index of food availability. Easily identified, locally common plants grouse are known to avoid in the summer, such as evergreen shrubs (e.g., *Kalmia* spp.), oak leaves (*Quercus* spp.), conifer seedings (e.g., *Pinus* spp.), and ferns were excluded from the sample. It is assumed that all other plants and their fruit are consumed or, at the very least, sampled.

In addition to vegetative and topographic variables, arthropod abundance was measured in each brood and random plot for the first 4 weeks of study. To measure ground-dwelling arthropods, 4 0.5-m^2 quadrats were established. One quadrat was centered 6 m from the 0.04 ha plot center in each of the following directions: 45°, 135°, 225°, and 315°. Field personnel observed each quadrat for 2.5 minutes and collected all arthropods seen crawling on the top of the litter with forceps and an aspirator. The observer then lightly disturbed the top portion of the litter within the quadrat with their hand and observed the contents for another 2.5 minutes, collecting arthropods as before. I believe this time period and degree of disturbance simulates the activity of a grouse chick feeding within a 0.5 m^2 area. Typically, grouse chicks scratch very little when feeding (Bump et al. 1947), and when feeding in litter, they are believed to rely on arthropods found on the ground surface or immediately within the top of the leaf litter.

Sweep-netting was done to collect arthropods that were clinging to vegetation or flying near the ground. Four 11.3 m transects were slowly walked in each of the cardinal directions, and a "sweep" performed at each step. The transects essentially formed a box around the 0.04 ha plot; the corners were located 16 m from plot center at 45°, 135°, 225°, and 315°. A "sweep" consisted of a full swing of the sampling net to the left and right of the collector through ground vegetation ($\leq$ 0.5 m tall). The contents of the net were emptied into a collection bag, marked by the plot number, and analyzed later (usually within 24 hours). Within each 0.04 ha plot, the total number of individuals (litter-dwelling and sweep-net sampled) were tallied by taxonomic order according to Borror et al. (1989). To simplify counting, collected individuals were killed by introducing ethyl acetate-soaked cotton wads into collection bags.

Since arthropod activity was believed to be low during and recently following rainfall, arthropod sampling was done only when the vegetation on a sampling site was dry. When the vegetation was wet, sites were visited and arthropod samples collected at the soonest available opportunity after drying (usually within 24 hours).

Data Analysis

The objectives of this study were to determine if brood habitat selection occurs and, if so, whether the criteria for selection change over the brood period. To detect temporal change, data were first analyzed weekly (weekly tests), then during early (weeks 1-3), middle (weeks 4-6), and late (weeks 7-9) brood periods (period tests). Weeks 1-3 were analyzed separately from the weeks following to detect changes in habitat selection between these periods that may occur due to the chicks' dietary change at approximately week 3 (Bump et al. 1947, Stewart 1956, King 1969). The remaining weeks were divided into 3 week periods to aid in discussion and provide for a test of selection during 3-week intervals later in the brood period. Because no data were available in week 12, weeks 10 and 11 are not included in the period analysis and are presented only in the weekly analysis.

Habitat plots sampled within the same week (7 day intervals post-hatch) were averaged by brood to use in weekly and period tests. Though most broods were sampled twice each week, no attempts were made to analyze data within weeks (i.e., early and late week). In many cases, a brood's 2 weekly habitat plots occurred during the first or last half of a week, and "early" and "late" week samples would have been unbalanced. Additionally, most broods were sampled twice each week, but in a few cases only 1 sample could be obtained.

For each variable, the null hypothesis tested was that there was no difference between the brood and random plot response. Weekly differences were tested by calculating mean weekly values from brood and random plots for each hen, then testing the mean difference between the brood and random plot response for all hens during each week. Period differences were tested by calculating period mean values from brood and random plots by hen, then testing the mean difference between the brood and random plot response for all hens during each period. To test the null hypothesis, a permutation test for matched pairs (PTMP) was used in program BLOSSOM (Midcontinent Ecological Science Center, Fort Collins, CO). Since PTMP is a distribution-free statistical test, it is the appropriate choice for these nonrandom data (Slauson et al. 1994). Additionally, this test is more powerful with small samples than many conventional nonparametric alternatives (Slauson et al. 1994).

Each brood's paired response (difference) is independent of other broods' samples because the brood and random plots are paired and the differences are being tested. This being the case, I pooled samples (broods) across study areas and years to increase the sample size and the power of statistical tests.

I found whole brood mortality to be high during the first 2 weeks of the brood period (see Chapter 2). I analyzed habitat data, post hoc, to determine if there was a difference between the habitat selected by successful ($\geq$ 1 chick lived at least 6 weeks) and unsuccessful broods (0 chicks by 2 weeks) in the first 2 weeks of the brood period. To compare habitat selection between the 2 categories, I tested the mean differences between the habitat variable response in brood and random plots of successful and unsuccessful broods during the first 2 weeks following hatch. To compare the habitat where broods were flushed (habitat assumed to be used) between the 2 categories, I tested the mean habitat variable response in brood plots only for successful and unsuccessful broods during the first 2 weeks following hatch. A multiresponse permutation procedure in program BLOSSOM was used to compare habitat selection (differences tested) and habitat use (mean brood plot responses tested) between successful and unsuccessful broods.

Shrub stems were sampled in subclasses (i.e., shrubs were classified and sampled in 4 categories: large or medium deciduous and evergreen shrubs), and after analysis the difference between brood and random plot response for subclasses appeared similar (Appendix B). Consequently, shrub subclasses were recombined into 1 variable ("shrubs") and the results reported are the sum of all 4 subclasses. Tree size classes (8-20 cm dbh, 21-40 cm dbh, 41-60 cm dbh, >60 cm dbh) were combined into 2 consolidated variables ("sawtimber" [> 20 cm dbh] and "all size classes") to aid in discussion. The results reported for these variables are the sum of all size classes relative to them. Data for all tree size classes are presented and discussed separately from consolidated variables when relevant.

Several authors have identified taxonomic orders of arthropods that are preferred by ruffed grouse chicks (Bump et al. 1947, Stewart 1956, Kimmel and Samuel 1984). These studies have indicated the orders Coleoptera, Diptera, Hymenoptera, Hemiptera, Homoptera, and Arachnida are consumed in the greatest quantities and are important in chick diets. Therefore, the availability of individuals in these preferred taxonomic orders were compared separately at brood and random sites, in addition to the availability of all arthropods (orders combined).

RESULTS

Vegetation structure, forage dry mass, and fruit data were obtained for 25 radio-collared hens with broods during summers of 1997 and 1998; 6 at VA/2, 7 at VA/3, and 12 at WV/2. During 1997-1998, 203 pairs of habitat plots were sampled; 62 at VA/2, 43 at VA/3, and 98 at WV/2. Arthropod data were obtained for 16 hens with broods during 1997-1998; 6 at VA/2, 7 at VA/3, and 3 at WV/2. Arthropod data were sampled at 157 pairs of plots; 57 at VA/2, 56 at VA/3, and 44 at WV/2. Mean weekly values for brood and random plots are presented in Appendix B.

Whole-brood mortality was high during this study (see Chapter 2), and because habitat sampling was discontinued after all of the chicks in a brood died, the sample available for statistical tests diminished as the brood season progressed. Therefore, early weekly tests have moderate sample sizes, while tests done later in the brood period (i.e., after week 6) have fewer broods available in the sample. For period tests (weeks 1-3, 4-6, and 7-9), broods were included in each period if they had compete data available for that period. In other words, all of the broods included in the early period tests had complete data for weeks 1-3. It should be noted that while some broods contribute data for all periods, some do not. This explains why the early period has a sample size of 9 and the latest period has a sample of 6. Also, more broods had complete data for weeks 4-6 (n=11) than the other 2 periods because several broods older than 3 weeks were added to the sample in June of 1997. No habitat data are available for these broods prior to week 4.

Vegetation Structure

Of the cover variables measured (percent ground cover, ground cover height, slash cover, slash cover height, and percent canopy cover), ground cover height was higher in brood plots than random plots during the early (P = 0.01), middle (P = 0.02), and late (P = 0.06) brood periods (Table 3.1). Percent ground cover was greater in brood plots than random plots in early

(P = 0.05) and middle (P = 0.06) brood periods but not in late brood period (P = 0.16) (Table 3.1). No other cover variables were different during the early, middle, or late brood period (Table 3.1). Likewise, small stem variables (total sapling, deciduous sapling, conifer sapling, and total shrub stems) did not differ significantly between brood and random plots during early, middle, or late brood periods (Table 3.2).

Of the tree variables measured (basal area, 8-20 cm dbh, 21-40 cm dbh, 41-60 cm dbh, > 60 cm dbh) only the number of trees in the 41-60 cm dbh size class (P = 0.05) was higher in brood plots than random plots during the early brood period (Table 3.3). All other tree variables were not different in brood and random plots during the early brood period (Tables 3.3 and 3.4). The number of trees in the 8-20 cm dbh size class were different in weeks 1 (P = 0.06), 2 (P = 0.06), and 3 (P = 0.08), though the direction of the difference was not consistent among weeks (Table 3.3). More trees in this size class were found at brood sites during week 1, while fewer were at brood sites in weeks 2 and 3 (Table 3.3). In the middle brood period, the number of trees in the 8-20 cm dbh size class was lower (P = 0.07) in brood plots than random plots (Table 3.3). In the late brood period, basal area (P = 0.03) and the number of sawtimber trees (P = 0.06) were lower in brood plots than random plots (Table 3.4). All other tree variables were not different between brood and random plots during the middle or late brood period (Tables 3.3 and 3.4).

Forage, Fruit, and Arthropod Abundance

To calculate forage dry mass using the ranked-set approach, estimator-specific regression models were derived from dried samples and used to estimate dry mass from volumetric estimates. Because grass, deciduous woody material, and forbs have grossly different forms, each category was estimated and modeled separately. Scatterplots of dry mass and volumetric estimates for each forage category and estimator indicated a curvilinear pattern fitted these data best, thus a polynomial regression model ($y=B_o+B_1x+B_2x^2+\varepsilon$) was used. Coefficient of determination, or R^2, values ranged from 0.47 to 0.97 (Table 3.5), and indicate that 47-97% of the variability in dry mass can be explained by volumetric estimates. The majority of R^2 values are > 0.7, suggesting dry mass estimates can be adequately predicted by volumetric estimates (Table 3.5).

Forage dry mass was higher (P = 0.03) in brood plots than random plots during the early brood period (Table 3.6). No difference was found in brood and random plots during the middle

(*P* = 0.23) and late (*P* = 0.13) brood periods. However, 7 of 8 mean weekly differences in weeks 4-11 are positive, suggesting forage dry mass was higher at brood sites during this period but not significantly (Table 3.6). Fruit dry mass was higher in brood plots than random plots only during the early (*P* = 0.11) brood period (Table 3.6).

No difference was observed in arthropod abundance in litter between brood and random plots (Appendix B); therefore, no statistical analyses were done with these data. No further reference will be made to our litter sample, and only sweep-net samples will be considered when referring to differences in arthropod abundance between brood and random plots. The abundance of sweep-net sampled arthropods (*P* = 0.02) was higher in brood plots than random plots during weeks 1-3 (Table 3.7). This indicates brood plots had a higher abundance of arthropods flying or clinging to low vegetation than random plots. Additionally, all weekly tests yielded positive mean differences in weeks 1-4 (Table 3.7). The abundance of individuals in the orders Coleoptera (*P* = 0.02), Homoptera (*P* = 0.05), and Arachnida (*P* = 0. 0.03) were higher in brood than random plots during the first 3 weeks of the brood season (Table 3.8).

Comparison of Habitat Selection and Use by Successful and Unsuccessful Broods

Other than selection of brood sites on the basis on conifer saplings, there was no difference between the habitat selected by successful ($\geq$ 1 chick lived at least 6 weeks) and unsuccessful broods (0 chicks by 2 weeks) during the first 2 weeks of the brood season (Table 3.9). My data indicate that, compared to unsuccessful broods, successful broods more often (*P* = 0.01) selected sites with fewer conifer saplings than what was available in random plots. There were no differences between the habitat at used sites of successful and unsuccessful broods (Table 3.10).

DISCUSSION

Percent ground cover and ground cover height were the most important characteristics of brood sites in this Appalachian region of Virginia and West Virginia. Selection for sites with higher percent ground cover and ground cover height was apparent throughout the first 9 weeks of the brood period but was less significant during weeks 7-9. Considering the size of the grouse hen and chicks and their vulnerability as ground-dwelling birds, it is understandable that brood site selection is made on the basis of ground cover. Percent slash cover and slash cover height were not significant selection criteria, although they were generally greater in brood plots. Slash cover may be less desirable cover because it acts as an obstacle to chick movement. Previous authors have suggested woody debris and logging slash may impede brood movement, particularly in dense vegetation and early successional stands (Kubisiak 1978, Harris 1981).

Authors of previous studies emphasize the importance of ground cover as a component of ruffed grouse brood habitat (Bump et al. 1947, Sharp 1963, Berner and Geysel 1969, Porath and Vohs 1972, Godfrey 1975, Kubisiak 1978, Harris 1981, Freiling 1985, Stauffer and Peterson 1985). Specifically, brood habitat is often characterized as having moderately dense ground cover (Bump et al. 1947, Hungerford 1951, Sharp 1963, Porath and Vohs 1972, and Maxson 1978). Working with imprinted turkey poults in West Virginia, Healy (1985) also reported that moderately dense cover is best for turkey brood habitat. He reported that managed wildlife clearings, the densest cover available on study areas, were too thick for young poults to travel through. In Wisconsin, Maxson (1978) found fern-covered, open forest to be best suited for ruffed grouse broods. Tall ferns provided cover up to 1 m in height and a relatively open space at ground-level for easy maneuvering (Maxson 1978). In West Virginia, Kimmel and Samuel (1984) reported that woody vegetation on brood areas provided shade, and moderately dense and diverse herbaceous growth provided adequate forage.

Most authors report the moderate ground cover selected by broods is associated with frequent forest openings and clearings (Bump et al. 1947, Hungerford 1951, Sharp 1963, Porath and Vohs 1972, and Maxson 1978). In this study, however, there was little difference between the presence of canopy cover on brood and random sites, and there is no evidence that brood sites resembled openings or clearings in early (mean canopy cover = 81.4%, SE = 5.3), middle (mean canopy cover = 80.4%, SE = 4.7), or late (mean canopy cover = 86.0%, SE = 8.4) brood period (Appendix B). Additionally, the occurrence of broods flushing in forest openings was noted during habitat sampling at brood sites in 1998 (Appendix C). Few flushes (15%, hens pooled) occurred in roads or clearings and half (50%, hens pooled) were $\geq$30 m from an opening.

