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Christopher A. Dobony
West Virginia University

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FACTORS INFLUENCING RUFFED GROUSE PRODUCTIVITY AND CHICK SURVIVAL IN WEST VIRGINIA

Christopher A. Dobony

Thesis submitted to the College of Agriculture, Forestry, and Consumer Sciences at West Virginia University
in partial fulfillment of the requirements for
the degree of

Master of Science
in
Wildlife and Fisheries Resources

John W. Edwards, Ph.D, Major Professor
Thomas J. Allen, M.S
W. Mark Ford, Ph.D
David E. Samuel, Ph.D

Division of Forestry

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ABSTRACT

Factors Influencing Ruffed Grouse Productivity and Chick Survival in West Virginia

Christopher A. Dobony

I examined productivity measures, chick mortality, and factors influencing chick survival of ruffed grouse (*Bonasa umbellus*) at 2 sites in West Virginia during 1998 and 1999.

I determined grouse productivity indices at the Westvaco Ecosystem Research Forest in Randolph County, West Virginia and the Westvaco Dutch Run Tract in Greenbrier County, West Virginia. I located the nests of radio-collared female grouse, and determined the proportion of radio-collared hens that nested, the nest success (proportion of hens successful in hatching ≥1 chick), clutch sizes, hatching success of successful nests, and hatch dates. The proportion of hens that attempted to nest was similar between age classes, between sites, and between years ($P > 0.05$). Nest success was similar between age classes, between sites, and between years ($P > 0.05$). Average clutch size and hatching success of successful nests was similar between age classes, between sites, and between years ($P > 0.05$). Hatch dates were similar between age classes and between sites ($P > 0.05$), however, were significantly different between years ($P = 0.049$). Depredation was the major cause of nest failure, and 30% of the nests monitored over the 2 years were disturbed or destroyed. Nests were monitored via video cameras and raccoon (*Procyon lotor*) and black rat snake (*Elaphe obsoleta*) were identified as nest predators.

I examined radio transmitter attachment methods in order to develop a method suitable for use in examining mortality and survival in <3-day-old grouse chicks. In 1998 I used a glue-on attachment method similar to that used in passerine research. Radio transmitters weighed approximately 0.54 g, were 4-5% of the body weight at attachment time, and had a 3 week life expectancy. The transmitters were applied to the skin and feathers between the scapulas using Skin Bond medical glue. In 1999 I developed a collar attachment method that was modeled after collars used on adult grouse. Transmitters weighed approximately 0.98 g, were 7-8% of the body weight at time of attachment, and had life expectancies of 5 weeks. The glue-on transmitter had poor retention time ($\bar{x} = 5.7 \pm 0.69$ days, $n = 15$) and is not recommended for this type of research. In contrast, all collar-type transmitters ($n = 35$) stayed on until the death of the chick or the end of the study, when they were removed. Initial problems in determining the correct circumference for the collars were encountered, however, were soon rectified. I believe this type of attachment could be valuable in examining mortality and survival in ruffed grouse chicks.

I examined causes of radio transmittered ruffed grouse chick mortality. Survival was examined using transmittered chicks and standard flush counts. Additionally, I examined factors that could influence that survival, specifically availability of arthropods and environmental conditions in different cover types. Chick survival was low (< 30%) for both methods (telemetry and flush counts) within the first 5 weeks post-hatch each year. Most mortality occurred within the first week post-hatch, and decreased over subsequent weeks. Predation accounted for the majority of mortality. Avian and mammalian predators took approximately equal numbers of grouse chicks. Incidence of complete brood loss was relatively high (approximately 32%). Chick mortality attributed to exposure was low. Non-forested roads and mesic-Allegheny hardwood regeneration $\geq$ 6-15 years produced greater arthropod abundance representing more families than all other cover types except upland hardwoods $\geq$ 55-85 years old ($P < 0.05$). Arthropods were least abundant in open cutovers < 2 years old ($P < 0.05$). Mesic-Allegheny hardwood regeneration $\geq$ 6-15 years produced greater arthropod biomass than open cutovers < 2 years old ($P < 0.05$); all other cover types had similar arthropod biomass. Open cutovers < 2 years old maintained the highest average temperature among cover types, and mesic-Allegheny regeneration 2-5 years old and non-forested roads received the highest amount of rainfall reaching the forest floor ($P < 0.05$). I also found that rainfall and temperature were poor predictors of arthropod abundance and biomass. These findings suggest that grouse brood habitat could be enhanced through management practices that result in areas containing escape cover and high numbers of arthropods.