In general, brood sites in this study were more open, having slightly fewer trees than randomly selected sites. At brood sites, basal area and the total number of trees were lower than at randomly selected sites in 11 of 12 weeks, though this trend was not significant in all weeks. In this case, the measure of basal area is similar to the total number of trees in that both indicate that more area within randomly selected plots contained woody stems than in brood plots. This trend is consistent throughout all of the brood season after week 1, when the number of trees at brood sites was greater than at random sites. Furthermore, during this first week, brood sites were characterized as having significantly more trees in the 8-20 cm dbh size class than randomly selected sites. One reason for this may be that plots sampled early in the first week were still near the hen's nest site. Although nest habitat was not analyzed in this study, other authors have reported nests in the southern portion of grouse range are commonly within pole timber stands (Harris 1981, Freiling 1985). This may account for the significant prevalence of 8-20 cm dbh trees (generally referred to as pole timber) during the first week only.

After hens and broods left the natal habitat, the number of 8-20 cm dbh trees was significantly less in brood plots during several weeks. During weeks 2-6, no other size class was consistently different in brood and random plots, and, therefore, when considering tree characteristics, brood sites were similar to randomly selected sites except for the lack of trees in the midstory (8-20 cm dbh size class). Fewer trees in the midstory to block light penetrating the canopy may be responsible for the taller, more complete ground cover characteristic of brood sites. Clearings and large openings in the canopy may encourage ground cover growth that is too dense for brood use, whereas with a well-developed midstory and canopy may allow too little light to penetrate and restrict cover growth.

Previous studies have found that high woody stem density is one of the most recognizable features of brood habitat. In the Great Lakes region, grouse broods most often were found within stands of regenerating aspen and pole-sized oak (Gullion 1977, Kubisiak 1978) and alder (*Alnus* spp.) bottoms (Godfrey 1975, Kubisiak 1978). The aspen stands broods used in that region had the highest stem densities reported, ranging from 19,000-25,000 stems/ha (Gullion 1977) in Minnesota to 33,000 stems/ha (Kubisiak 1978) in Wisconsin. In Alberta, Rusch and Keith (1971) found that aspen woods were the most used habitat type by ruffed grouse in all seasons.

At the southern extent of ruffed grouse range, however, aspen stands of the magnitude found in the Great Lakes region and Canada are uncommon or nonexistent. Accordingly, authors report broods are often found in stands with considerably lower stem densities, though these stands often offer higher stem densities than other stands available in the local area. In Idaho, Stauffer and Peterson (1985) found broods in stands with high stem densities, a characteristic of early successional habitat. They determined, however, that at the micro-habitat scale the locations where broods were found were more open than surrounding areas. In Missouri, Freiling (1985) characterized brood habitat as having higher deciduous shrub density and total woody stem density than randomly selected locations. Porath and Vohs (1972) reported broods in Iowa often occupied regenerating hardwood stands and early successional woody growth. In northern Georgia, Harris (1981) found broods selected upland and cove hardwood sapling and poletimber stands. However, in North Carolina, Hein (1970) reported broods selected mature oak-pignut hickory stands.

In regard to the presence of trees, it appears the results of this study differ from most previous studies. Most authors working outside the southern Appalachians report brood sites have high numbers of woody stems, but, in general, brood sites in my study are best characterized as having slightly fewer trees than randomly available. However, it is important to consider scale when comparing most previous studies to mine. Previous brood habitat studies often were done at a cover-type level of habitat analysis, i.e., determining brood use of a cover-type relative to a cover-type's availability. My study investigated habitat selection on a micro-scale: determining brood use of a site-type relative to its availability within the brood's range. These scales are not totally compatible with one another. For example, Stauffer and Peterson (1985) investigated ruffed grouse brood habitat use on a cover-type (macro-) scale and micro-scale. While they found broods selected stands with high stem densities (macro-scale), they also found that broods most often were flushed in open areas within these stands (micro-scale). Therefore, it is debatable whether results from a micro-scale habitat study can be fairly compared to those of macro-scale studies.

In my study, fewer trees in the midstory may have contributed to the higher abundance of forage and fruits in brood plots during the early weeks of the brood period. The abundance of vegetative foods was highest in brood plots during the early portion of the brood period, and this was unexpected considering a chick's diet is still primarily arthropods during this period. However, there may be several reasons for this that have little to do with the chick's diet. First, the hen's diet is dominated by fruit and forage (Bump et al. 1947), and it is possible that she is benefiting from their high availability at these sites. Second, because most forage items also are considered ground cover, it is not unexpected that, in general, the difference of forage and ground cover in brood and random sites decreases similarly as the brood season progresses. Finally, as the brood season and summer months progress, fruit and forage abundance increase throughout the forest. Habitat selection may be stronger early in the brood period because fruit and forage availability is limited to sites selected by broods. Later in the brood period, the availability of forage and fruit is more widespread and little difference is found in brood and random sites. Whatever the reason, a late brood season decrease in selection for fruit and forage abundance probably does not indicate habitats containing these food items are unimportant to broods.

In this study, arthropod abundance was greater in brood plots than random plots throughout all weeks sampled, though this trend was not significant in all weeks. Additionally, individuals in 3 preferred taxonomic orders were more abundant at brood-selected sites. The open midstory and higher ground cover that characterize brood sites in weeks 1-6 not only provided cover for hens and their chicks but abundant vegetative and animal food as well. Many authors have found arthropod abundance greatest in open, mature, forest stands with abundant herbaceous growth. In Tennessee, Hollifield (1995) found seeded logging roads and mature forest stands with herbaceous ground cover to have higher arthropod abundance than regenerating stands and unseeded logging roads. Additionally, he found taxonomic orders preferred by ruffed grouse chicks to be most abundant in seeded roads and mature stands. Healy (1985) found arthropod abundance and vegetation dry mass to be highly correlated. Feeding rates of imprinted wild turkey poults were highest in habitats with abundant vegetation and arthropod abundance (Healy 1985). Emphasizing the connection between ground cover and arthropod abundance, Healy (1985) suggested that early brood habitat can be best defined by ground cover characteristics.

Additionally, no difference was found in brood and random plot litter samples, agreeing with the assumptions of previous authors who concluded broods do not select sites on the basis of litter-inhabiting arthropod abundance. Few authors suggest litter-dwelling arthropods are important to grouse, and sampling is usually limited to low ground vegetation using sweep-nets (Healy 1985, Hollifield 1995). Researchers working with imprinted, captive ruffed grouse chicks found feeding activity was largely limited to gleaning arthropods from low vegetation (Kimmel and Samuel 1978), and others (Bump et al. 1947) report grouse chicks do not often scratch with their feet in litter when feeding.

Following week 6, brood plots had consistently fewer sawtimber-sized trees, indicating a habitat selection change towards sites with significantly fewer large trees. Additionally, basal area was considerably higher in random plots during these weeks, and this is likely due to the effect of more sawtimber in randomly selected sites than brood sites. Though there are fewer large trees in brood plots, broods are not selecting clearings or openings because brood and random plots do not differ in their percent canopy cover after week 6. It is possible that following week 6, broods selected sites with stem densities < 20 cm dbh; however, this cannot be confirmed from my data. The occurrence of trees in the 8-20 cm dbh size class at brood sites is inconsistent and though there seems to be a general trend towards brood sites having more sapling stems following week 6, the difference is not significant.

If broods were selecting sites with more small stems after week 6, it would seem unlikely that arthropods were still the brood's principal food. According to many authors, this habitat change should have occurred following week 3 as the diet of chicks change from arthropods to vegetative foods (Bump et. al. 1947, Stewart 1956, King 1969). However, Kimmel and Samuel (1978) working in West Virginia found arthropods were a major food source for ruffed grouse chicks beyond the first 3 weeks. They suggest previous diet studies based their results on stomach, crop-gizzard, or dropping contents that underestimated the amount of soft-bodied arthropods ingested. In their work with live, imprinted grouse chicks, they found arthropods dominate the diet until week 5 (Kimmel and Samuel 1978). During weeks 6 and 7 arthropod ingestion equaled plant food ingestion, and after week 7 plant food dominated the diet (Kimmel and Samuel 1978). A dietary shift after approximately week 5 may explain why, in this study, habitat selection did not change between weeks 3 and 4 as expected, but between weeks 6 and 7.

CONCLUSIONS AND MANAGEMENT IMPLICATIONS

Major Findings

The objectives of this study were to determine if brood habitat selection occurs and, if so, does the criteria for selection change over the brood period.

(1) My results indicate ruffed grouse broods select for sites with tall, complete, vegetative ground cover, particularly in the first half of the brood season (weeks 1-6).

(2) Broods selected forested, canopied sites, rather than areas affected by large canopy gaps or openings. Higher ground cover at brood sites may have been due to a lack of midstory structure because brood sites had similar canopy coverage as random sites.

(3) Broods also selected sites that had higher abundance of arthropods, fruit, and forage during the first few weeks of the brood season. High abundance of arthropods and vegetative food at brood sites in the early brood season may be due to these sites being located in open, mid-age or mature forest.

(4) I speculated the chick's dietary shift from arthropods to vegetative food would parallel a change in the type of habitat selected. However, a change in habitat selection did not occur between weeks 3 and 4 as expected, but after week 6. After 6 weeks of age, broods selected sites with less sawtimber, possibly moving into younger, regenerating stands, though our data only weakly support this. If this was true, however, broods were leaving habitat where arthropod abundance was high for habitat where lower abundance could be expected (Hollifield 1995). This may indicate the chick's dietary shift occurs later than first supposed, agreeing with the conclusions of researchers in West Virginia who documented arthropods dominated chick diets until week 6 (Kimmel and Samuel 1978).

Management Implications

Though ruffed grouse population densities are lower in the southern Appalachians than in most portions of its range, it is still a popular game bird in the region. Despite its status as a popular game species, little research has been conducted on ruffed grouse in this region, particularly related to brood habitat selection. Most ruffed grouse research has been done in the Great Lakes states and southern Canada, where population densities are highest, and, therefore, most management prescriptions for the species are based on conditions in this region. However, vegetative communities in the Great Lakes states and southern Canada are quite different than those in the southern Appalachians, the southern extent of ruffed grouse range. Aspen, considered the most important habitat feature for grouse in the Great Lakes states and southern Canada (Rusch and Keith 1971, Gullion 1977), is nonexistent in most of the southern Appalachians. Therefore, habitat management prescriptions based on aspen management are of little use in this region.

The results of this study should be of great benefit to ruffed grouse managers in the southern Appalachians, particularly those interested in improving brood habitat. However, habitat management is impractical on the scale of micro-habitat. Managers need practical stand-level prescriptions that can be applied to large areas. Extrapolations as to what type of forest stands may be selected by broods can be made from the assemblage of variables selected at the site-level.

Based on the results of this study and other research in the southern Appalachians, mid-age or mature stands with open midstory and abundant vegetative cover seem best suited for broods during the first 6 weeks of the brood period. In this study, brood sites were found to be canopy covered, have high, complete ground cover, fewer midstory trees, and high forage and arthropod abundance, all characteristics of open, mid-age or mature stands. These types of stands could be achieved through light thinning and removal of midstory trees. Firewood sales are currently being conducted on public lands in Virginia (Gary Norman, Virginia Department of Game and Inland Fisheries, pers. comm.) and may be a practical option for thinning trees in the midstory (specifically, trees in the 8-20 cm dbh size class). Researchers in West Virginia suggested oak-hickory stands were most improved for wild turkey broods by first thinning stands then prescribed burning (Pack et al. 1988). They found sites that were thinned then burned had an abundance of herbaceous forbs, grasses, and sedges for 3 growing seasons after the burns (Pack et al. 1988). Rogers and Samuel (1984) suggested that light burns every 3 years provide adequate ruffed grouse brood escape cover and invertebrate food availability. Additionally, Rogers and Samuel (1984) found imprinted grouse chick feeding rates highest for arthropods on recent (< 1 year) burn sites and feeding rates for plant foods highest on 2-year old burn sites. They suggested interspersing burn sites of different years to offer a high availability of arthropod and plant foods for broods (Rogers and Samuel 1984). To further increase arthropod abundance, Hollifield (1995) suggested seeding logging roads with clover (*Trifolium* spp.) or both clover and orchardgrass (*Dactylis glomerata*), and Pack et al. (1988) suggested seeding burn sites with orchard grass.

Following week 6, mid-age or mature stands may be less important for broods. It is unclear what type of habitat is selected during the later portion of the brood period, but younger, regenerating stands may be of importance. Because ruffed grouse use a variety of habitats throughout the year (Bump et al. 1947), it would be wise to include younger, regenerating stands in any ruffed grouse management prescription. Macro-scale brood habitat selection research is needed in the southern Appalachians to confirm my early brood period stand-level assumptions and provide a clearer picture as to what cover types broods select during the later brood season.

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Table 3.1. Weekly mean differences between brood and random plots in cover variables. Data were collected during May-August, 1997 and 1998, at 3 sites in the southern Appalachian region.

		% Ground Cover			Ground Cover Height (cm)			% Slash Cover			Slash Cover Height (cm)			% Canopy Cover		
Weeks	n[a]	Mean[b]	SE	*P*	Mean	SE	*P*	Mean	SE	*P*	Mean	SE	*P*	Mean	SE	*P*
1	13	3.5	7.0	0.81	2.0	1.9	0.23	-0.6	0.2	1.00	0.0	0.4	1.00	3.8	6.6	0.35
2	12	16.5	9.5	0.13	5.4	2.7	0.06	4.0	0.4	0.03	0.5	0.7	0.56	-10.2	5.1	0.04
3	13	16.7	7.8	0.06	6.8	1.9	<0.01	0.0	0.3	0.86	0.0	0.3	0.62	1.9	4.5	0.08
1-3	9	13.0	1.0	0.05	5.4	1.5	0.01	0.8	0.1	0.34	0.1	0.2	1.00	0.9	3.8	0.64
4	14	23.2	5.7	0.01	7.8	1.9	<0.01	-0.5	0.3	0.36	0.1	0.4	0.68	-1.9	5.9	1.00
5	12	13.8	9.2	0.22	4.2	3.7	0.45	2.3	0.3	0.16	0.5	0.3	0.08	-3.3	7.9	0.49
6	12	15.2	7.0	0.08	7.6	2.5	0.02	0.4	0.2	1.00	0.1	0.3	0.75	-2.1	4.4	0.68
4-6	11	15.8	1.4	0.06	6.5	2.4	0.02	0.9	0.1	0.22	0.2	0.2	0.43	-1.6	5.1	0.49
7	9	-2.5	4.9	1.00	-0.7	1.0	0.53	-1.4	0.5	0.65	-0.4	0.5	0.76	-4.2	9.8	0.80
8	9	7.0	9.0	0.47	3.7	2.6	0.24	0.8	0.2	0.45	0.4	0.4	0.34	5.6	3.7	0.23
9	8	10.0	6.6	0.22	4.7	3.1	0.20	6.25	0.5	0.06	1.5	0.8	0.09	-18.1	9.6	0.10
7-9	6	7.7	0.9	0.16	3.2	1.3	0.06	1.8	0.5	0.75	0.4	0.6	1.00	-7.5	6.6	0.44
10	7	21.1	10.1	0.08	9.8	3.4	0.03	1.1	0.3	1.00	0.6	0.5	0.38	-4.3	13.0	0.81
11	5	13.0	13.2	0.63	8.4	4.8	0.19	0.5	0.2	1.00	-0.3	0.4	1.00	-8.5	9.1	0.63

[a] Sample size in periods (i.e. weeks 1-3, 4-6, and 7-8) represent only broods with complete data for all weeks in that period. Period samples will be smaller than weekly samples because some broods that were included in weekly tests could not be used in period tests.

[b] mean difference between brood and random plots (brood plot response – random plot response)

Table 3.2. Weekly mean differences between brood and random plots in small woody stem variables. Data were collected during May-August, 1997 and 1998, at 3 sites in the southern Appalachian region.

		Deciduous Saplings			Conifer Saplings			Total Saplings			Shrub Stems		
Weeks	n[a]	Mean[b]	SE	*P*	Mean	SE	*P*	Mean	SE	***P***	Mean	SE	***P***
1	13	12.8	17.2	0.69	-0.2	0.4	1.00	12.6	16.9	0.67	-31.6	20.6	0.05
2	12	-21.8	34.4	0.98	-5.5	5.3	0.50	-27.3	39.5	1.00	4.2	4.1	0.38
3	13	18.8	30.0	0.69	0.1	0.2	1.00	18.8	29.9	0.71	3.8	6.1	0.75
1-3	9	5.0	8.3	0.91	-2.6	2.5	0.25	4.8	6.2	0.46	-4.4	5.2	0.50
4	14	-2.7	10.7	0.74	0.6	0.4	0.25	-2.1	10.6	0.76	-3.8	5.8	1.00
5	12	10.8	13.6	0.61	0.0	0.2	1.00	10.9	13.7	0.62	-0.6	1.4	1.00
6	12	-1.6	5.8	0.47	0.4	0.7	1.00	-1.2	5.9	0.45	-0.1	3.0	0.69
4-6	11	0.6	8.7	0.52	-0.2	0.7	0.66	0.5	9.0	0.45	0.3	1.0	1.00
7	9	5.7	10.7	0.61	-0.2	0.2	1.00	5.5	10.7	0.61	-6.3	4.6	0.13
8	9	-8.2	10.3	0.49	0.3	0.9	1.00	-7.9	10.3	0.52	-11.1	11.0	0.50
9	8	26.3	14.1	0.02	0.1	0.1	1.00	26.4	14.0	0.01	2.8	11.9	1.00
7-9	6	7.8	6.3	0.25	0.1	0.9	0.50	7.9	6.4	0.25	-5.4	3.4	0.22
10	7	46.0	46.5	0.33	0.6	0.6	0.375	46.6	46.4	0.32	3.1	4.6	1.00
11	5	5.0	10.6	0.63	4.5	4.2	0.63	9.5	12.8	0.75	56.7	47.7	0.13

[a] Sample size in periods (i.e. weeks 1-3, 4-6, and 7-8) represent only broods with complete data for all weeks in that period. Period samples will be smaller than weekly samples because some broods that were included in weekly tests could not be used in period tests.

[b] mean difference between brood and random plots (brood plot response – random plot response)

Table 3.3. Weekly mean differences between brood and random plots in tree size classes. Data were collected during May-August, 1997 and 1998, at 3 sites in the southern Appalachian region.

		8-20 cm dbh			21-40 cm dbh			41-60 cm dbh			> 60 cm dbh		
Weeks	n[a]	Mean[b]	SE	*P*	Mean	SE	*P*	Mean	SE	*P*	Mean	SE	*P*
1	13	4.0	2.0	0.06	-0.5	1.5	0.97	0.9	0.6	0.18	-0.2	0.1	1.00
2	12	-3.6	1.8	0.06	-1.7	1.4	0.34	-0.6	0.5	0.33	0.3	0.2	0.63
3	13	-5.2	2.8	0.08	1.0	1.1	0.34	1.6	0.7	0.04	0.1	0.1	1.00
1-3	9	-2.0	2.5	0.45	-0.3	0.8	0.64	1.0	0.3	0.05	0.0	0.2	1.00
4	14	-0.8	1.5	0.58	-1.5	0.9	0.19	0.6	0.2	0.01	0.0	0.1	1.00
5	12	-4.3	3.6	0.39	-1.0	0.8	0.26	-0.4	0.4	0.51	0.3	0.2	0.38
6	12	-6.4	1.9	<0.01	1.0	0.6	0.16	0.2	0.2	0.38	0.2	0.1	1.00
4-6	11	-3.1	1.5	0.07	-0.3	0.7	0.77	0.15	0.2	0.47	0.2	0.1	0.13
7	9	0.3	2.7	1.00	-2.2	1.0	0.08	0.1	0.4	1.00	0.0	0.0	1.00
8	9	0.2	1.3	1.00	-0.6	0.9	0.81	-0.7	0.4	0.25	-0.2	0.3	1.00
9	8	0.8	4.0	0.78	-2.3	1.2	0.05	-0.1	0.9	1.00	-0.3	0.5	1.00
7-9	6	0.1	2.2	0.22	-1.7	0.7	0.06	-0.4	0.3	0.31	-0.1	0.2	0.58
10	7	0.5	3.7	0.81	-0.7	1.4	0.53	0.0	0.9	1.00	-0.6	0.3	0.25
11	5	-6.1	2.9	0.06	-1.8	1.9	0.50	0.0	0.6	1.00	0.0	0.0	1.00

[a] Sample size in periods (i.e. weeks 1-3, 4-6, and 7-8) represent only broods with complete data for all weeks in that period. Period samples will be smaller than weekly samples because some broods that were included in weekly tests could not be used in period tests.

[b] mean difference between brood and random plots (brood plot response – random plot response)

Table 3.4. Weekly mean differences between brood and random plots in tree size classes and basal area. Data were collected during May-August, 1997 and 1998, at 3 sites in the southern Appalachian region.

		Sawtimber[a]			All Size Classes			Basal Area (m^2/ha)		
Weeks	n[b]	Mean[c]	SE	*P*	Mean	SE	*P*	Mean	SE	*P*
1	13	-0.5	1.5	0.69	4.3	2.8	0.23	1.4	3.9	0.64
2	12	-1.7	1.4	0.23	-5.7	2.2	0.02	-5.1	2.9	0.09
3	13	1.0	1.1	0.08	-2.6	3.5	0.60	-1.2	2.6	0.91
1-3	9	0.4	0.8	0.66	-1.6	2.9	0.67	-1.7	2.1	0.64
4	14	-1.5	0.9	0.60	-1.6	1.8	0.54	-1.8	1.8	0.34
5	12	-1.0	0.8	0.27	-5.4	3.4	0.17	-3.3	2.6	0.22
6	12	1.0	0.6	0.06	-5.0	2.2	0.04	-0.6	3.2	0.72
4-6	11	0.02	0.7	0.75	-3.1	1.7	0.12	-1.1	2.1	0.46
7	9	-2.2	1.0	0.07	-1.8	2.7	0.69	-6.4	2.9	0.06
8	9	-0.6	0.9	0.44	-1.3	1.9	0.69	-1.5	1.6	0.53
9	8	-2.3	1.2	0.25	-1.9	3.8	0.72	-9.5	3.3	0.04
7-9	6	-2.3	0.9	0.06	-2.0	2.0	0.34	-5.4	1.2	0.03
10	7	-0.7	1.4	0.66	-0.8	5.7	0.88	-5.6	4.5	0.25
11	5	-1.8	1.9	0.63	-7.9	2.5	0.06	-1.1	3.9	0.75

[a] trees > 20 cm dbh

[b] Sample size in periods (i.e. weeks 1-3, 4-6, and 7-8) represent only broods with complete data for all weeks in that period. Period samples will be smaller than weekly samples because some broods that were included in weekly tests could not be used in period tests.

[c] mean difference between brood and random plots (brood plot response – random plot response

Table 3.5. Coefficient of determination (R^2), intercept (B_o), and slopes(B_1 and B_2) used to calculate forage dry mass estimates. Data used in regression analysis collected during May-August, 1997 and 1998, at 3 sites in the southern Appalachian region.

		Deciduous Woody				Grass/Sedge				Forbs			
Estimator[a]	Year	R^2	B_o	B_1	B_2	R^2	B_o	B_1	B_2	R^2	B_o	B_1	B_2
CKC	1997	0.832	-0.134	0.912	-0.009	0.714	0.227	0.352	0.006	0.720	0.028	0.804	-0.011
GSH	1997	0.714	0.367	0.285	0.012	0.882	0.361	-0.117	0.040	0.770	-0.755	0.763	-0.006
JSM	1997	0.745	-0.120	0.677	0.004	0.712	0.113	0.452	0.004	0.648	0.408	0.593	-0.008
KWD	1997	0.754	-0.557	1.320	-0.030	0.943	-0.789	0.422	0.069	0.450	0.599	0.766	-0.020
KLS	1998	0.915	0.111	0.438	0.001	0.920	-0.349	0.605	0.004	0.580	2.542	0.383	0.000
KWD	1998	0.843	0.148	0.541	-0.011	0.919	-0.005	0.493	-0.001	0.628	0.269	0.376	0.000
SAH	1998	0.790	0.666	0.716	0.002	0.973	-0.232	1.028	-0.009	0.751	0.573	0.800	-0.007

[a] Initials (first, middle, last) of personnel estimating volume

Table 3.6. Weekly mean differences between brood and random plots in forage and fruit variables. Data were collected during May-August, 1997 and 1998, at 3 sites in the southern Appalachian region.

Week	n	Forage Dry Mass[a] (g)			Fruit Dry Mass[a] (g)		
		Mean[b]	SE	*P*	Mean	SE	*P*
1	13	5.0	2.5	0.09	2.49	2.26	0.31
2	12	6.9	2.1	0.01	0.71	0.65	0.27
3	13	2.0	2.4	0.19	2.81	2.40	0.11
1-3	9	3.3	1.2	0.03	1.94	1.73	0.11
4	14	3.7	1.3	0.01	0.19	0.20	0.21
5	12	2.6	3.5	0.51	-0.17	0.30	0.91
6	12	1.0	2.2	0.70	0.41	0.19	0.04
4-6	11	2.1	1.8	0.23	0.26	0.17	0.12
7	9	0.8	1.2	0.58	0.24	0.35	0.72
8	9	-1.7	2.0	0.61	0.44	0.22	0.03
9	8	3.0	1.1	0.14	0.20	0.29	0.62
7-9	6	1.2	0.6	0.13	0.29	0.24	0.50
10	7	0.1	4.4	0.06	0.44	0.42	0.68
11	5	2.5	2.3	0.44	0.47	0.44	0.31

[a] mass of dried fruit or vegetation (forage) within 1 m x 1 m x 0.5 m

[b] mean difference between brood and random plots (brood plot response – random plot response)

Table 3.7. Weekly mean differences between brood and random plots in arthropod abundance. Data were collected during May-August, 1997 and 1998, at 3 sites in the southern Appalachian region.

Week	n	Mean[a]	SE	*P*
1	13	11.2	7.5	0.19
2	11	13.5	9.5	0.09
3	11	16.9	8.7	0.03
1-3	8	16.5	6.9	0.02
4	8	3.1	5.6	0.13

[a] mean difference between brood and random plots (brood plot response – random plot response)

Table 3.8. Mean differences between brood and random plots in abundance of arthropods in taxonomic orders preferred by ruffed grouse chicks. Data were collected during May-August, 1997 and 1998, at 3 sites in the southern Appalachian region.

		Hymenoptera			Coleoptera			Diptera			Hemiptera			Homoptera			Arachnida		
Weeks	n	Mean[a]	SE	*P*	Mean	SE	*P*	Mean	SE	*P*	Mean	SE	*P*	Mean	SE	*P*	Mean	SE	*P*
1	13	0.0	1.6	1.00	0.5	1.7	0.86	4.3	3.0	0.16	1.6	2.5	0.47	6.0	4.6	0.03	-0.4	1.0	0.78
2	11	1.2	1.2	0.37	1.2	1.6	0.38	7.7	8.1	0.84	0.2	1.1	0.65	1.4	1.0	0.14	1.3	0.9	0.25
3	11	-2.9	3.6	0.51	7.9	1.4	0.002	3.9	1.8	0.01	3.5	3.0	0.23	0.6	0.3	0.09	2.8	1.0	0.001
1-3	8	-0.8	2.2	0.98	4.4	1.0	0.008	5.8	5.0	0.25	1.3	0.7	0.17	4.0	2.3	0.02	1.4	0.7	0.07
4	8	1.6	2.0	0.39	3.1	0.9	0.02	0.8	0.7	0.42	-2.8	2.4	0.32	-0.4	1.4	0.53	0.8	1.0	0.5

[a] mean difference between brood and random plots (brood plot response – random plot response

Table 3.9. Mean differences between the habitat variable response in brood and random plots of successful (≥1 chick at 6 weeks after hatch) and unsuccessful (0 chicks by 2 weeks after hatch) ruffed grouse broods during the first 2 weeks following hatch. Data were collected during May-August, 1997 and 1998, at 3 sites in the southern Appalachian region.

	Mean Difference[a]				
	Successful		Unsuccessful		
Habitat Variables	Broods	SE	Broods	SE	*P*
% Canopy Cover	-0.3	6.7	-1.0	9.7	0.85
Ground Cover Height (cm)	5.5	3.2	3.4	3.7	0.73
% Ground Cover	13.5	10.7	8.5	17.5	0.65
Slash Height (cm)	0.4	0.4	0.5	1.0	0.68
% Slash Cover	1.5	0.2	1.0	0.2	0.37
Deciduous Saplings	-12.5	29.0	12.2	9.1	0.46
Conifer Saplings	-7.3	6.5	0.7	0.6	0.01
All Saplings	-19.8	34.2	12.9	9.5	0.46
All Shrub Stems	-5.6	6.1	-23.2	21.5	0.80
8-20 cm dbh Trees	0.7	2.9	3.1	2.6	0.82
21-40 cm dbh Trees	-2.2	0.7	-2.7	2.8	0.45
41-60 cm dbh Trees	0.6	0.6	0.0	0.9	0.75
> 60 cm dbh Trees	0.1	0.1	-0.2	0.2	1.00
> 20 cm dbh Trees	-1.5	1.0	-2.9	3.8	0.67
All Trees	-0.9	3.8	0.3	2.2	0.86
Basal Area (m^2/ha)	-6.4	3.6	0.0	6.2	0.31
Fruit Dry Mass (g)	0.78	0.73	2.9	3.2	0.82
Vegetation Dry Mass (g)	2.3	2.2	5.9	4.0	0.49
Arthropods (sweep sample)	5.9	7.7	7.9	7.4	0.92

[a] mean difference between brood and random plots (brood plot response – random plot response)

Table 3.10. Mean habitat variable response in brood plots for successful ($\geq$1 chick at 6 weeks after hatch) and unsuccessful (0 chicks by 2 weeks after hatch) ruffed grouse broods during the first 2 weeks following hatch. Data were collected during May-August, 1997 and 1998, at 3 sites in the southern Appalachian region.