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INTRODUCTION, RESEARCH JUSTIFICATION, AND OBJECTIVES

The ruffed grouse (*Bonasa umbellus*) is one of the most widely distributed, non-migratory game birds on the North American continent (Gullion 1977). The range extends east from Alaska, along the tree line in Canada's Northwest and Yukon territories, to the Maritime provinces, south to the Great Lakes region, and the lower reaches of the Rocky and Appalachian mountains (Bump et al. 1947, Gullion 1977). For unknown reasons, ruffed grouse densities are lower in the southern portion of its range than in the more northern reaches (Bump et al. 1947, Rusch and Destefano 1989).

Because most research has been concentrated in the north, the factors that may be limiting grouse numbers in the southern portion of its range are not well known or understood (Dorney and Kabot 1960, Rusch et al. 1984, Small et al. 1991). Some evidence suggests that the differences in grouse densities are a result of differing habitat and forest community composition (Servello and Kirkpatrick 1987). Many researchers have shown that grouse use a wide array of climax forest communities, but are usually found where early succession stages of *Betula* and *Populus* stands exist (Bump et al. 1947, Gullion 1977, Johnsgard 1983). These tree species are absent in the central Appalachians. Servello and Kirkpatrick (1987) believe these regional differences in forest composition may result in differences in diet quality and food abundance. Similarly, Stafford and Dimmick (1979), Norman and Kirkpatrick (1984), and Hewitt (1994) have suggested that the ruffed grouse's nutritional needs may not always be adequately fulfilled in the southern portion of its range. The lack of adequate drumming, nesting and brooding habitat may lead to lower densities of grouse (Stewart 1956, Berner and Gysel 1969, Thompson et al. 1987). Predation may be an important factor as well

(Gullion 1970, Rusch and Keith 1971, Bergerud 1988, Small et al. 1991). Because the above factors are difficult to examine, and may interact with each other, it is difficult to ascertain to what degree they influence grouse populations.

The Appalachian Cooperative Grouse Research Project (ACGRP) was initiated in 1996 to investigate the decline of the species in the central and southern Appalachian region. The primary objectives of the ACGRP are to investigate population trends and factors influencing ruffed grouse survival in this region and develop beneficial management strategies. This project initially involved a cooperative effort among Kentucky, Maryland, Ohio, Virginia, and West Virginia. As the scope of this effort broadened, Pennsylvania, Tennessee and North Carolina became cooperators. This cooperative effort may help to gather information on ruffed grouse population dynamics at a landscape and regional level that would not be possible with a single study site effort.

West Virginia University's and West Virginia Division of Natural Resource's (WVDNR) role in the ACGRP has been to investigate the factors influencing ruffed grouse chick survival in the central Appalachians. Although brood habitat and ecology have been examined in the northern portion of the ruffed grouse range (Berner and Geysel 1969, Kubisiak 1978, Maxson 1978, Lyons 1981), this is poorly known in the central Appalachians. Specifically, there have been few investigations into the specific causes of mortality of ruffed grouse chicks within the first few weeks of life. Consequently, I developed the following study objectives: 1) to determine productivity parameters of ruffed grouse in West Virginia, 2) to develop a radio transmitter attachment method for <3-day-old ruffed grouse chicks that could be implemented in the field to gain pertinent information on survivorship and mortality causes in broods during the first few weeks of life, and 3) to determine cause-specific mortality in ruffed grouse broods in West Virginia, and to assess which factors may be influencing mortality and survival.