	Mean Brood Plot Response				
	Successful		Unsuccessful		
Habitat Variables	Broods	SE	Broods	SE	*P*
% Canopy Cover	85.5	3.3	70.8	9.5	0.20
Ground Cover Height (cm)	13.2	2.7	14.3	2.9	0.95
% Ground Cover	53.5	8.0	58.5	12.0	0.68
Slash Height (cm)	1.5	0.6	1.5	1.0	0.69
% Slash Cover	5.8	2.3	3.8	3.4	0.36
Deciduous Saplings	79.7	42.5	27.9	9.7	0.38
Conifer Saplings	1.1	0.7	0.7	0.6	0.80
All Saplings	80.8	43.2	28.6	10.2	0.39
All Shrub Stems	5.9	4.0	6.6	5.2	0.81
8-20 cm dbh Trees	16.6	2.7	18.5	4.6	0.70
21-40 cm dbh Trees	4.1	0.7	3.3	1.8	0.23
41-60 cm dbh Trees	1.4	0.4	1.2	1.0	0.34
> 60 cm dbh Trees	0.3	0.2	0.2	0.2	0.74
> 20 cm dbh Trees	5.8	0.8	4.7	2.9	0.16
All Trees	22.3	3.0	23.2	3.2	0.89
Basal Area (m^2/ha)	13.8	1.8	17.7	5.7	0.94
Fruit Dry Mass (g)	1.32	1.00	3.30	3.11	0.83
Vegetation Dry Mass (g)	7.7	2.0	18.5	10.0	0.48
Arthropods (sweep sample)	35.0	9.5	41.1	12.2	0.75

APPENDIX A

Mean monthly (April and May) precipitation amount for ACGRP study sites and study regions, 1997-1998. Precipitation data[a] presented here were recorded at National Oceanic Atmospheric Administration weather stations closest (< 10 miles) to each study site.

	April Precipitation (in.)		May Precipitation (in.)	
Study Sites	1997	1998	1997	1998
OH/1	1.7	4.9	4.5	4.0
OH/2	1.0	5.9	3.4	4.6
KY/1	2.0	5.8	3.6	4.8
MD/1	1.8	5.6	4.2	5.5
WV1	4.8	5.9	7.1	5.6
WV/2	2.4	5.0	3.3	7.3
VA1	2.0	3.8	1.6	4.8
VA2	2.7	5.3	2.2	6.4
VA3	3.4	7.6	3.2	5.8
Study Regions				
Alleghany Plateau	2.9[b]	5.8	5.0	5.3
Ohio River Valley	1.4[c]	5.4	3.5	4.3
Ridge and Valley	2.6[d]	5.4	2.6	6.1

[a] National Oceanic Atmospheric Administration. NCDC: get/view online climate data. Online. Internet. June 21, 1999. Available HTTP://www.nndc.noaa.gov/cgibin/nndc/buyOC-005.cgi

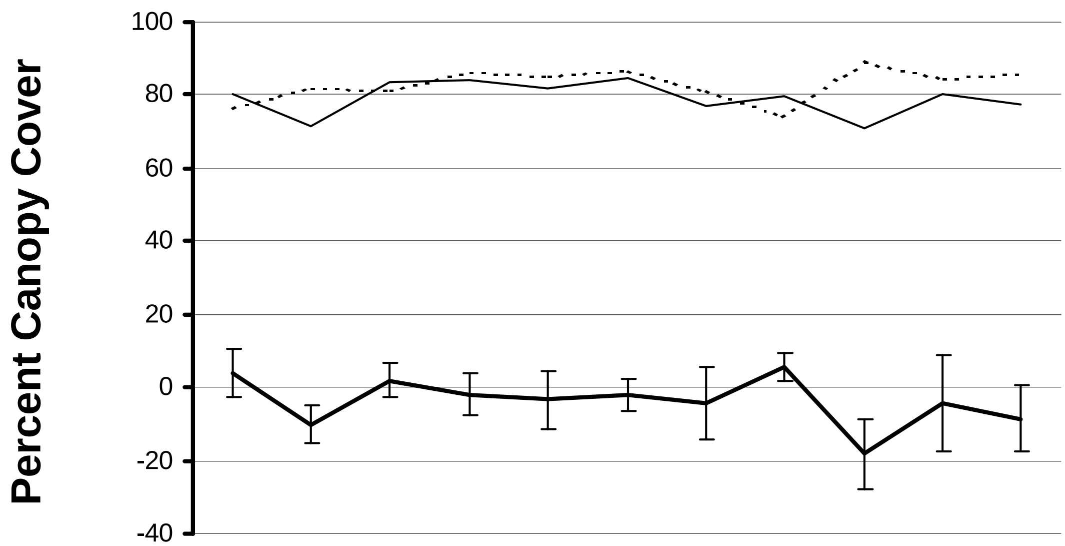
[b] mean precipitation amount at ACGRP study sites (MD/1, KY/1, WV/1) within region

[c] mean precipitation amount at ACGRP study sites (OH/1, OH/2) within region

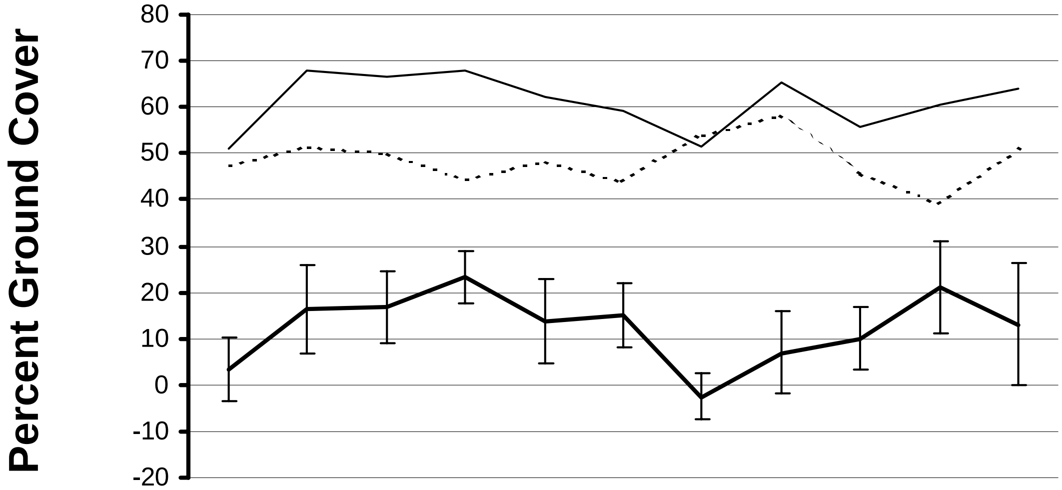
[d] mean precipitation amount at ACGRP study sites (WV/2, VA/1, VA/2, VA/3) within region

APPENDIX B

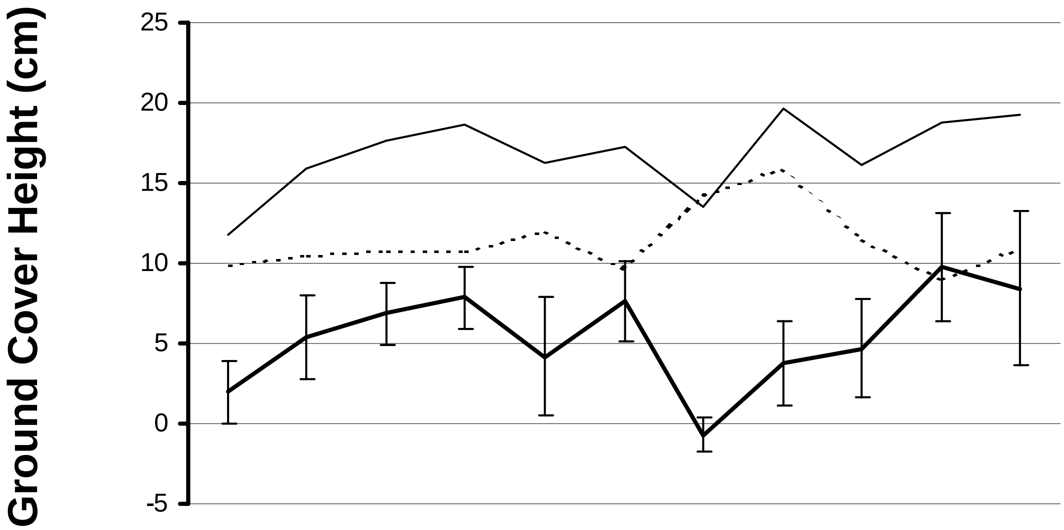
Weekly mean brood and random plot response and the difference between brood and random plots for each habitat variable sampled are shown. Weekly mean values were first calculated for each hen, then averaged over all hens for each week. Data were pooled across all study sites (VA/2, VA/3, and WV/2) and years (1997 and 1998). Error bars illustrate the standard error associated with the weekly mean difference between brood and random plot response. For the purposes of these figures, values related to stem-count variables have been converted from the raw data (stems/plot) used for statistical testing to stem density (stems/ha). Refer to Methods section of Chapter 3 for a complete description of each habitat variable.



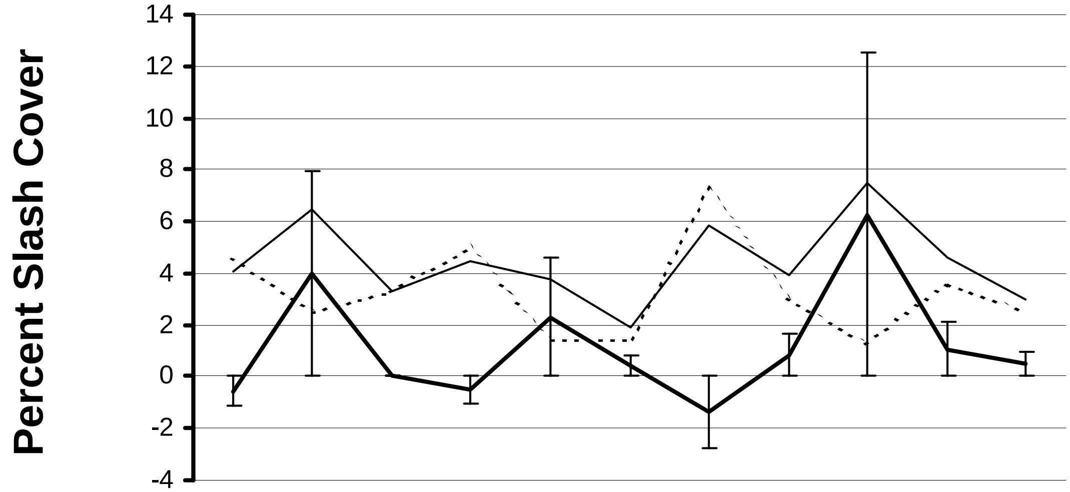
week	1	2	3	4	5	6	7	8	9	10	11
n	13	12	13	14	12	12	9	9	8	7	5
brood	80.2	71.7	83.5	84.3	81.9	84.6	76.9	79.9	70.9	80.4	77.5
random	76.3	81.9	81.5	86.3	85.2	86.7	81.1	74.4	89.1	84.6	86.0
difference	3.8	-10.2	1.9	-2.0	-3.3	-2.1	-4.2	5.6	-18.1	-4.3	-8.5



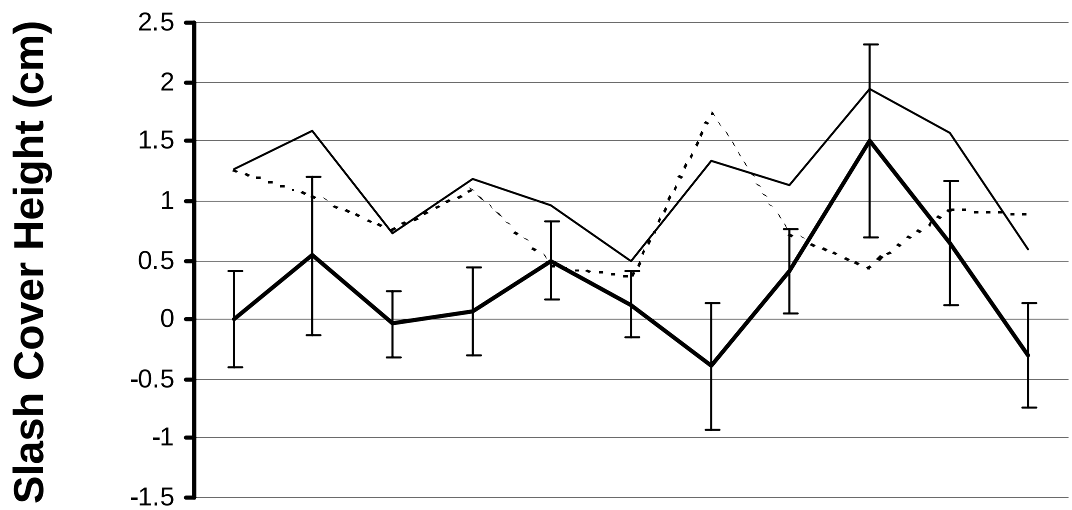
week	1	2	3	4	5	6	7	8	9	10	11
n	13	12	13	14	12	12	9	9	8	7	5
—— brood	51.2	67.7	66.7	67.9	62.3	59.4	51.4	65.5	55.9	60.4	64.0
------ random	47.7	51.3	50.0	44.6	48.5	44.2	53.9	58.4	45.9	39.3	51.0
—— difference	3.5	16.5	16.7	23.2	13.8	15.2	-2.5	7.0	10.0	21.1	13.0



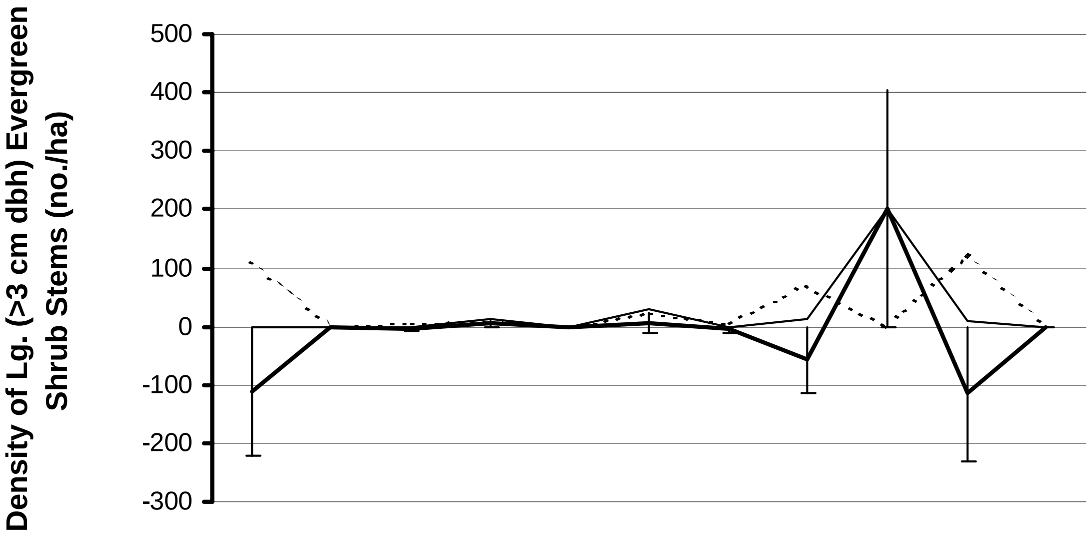
week	1	2	3	4	5	6	7	8	9	10	11
n	13	12	13	14	12	12	9	9	8	7	5
—— brood	11.8	15.9	17.6	18.6	16.2	17.3	13.6	19.6	16.2	18.8	19.3
------ random	9.8	10.5	10.8	10.8	12.0	9.6	14.3	15.8	11.5	9.0	10.9
—— difference	2.0	5.4	6.8	7.8	4.2	7.6	-0.7	3.7	4.7	9.8	8.4



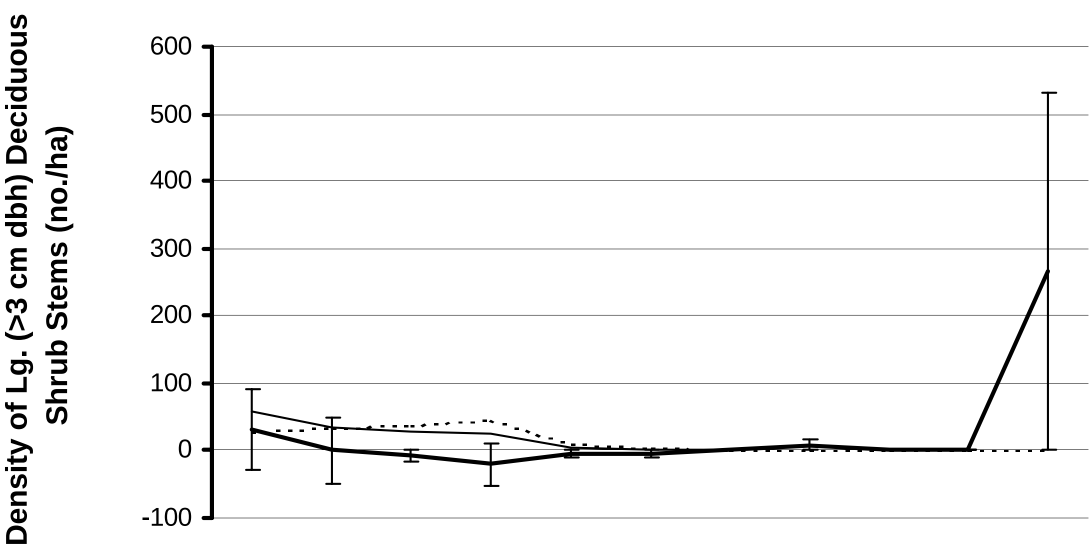
week	1	2	3	4	5	6	7	8	9	10	11
n	13	12	13	14	12	12	9	9	8	7	5
brood	4.0	6.5	3.3	4.5	3.8	1.9	5.8	3.9	7.5	4.6	3.0
random	4.6	2.5	3.3	5.0	1.5	1.5	7.2	3.1	1.3	3.6	2.5
difference	-0.6	4.0	0.0	-0.5	2.3	0.4	-1.4	0.8	6.3	1.1	0.5



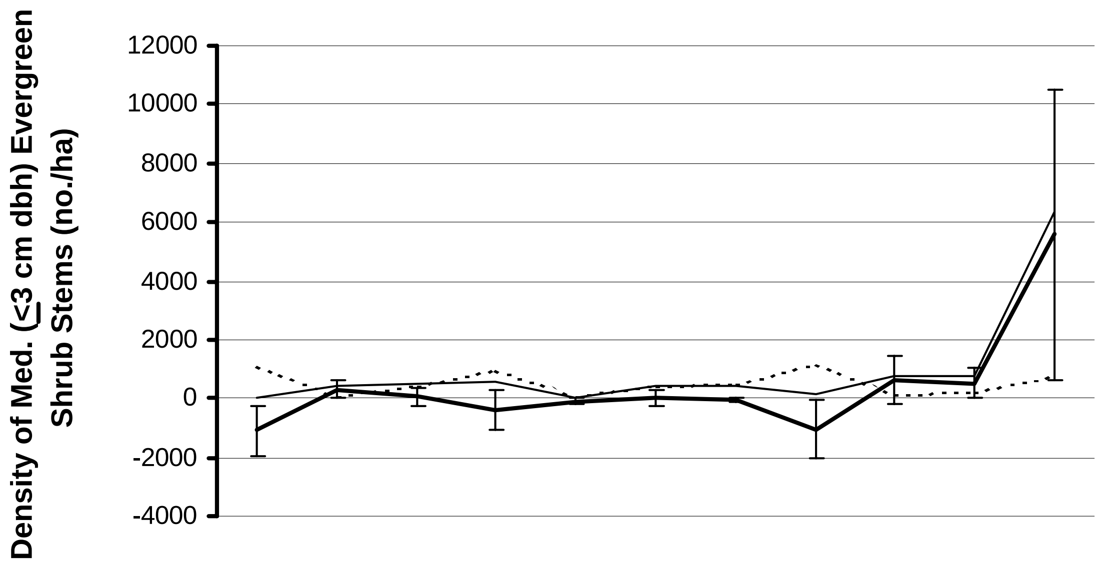
week	1	2	3	4	5	6	7	8	9	10	11
n	13	12	13	14	12	12	9	9	8	7	5
brood	1.3	1.6	0.7	1.2	1.0	0.5	1.3	1.1	1.9	1.6	0.6
random	1.3	1.0	0.8	1.1	0.5	0.4	1.7	0.7	0.4	0.9	0.9
difference	0.0	0.5	0.0	0.1	0.5	0.1	-0.4	0.4	1.5	0.6	-0.3



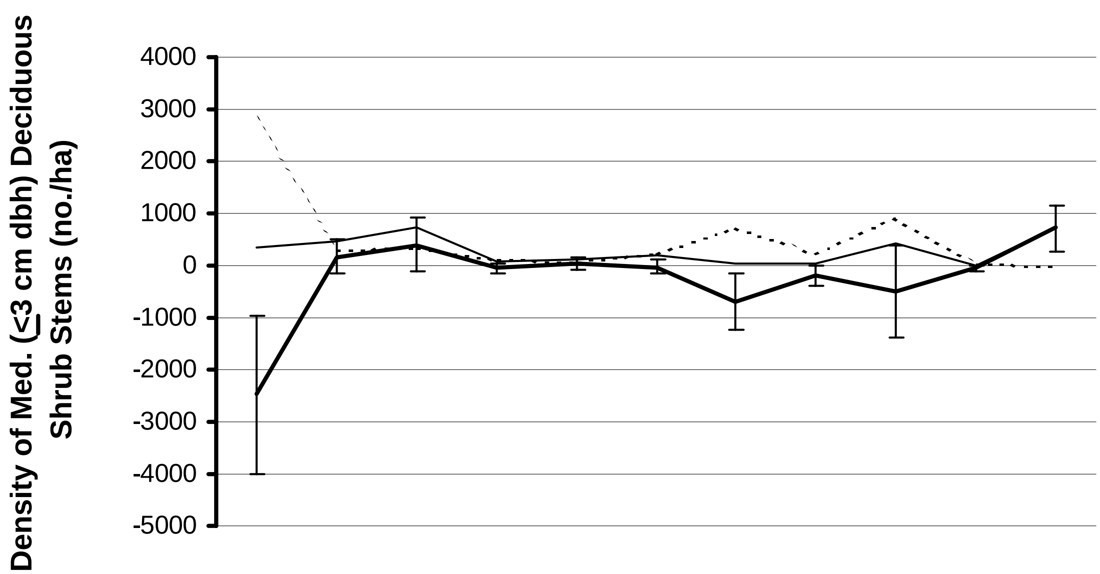
week	1	2	3	4	5	6	7	8	9	10	11
n	13	12	13	14	12	12	9	9	8	7	5
—— brood	0	0	0	12	0	29	0	13	202	8	0
- - - - - - random	111	0	4	8	0	24	6	71	0	124	0
—— difference	-111	0	-4	4	0	5	-6	-58	202	-116	0



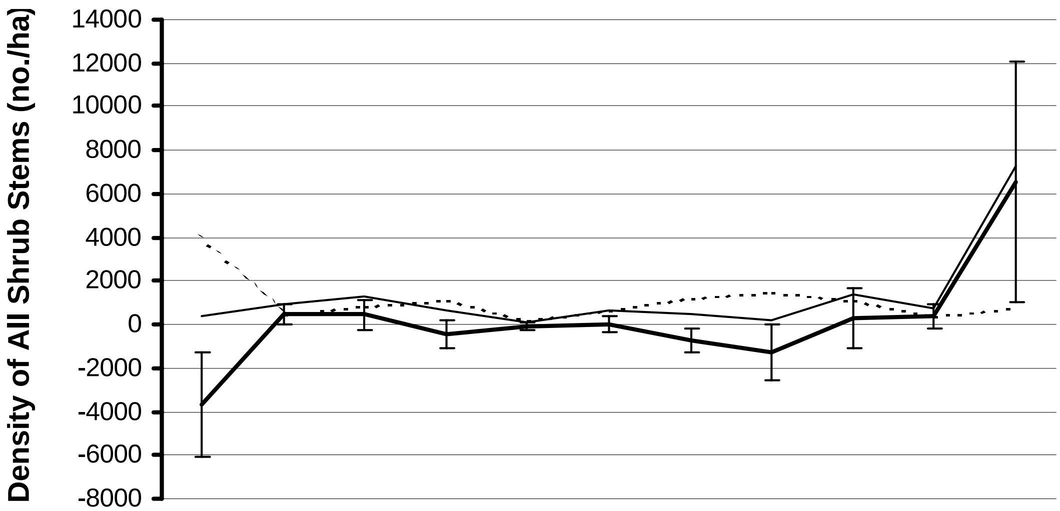
week	1	2	3	4	5	6	7	8	9	10	11
n	13	12	13	14	12	12	9	9	8	7	5
—— brood	58	34	27	25	5	0	0	9	0	0	266
- - - - - - random	27	34	36	45	10	5	0	0	0	0	0
—— difference	31	0	-9	-21	-5	-5	0	9	0	0	266



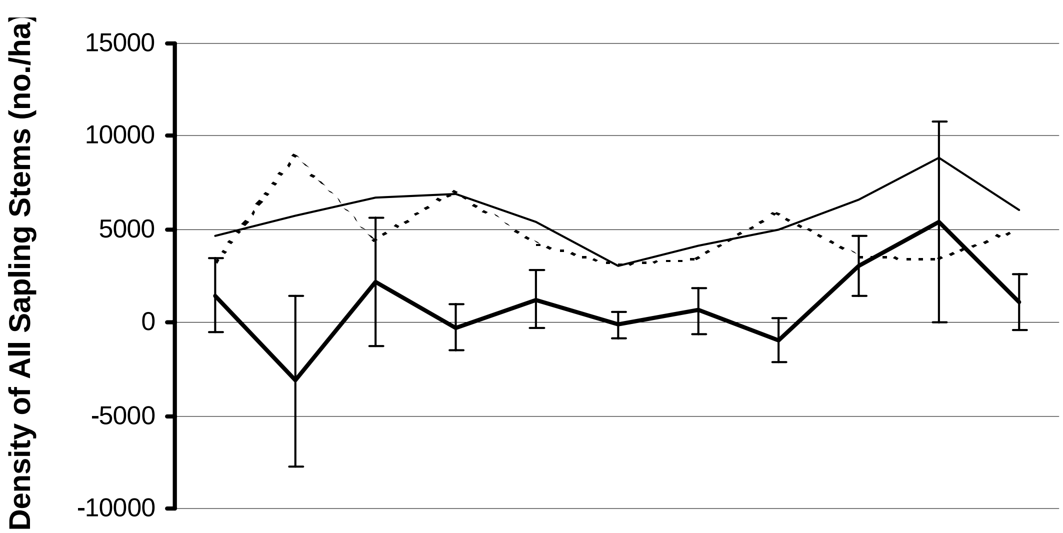
week	1	2	3	4	5	6	7	8	9	10	11
n	13	12	13	14	12	12	9	9	8	7	5
—— brood	27	410	498	566	14	424	431	154	788	760	6329
- - - - random	1130	96	436	938	116	405	476	1196	159	240	752
—— difference	-1104	313	62	-372	-101	19	-45	-1041	629	521	5577



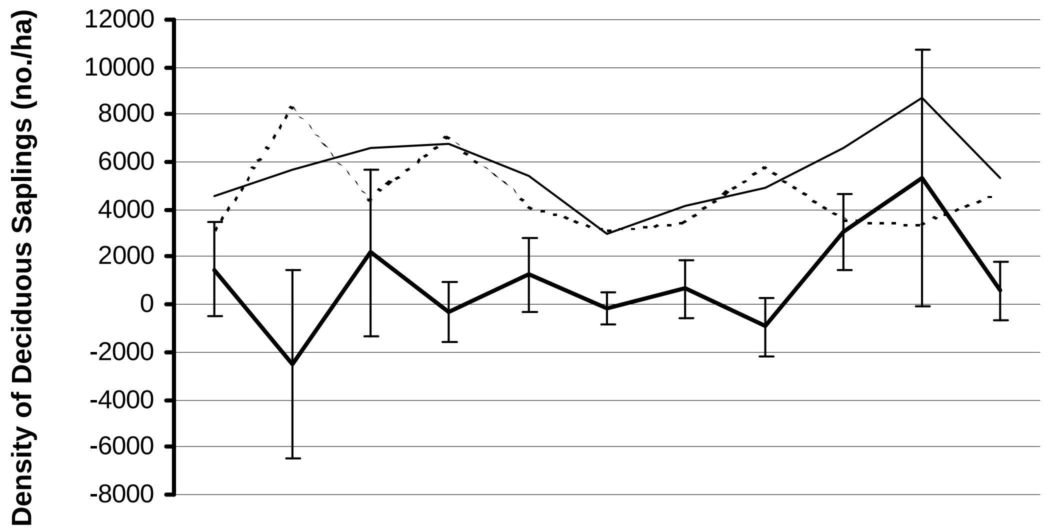
week	1	2	3	4	5	6	7	8	9	10	11
n	13	12	13	14	12	12	9	9	8	7	5
—— brood	334	463	743	58	111	183	51	24	412	0	717
- - - - random	2808	294	347	112	72	217	726	219	926	50	0
—— difference	-2474	169	396	-54	39	-34	-675	-195	-513	-50	717