CHAPTER 1—BREEDING ECOLOGY AND PRODUCTIVITY OF RUFFED GROUSE IN WEST VIRGINIA

INTRODUCTION

Ruffed grouse densities are lower in the southern portion of its range than in the more northern reaches (Bump et al. 1947). It has been suggested that lower productivity of ruffed grouse in southern latitudes may account for lower population densities (Bergerud 1988). However, little is known about their productivity parameters in the southern portion of the range (Bump et al. 1947, Stafford and Dimmick 1979, Norman and Kirkpatrick 1984, Small et al. 1991).

Grouse productivity in the southern portion of its range may be limited by a number of factors. Bergerud (1988) suggested that nest depredation for gallinaceous birds is greater in southern latitudes, and he indicated that higher rates of nest depredation might account for lower productivity. Hewitt and Kirkpatrick (1993) measured depredation rates in Virginia through an artificial nesting experiment simulating ruffed grouse nests and found weak evidence to support this hypothesis. Ortega et al. (1998), however, reported that predators respond differently to artificial and natural nests. They suggested that results from artificial nest experiments should be carefully scrutinized. Beckerton and Middleton (1982) suggested that ruffed grouse hens on a protein deficient diet may have low-quality eggs, which may negatively influence hatching and survival. They indicated that hens entering the breeding season in poor condition may have lower hatching success and chick survival. Poor diets may decrease productivity in pheasants (*Phasianus colchicus*) in Great Britain (Draycott et al. 1998). They believed that unless supplemental feeding was maintained throughout the spring, fat reserves and body mass would be lowered, inhibiting productivity.

Examination of the breeding ecology and productivity parameters of ruffed grouse in southern latitudes may help in developing a better understanding of regional variation. Consequently, my objective was to examine productivity and nest depredation in ruffed grouse in West Virginia.

STUDY AREAS

My study was conducted on the Westvaco Wildlife and Ecosystem Research Forest (WERF) located in the Allegheny Mountain Physiographic Province (Fenneman 1938) in Randolph County, West Virginia, and the Westvaco Dutch Run Tract (DRT) located in the Ridge and Valley Physiographic Province (Fenneman 1938) in Greenbrier County, West Virginia.

The WERF is a 3,413 ha area established by Westvaco Corporation in 1994 to study industrial forestry impacts on ecosystems and ecological processes. Forest management is ongoing, and the oldest forests are second-growth forest stands established after turn of the century logging (Tilghman 1989, Clarkston 1993). The area is managed on a 60-70-year harvest rotation. Harvest methods include diameter-limit, clearcutting, and 2-aged regeneration harvests. Elevations range from 740 to 1200 m, and topography is characterized by plateau-like ridgetops with steep slopes and narrow valleys (Fenneman 1938, Ford and Rodrigue 2000).

The WERF is characterized by a cool, moist climate, and average annual precipitation exceeding 198 cm (http://www.nndc.noaa.gov), and contains 3 primary Society of American Foresters (SAF) hardwood forest types (Eyre 1980) typical of the Allegheny Mountain Province of West Virginia, as well as small areas of non-forested land. Sugar maple (*Acer saccharum*), American beech (*Fagus grandifolia*), yellow birch

(*Betula allegheniensis*), and black cherry (*Prunus serotina*) comprise the Allegheny hardwood-northern-hardwood type. These stands are typically found on well-drained soils and cover approximately 90% of the site (3,056 ha or 7,548 acres). The second forest type is a mixed mesophytic association of yellow-poplar (*Liriodendron tulipifera*), American basswood (*Tilia americana*), northern red oak (*Quercus rubra*), and white oak (*Q. alba*) or Cove-hardwoods. These associations are typically found at lower elevations and make up about 6% of the hardwood forest cover (195 ha or 483 acres). The remaining hardwood forest cover (21 ha or 53 acres) is classified as the xeric mixed oak type. These stands are found along ridgelines and southwest facing slopes. Primary conifer cover consists of high elevation spruce (*Picea* spp)- hemlock (*Tsuga canadensis*) associations along with patches of riparian hemlock found in sheltered stream drainages. Rhododendron (*Rhododendron maximum*) communities exist throughout upland areas on the site as well (Ford and Rodrigue 2000).