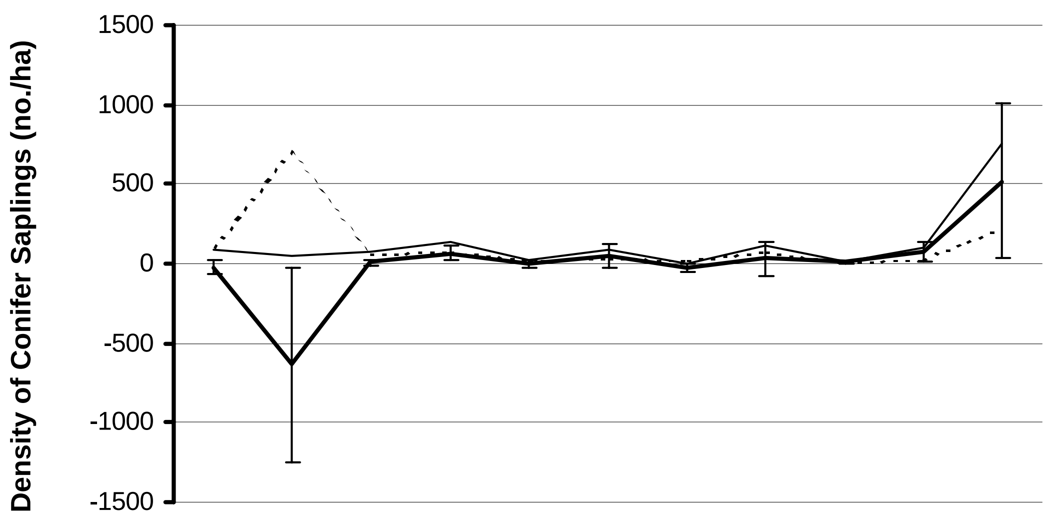
week	1	2	3	4	5	6	7	8	9	10	11
n	13	12	13	14	12	12	9	9	8	7	5
brood	418	906	1268	661	130	636	482	199	1403	769	7312
random	4076	424	823	1103	198	651	1208	1485	1085	413	752
difference	-3658	482	445	-442	-67	-14	-726	-1286	318	355	6560



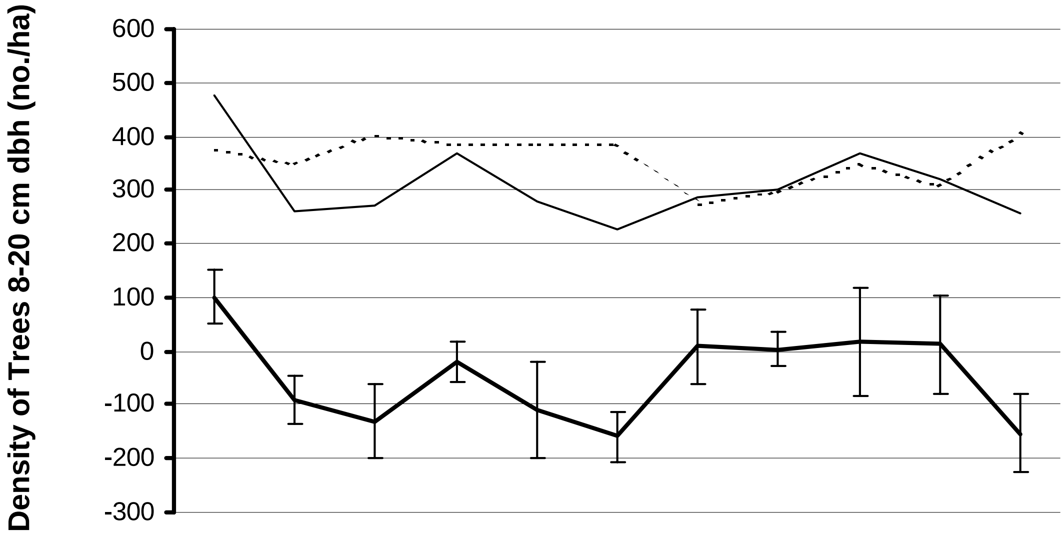
week	1	2	3	4	5	6	7	8	9	10	11
n	13	12	13	14	12	12	9	9	8	7	5
brood	4699	5737	6653	6901	5457	3032	4127	5029	6602	8818	6097
random	3240	8890	4472	7149	4199	3167	3490	5948	3551	3421	4998
difference	1460	-3153	2181	-248	1258	-135	636	-919	3052	5397	1099



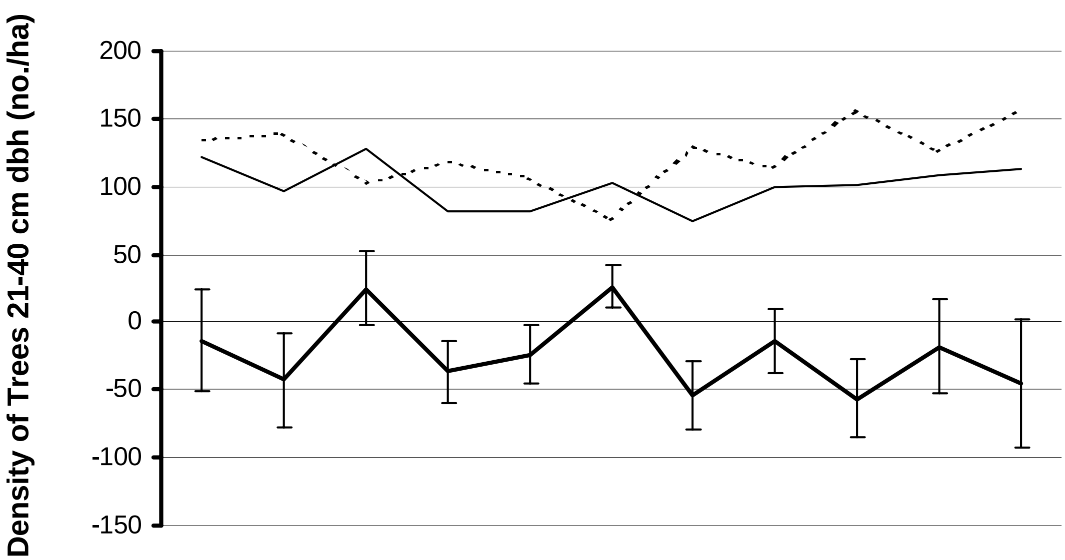
week	1	2	3	4	5	6	7	8	9	10	11
n	13	12	13	14	12	12	9	9	8	7	5
brood	4615	5684	6577	6760	5428	2946	4127	4919	6588	8719	5345
random	3133	8200	4406	7074	4175	3129	3465	5871	3543	3397	4767
difference	1482	-2516	2172	-314	1253	-183	662	-951	3044	5322	579



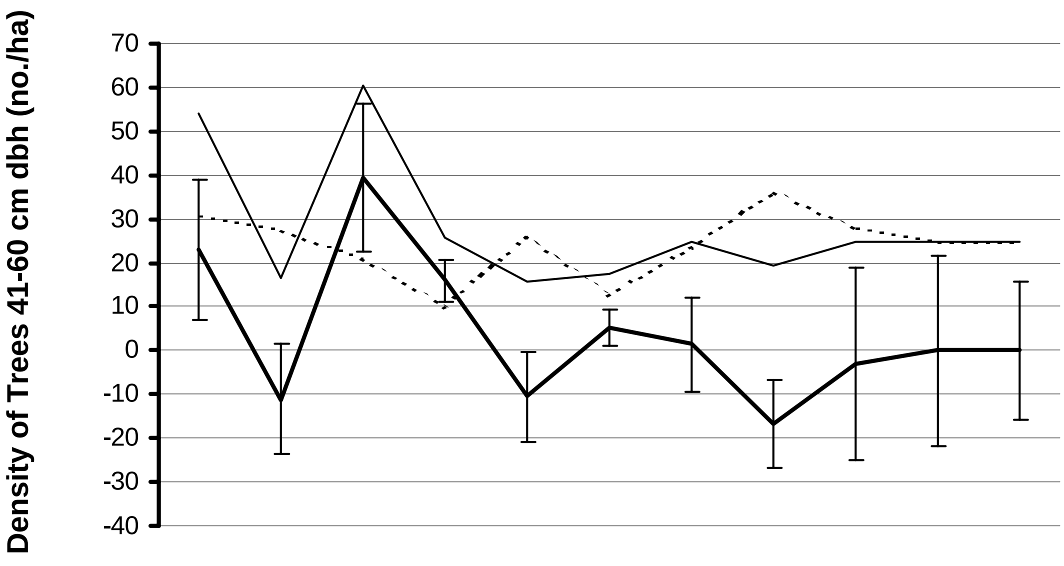
week	1	2	3	4	5	6	7	8	9	10	11
n	13	12	13	14	12	12	9	9	8	7	5
brood	85	53	76	140	29	87	0	109	14	99	752
random	107	689	67	74	24	39	26	77	7	25	231
difference	-22	-636	9	66	5	48	-26	32	7	74	521



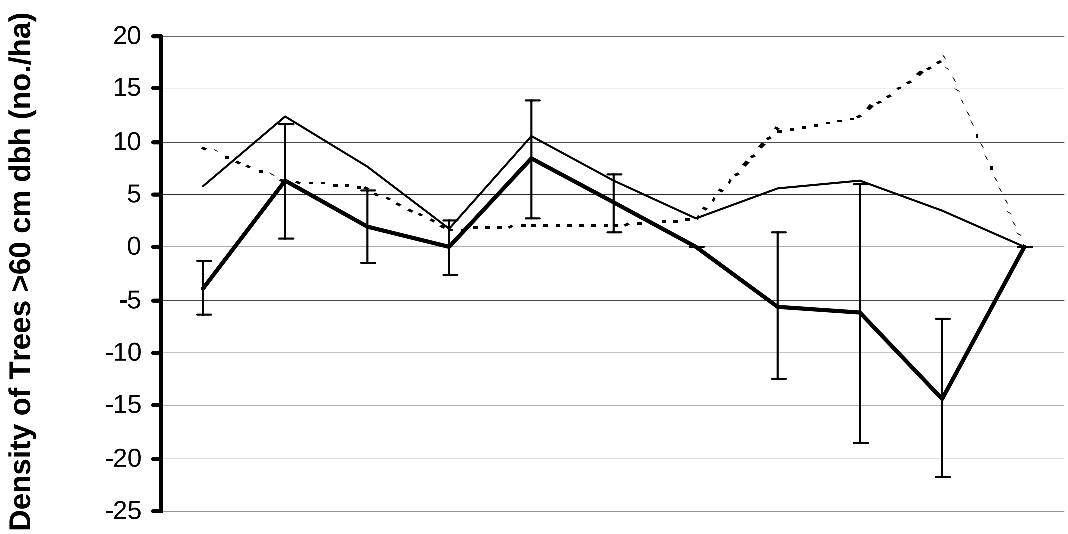
week	1	2	3	4	5	6	7	8	9	10	11
n	13	12	13	14	12	12	9	9	8	7	5
brood	477	260	271	368	280	228	285	301	369	320	255
random	376	351	402	388	389	388	276	297	350	307	408
difference	101	-91	-131	-20	-108	-159	8	4	19	13	-153



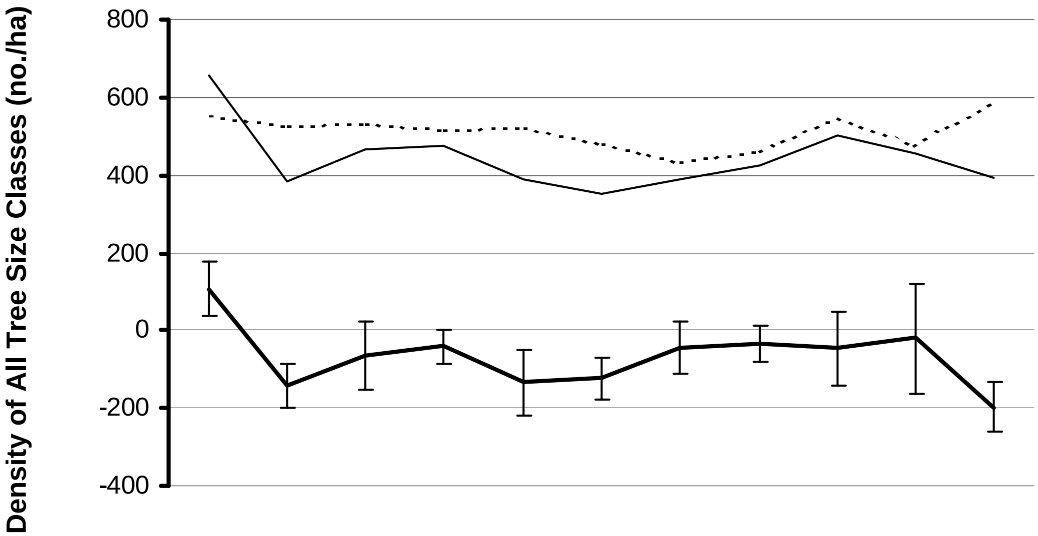
week	1	2	3	4	5	6	7	8	9	10	11
n	13	12	13	14	12	12	9	9	8	7	5
brood	121	97	128	82	82	102	75	100	102	109	113
random	135	140	103	119	106	76	129	114	158	127	158
difference	-13	-43	25	-37	-24	26	-54	-15	-56	-18	-45



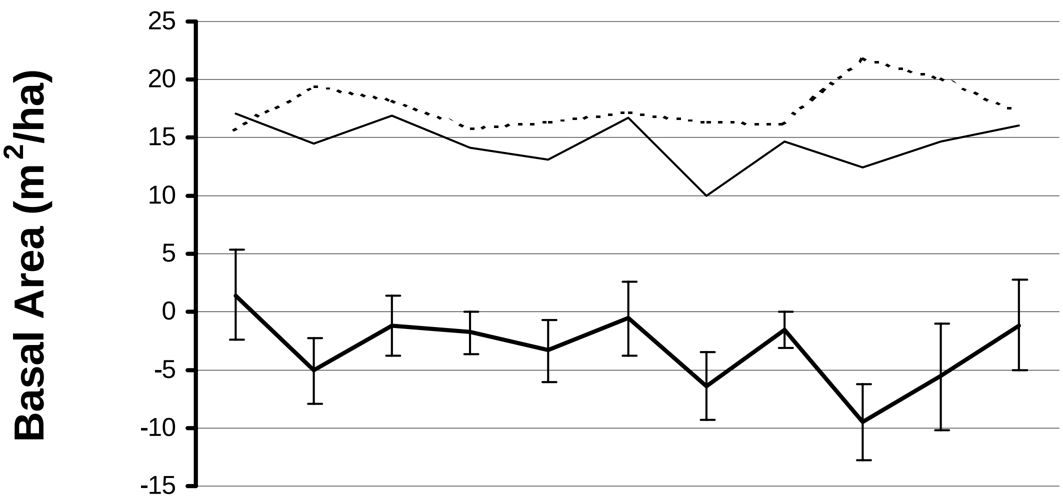
week	1	2	3	4	5	6	7	8	9	10	11
n	13	12	13	14	12	12	9	9	8	7	5
brood	54	17	61	26	16	18	25	19	25	25	25
random	31	28	21	10	26	13	24	36	28	25	25
difference	23	-11	39	16	-10	5	1	-17	-3	0	0



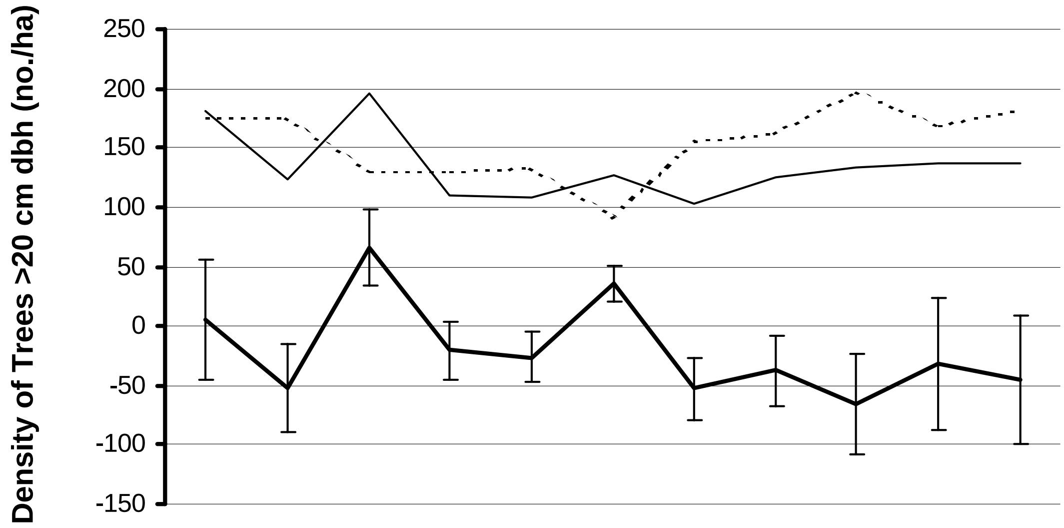
week	1	2	3	4	5	6	7	8	9	10	11
n	13	12	13	14	12	12	9	9	8	7	5
brood	6	13	8	2	10	6	3	6	6	4	0
random	10	6	6	2	2	2	3	11	13	18	0
difference	-4	6	2	0	8	4	0	-6	-6	-14	0



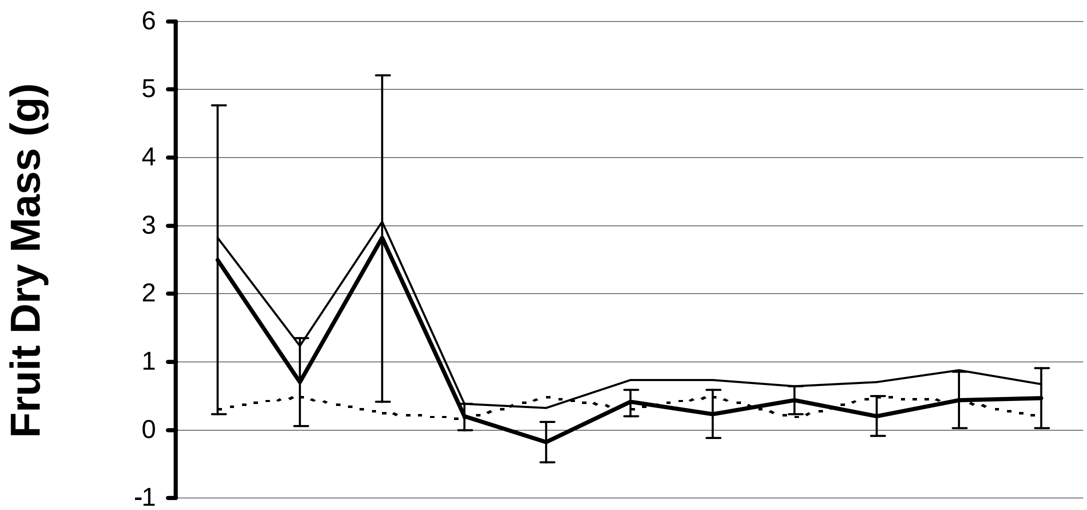
week	1	2	3	4	5	6	7	8	9	10	11
n	**13**	**12**	**13**	**14**	**12**	**12**	**9**	**9**	**8**	**7**	**5**
brood	**658**	**384**	**467**	**478**	**389**	**354**	**388**	**426**	**502**	**457**	**393**
random	**551**	**527**	**532**	**518**	**523**	**478**	**432**	**459**	**548**	**477**	**590**
difference	**107**	**-143**	**-64**	**-40**	**-134**	**-124**	**-44**	**-33**	**-47**	**-20**	**-198**



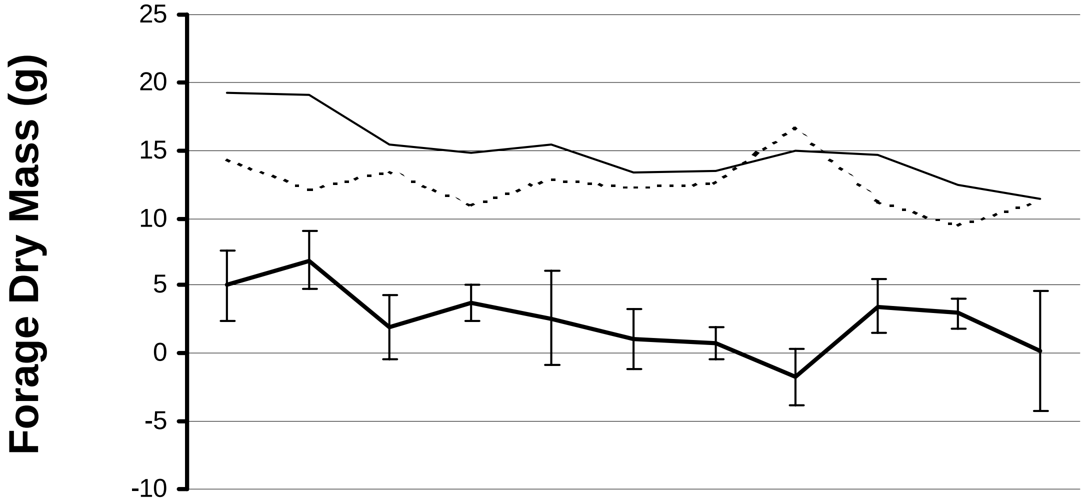
week	1	2	3	4	5	6	7	8	9	10	11
n	**13**	**12**	**13**	**14**	**12**	**12**	**9**	**9**	**8**	**7**	**5**
brood	**17.1**	**14.4**	**17.0**	**14.1**	**13.1**	**16.6**	**9.9**	**14.7**	**12.5**	**14.6**	**16.1**
random	**15.7**	**19.5**	**18.2**	**15.9**	**16.5**	**17.2**	**16.3**	**16.2**	**22.0**	**20.2**	**17.2**
difference	**1.4**	**-5.1**	**-1.2**	**-1.8**	**-3.3**	**-0.6**	**-6.4**	**-1.5**	**-9.5**	**-5.6**	**-1.1**



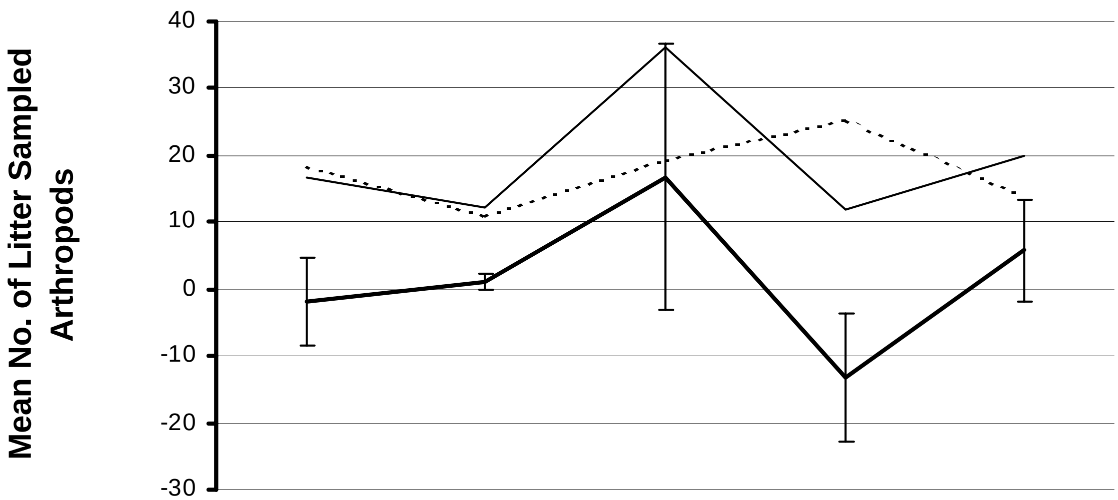
week	1	2	3	4	5	6	7	8	9	10	11
n	13	12	13	14	12	12	9	9	8	7	5
brood	181	124	196	110	108	126	103	125	133	138	138
random	175	176	130	130	134	91	156	162	198	170	183
difference	6	-52	66	-21	-26	35	-53	-37	-66	-32	-45



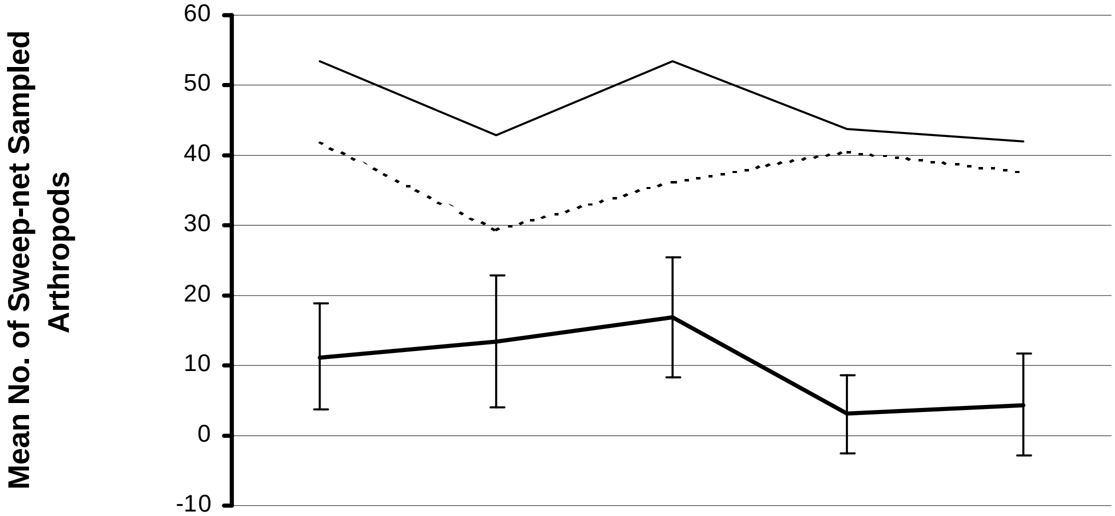
week	1	2	3	4	5	6	7	8	9	10	11
n	13	12	13	14	12	12	9	9	8	7	5
brood	2.8	1.2	3.1	0.4	0.3	0.7	0.7	0.6	0.7	0.9	0.7
random	0.3	0.5	0.3	0.2	0.5	0.3	0.5	0.2	0.5	0.4	0.2
difference	2.5	0.7	2.8	0.2	-0.2	0.4	0.2	0.4	0.2	0.4	0.5



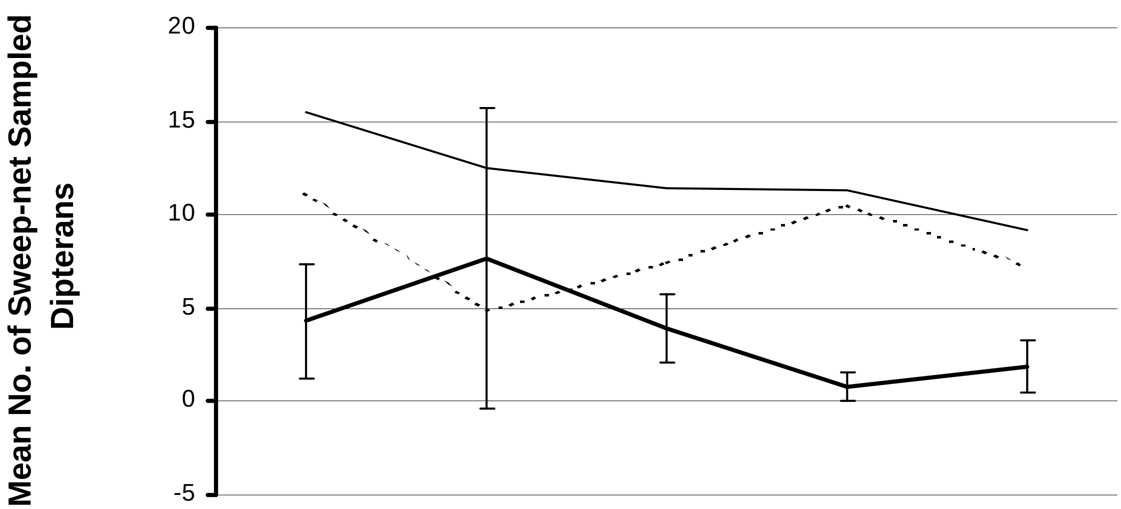
week	1	2	3	4	5	6	7	8	9	10	11
n	13	12	13	14	12	12	9	9	8	7	5
brood	19.3	19.0	15.4	14.8	15.5	13.4	13.4	15.0	14.7	12.4	11.4
random	14.3	12.1	13.4	11.0	12.9	12.3	12.6	16.7	11.2	9.5	11.3
difference	5.0	6.9	2.0	3.7	2.6	1.0	0.8	-1.7	3.5	3.0	0.1



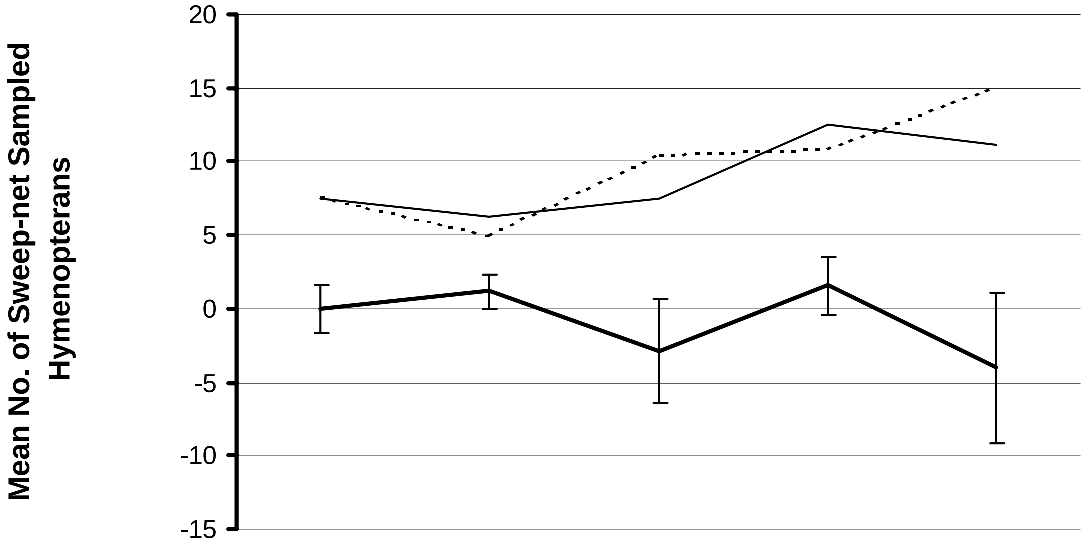
week	1	2	3	4	5
n	12	11	11	8	4
brood	16.6	12.1	36.0	11.9	19.9
random	18.5	11.0	19.3	25.3	14.0
difference	-1.9	1.1	16.7	-13.3	5.9



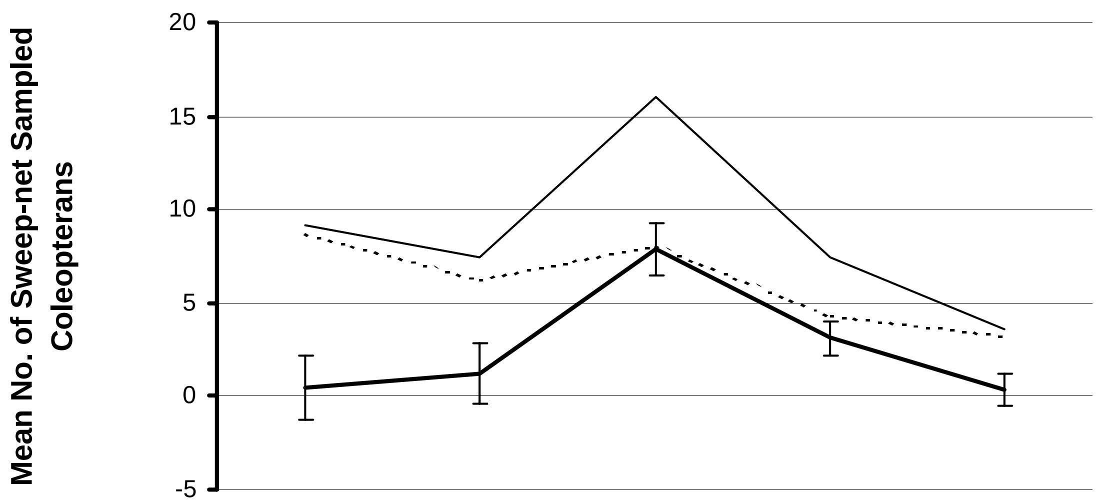
week	1	2	3	4	5
n	12	11	11	8	4
brood	53.3	42.9	53.3	43.6	42.0
random	42.1	29.5	36.4	40.6	37.6
difference	11.2	13.5	16.9	3.1	4.4



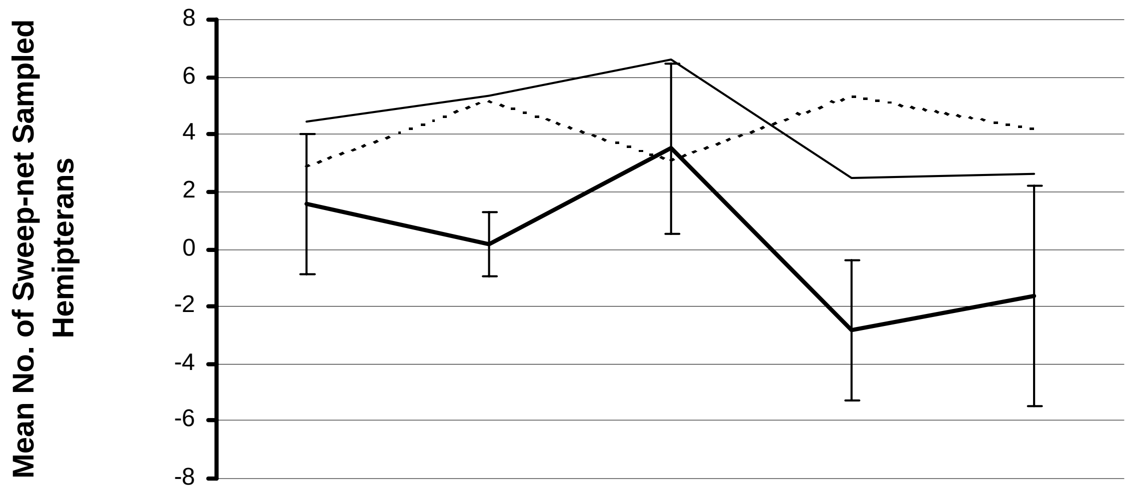
week	1	2	3	4	5
n	12	11	11	8	4
brood	15.5	12.5	11.4	11.3	9.1
random	11.2	4.8	7.5	10.6	7.3
difference	4.3	7.7	3.9	0.8	1.9



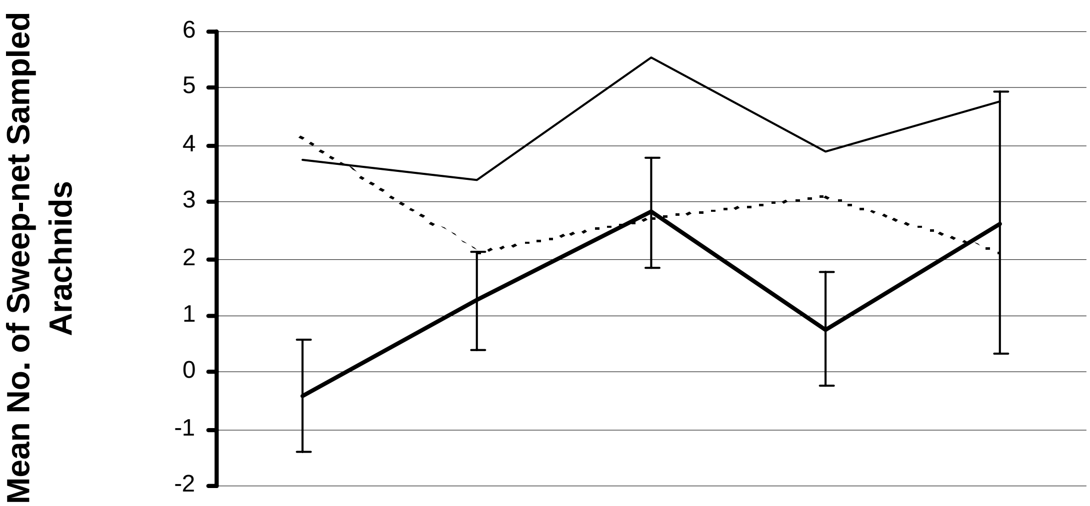
week	1	2	3	4	5
n	12	11	11	8	4
brood	7.5	6.2	7.5	12.5	11.1
random	7.6	5.0	10.4	10.9	15.1
difference	0.0	1.2	-2.9	1.6	-4.0



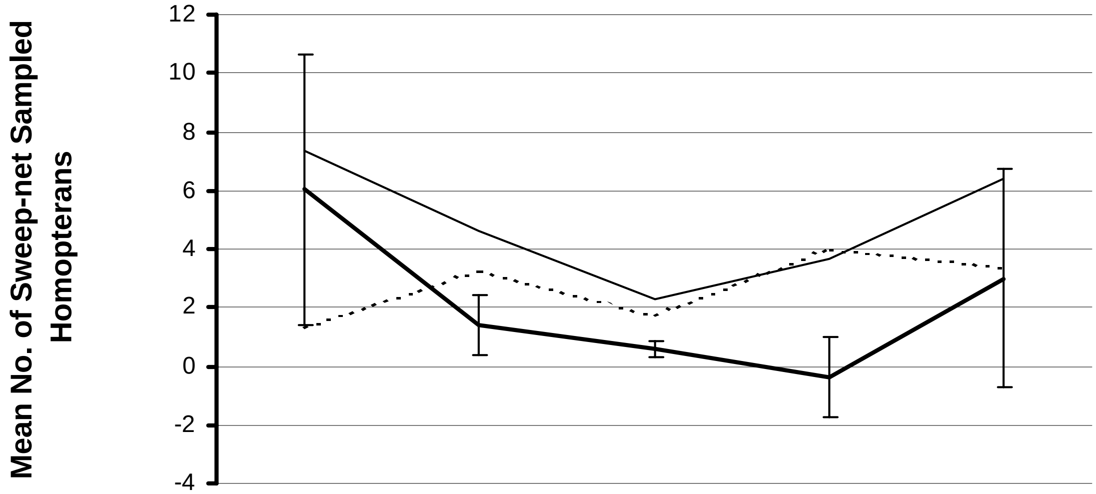
week	1	2	3	4	5
n	12	11	11	8	4
brood	9.2	7.5	16.0	7.4	3.6
random	8.7	6.3	8.1	4.3	3.3
difference	0.5	1.2	7.9	3.1	0.4



week	1	2	3	4	5
n	12	11	11	8	4
brood	4.5	5.4	6.6	2.5	2.6
random	2.9	5.2	3.1	5.3	4.3
difference	1.6	0.2	3.5	-2.8	-1.6



week	1	2	3	4	5
n	12	11	11	8	4
brood	3.7	3.4	5.5	3.9	4.8
random	4.2	2.1	2.7	3.1	2.1
difference	-0.4	1.3	2.8	0.8	2.6



	week	1	2	3	4	5
	n	12	11	11	8	4
———	brood	7.3	4.6	2.3	3.6	6.4
- - - - - - -	random	1.3	3.2	1.7	4.0	3.4
━━━	difference	6.0	1.4	0.6	-0.4	3.0

APPENDIX C

In 1998, the occurrence of a ruffed grouse brood flushing in an opening was noted on habitat data forms. Openings were categorized as roads or clearings and generally defined as moderate or large areas devoid of trees with obvious gaps in the tree canopy. Roads were either dirt-covered or grassy (abandoned logging roads or skid trails). Skid landings, logging decks, right-of-ways, wildlife clearings, meadows, or recent (< 1 year) clearcuts were considered clearings. The distance from the brood flush site to an opening was visually estimated by the habitat sampling personnel. Data are presented for 7 hens with broods radio-tracked in 1998.

	Flushes In Opening		Distance (m) to Opening			
Hen ID Number	Road[a]	Clearing	0	1-9	10-29	$\geq$30
10	0/17	0/17	0/17	3/17	2/17	12/17
85	0/12	1/12	1/12	1/12	3/12	7/12
3008	0/12	4/12	4/12	1/12	4/12	3/12
220	1/11	0/11	1/11	0/11	0/11	10/11
73	2/16	2/16	4/16	1/16	10/16	1/16
2181	0/3	0/3	0/3	0/3	0/3	3/3
29	0/3	1/3	1/3	1/3	0/3	1/3
Hens Pooled (%)	4	11	15	9	26	50

[a] number of brood flushes in a road / total number of brood flushes

APPENDIX D

Estimated brood range area of 8 ruffed grouse broods on 2 study sites in the southern Appalachians, 1997-1998. Radio-collared hens with broods were flushed and flush-site locations were determined using a geographic positioning unit (Corvallis Micro Technology, Inc., Corvallis, OR). Uncorrected location data were used to calculate 95% and 50% minimum convex polygons (MCP) in Calhome home range analysis software (U.S. Forest Service, Pacific Southwest Research Station, Fresno, CA). Because brood range size may vary with age and ranges of broods differing in age may not be comparable, the age of each brood when its locations were determined is presented.

					Brood Range Area (ha)	
Brood ID No.	Site	Year	n[a]	Brood Age (weeks)[b]	95% MCP	50% MCP
116	VA2	1997	24	1-12	75.8	9.7
218	VA2	1997	22	3-11	44.9	10.0
220	VA2	1998	12	1-6	13.9	0.9
22	WV2	1997	10	3-8	42.6	0.6
30	WV2	1997	12	4-11	250.7	6.6
49	WV2	1997	10	1-7	76.3	2.2
10	WV2	1997	12	3-11	166.2	2.2
10	WV2	1998	13	1-10	50.0	4.6

[a] number of locations used in brood range size calculation

[b] age of brood when locations were determined

APPENDIX E

The linear distance (m) between ruffed grouse nest sites and brood flush sites for 11 hens with broods during the first 12 days after hatch, 1997-1998. Radio-collared hens with broods were flushed and flush-site locations were determined using a geographic positioning unit (Corvallis Micro Technology, Inc., Corvallis, OR). Uncorrected location data were used with PC-GPS software (Corvallis Micro Technology, Inc., Corvallis, OR) to calculate the linear distance between successive locations.

	Day Post-Hatch											
Hen	1	2	3	4	5	6	7	8	9	10	11	12
94											638	
99						260						619
3008		217				932						
73		508									937	
29										262		
116		679		947					1795			
229				513		630						
220	147				591		813					
2181	286				562			937				
85		202				602						1698
10			424				2095			2145		

VITA

G. Scott Haulton was born in Binghamton, New York on December 9, 1968. He graduated from Chenango Forks High School in 1987. In 1992, Scott graduated with a Bachelor's degree in English from the State University of New York College at Geneseo. In 1994, Scott attended the State University of New York College of Environmental Science and Forestry (SUNY ESF) and worked as an undergraduate research assistant and wildlife technician during 2 summers at the Huntington Wildlife Forest (HWF). While at HWF he completed 2 undergraduate research projects: "Summer food habits of eastern coyotes in the central Adirondacks" and "Day and night ranges of Adirondack white-tailed deer." In 1996, Scott graduated Magna Cum Laude from SUNY ESF with a Bachelor's degree in Environmental and Forest Biology. Scott began a Master's program in the Department of Fisheries and Wildlife Sciences at Virginia Polytechnic Institute and State University in 1997. He received his Master's degree in Fisheries and Wildlife Science in May of 1999.