The DRT is a 2,036 ha area managed strictly for fiber production. The area is managed on an even-aged rotation length of 40-70 years, and has a lower site quality and site index than the WERF. Elevations range from 520 to 1100 m, and the topography is extremely steep and rugged, with ephemeral seeps and streams running throughout. Soils derived mainly from shale parent materials typical of this portion of the Ridge and Valley region give this area the aforementioned low site quality attributes. This well drained soil, combined with a lower annual average precipitation of approximately 107 cm (http://www.nndc.noaa.gov) resulting from a rain shadow from the Allegheny mountains immediately to the west, results in a more xeric climate (Hicks 1998).

Approximately 94% (1,914 ha) of this area is dominated by SAF designated oak-hickory associations typical of the Ridge and Valley Physiographic Province. The remaining 6% consists of cove hardwoods (yellow-poplar and oak mixture - 4%) and pine (*Pinus* spp) stands - 2%. Both sites have well maintained road systems.

METHODS

Trapping and Monitoring Females

Female ruffed grouse trapping began in the fall of 1997 and continued until ≥10 hens were captured on both sites. Trapping resumed in the early spring to replace hens lost to mortality and radio-failures from the previous year and continued until the second week of April. Grouse were captured using modified lily-pad traps (Gullion 1965). Ten- to 16-m leads consisting of 46-cm tall poultry wire were used to guide grouse into the funnel and body of the lily-pad trap. There was one trap body at each end of the wire lead (Allen 1996). Once captured, birds were weighed, aged based on feather molt and wear (after Kalla and Dimmick 1995), and leg banded with an aluminum identification tag (# 12, butt-end tags, National Band and Tag, Newport, KY). Each hen was equipped with a necklace-type radio transmitter (Advanced Telemetry Systems, Isanti, MN). Transmitters weighed 10-11 g, had a 2 year life expectancy, operated on the 150-152 mHz frequency range, and were equipped with a mortality sensor.

Transmittered hens were monitored twice weekly in 1998 using a 2-element yagi antennae and portable receiver (Wildlife Materials, Carbondale, IL, and Advanced Telemetry Systems, Isanti, MN). Starting 1 March 1999, hens were monitored 3 times weekly to accurately document nest initiation. I obtained a minimum of 3 azimuths from permanently located Global Positioning System (GPS) stations, and determined locations via triangulation (Mech 1983). I recorded and plotted all locations by hand on topographic maps of the area. As the breeding season progressed, I used these telemetry azimuths to aid in locating nests.

Johnsgard (1983) found that the female's time on the nest increased proportionately to clutch size. Similarly, Maxson (1977, 1978) noted a marked decrease in both activity and movement once hens started nesting, laying eggs, and incubating. These behaviors helped to determine the onset of egg laying and incubation. Once observed, I used telemetry to "home in" and locate nests (Mech 1983).

In 1999, I placed infrared cameras (Fuhrman Industries, Seabrook, TX) on 10 nests on the WERF. When possible, cameras were placed on nests when hens were absent. However, 6 of 10 hens were flushed to allow for camera placement. I only placed the actual camera lens and attachment arm near the nest. A cable ran from the camera lens to the video recording unit and power source 20 m away from the nest. Therefore, subsequent daily visits to the VCR unit of the camera to change tapes and batteries did not disturb the grouse.

I used camera footage to determine the onset of incubation. The onset of incubation was defined as the first instance where the female remained on her nest the entire day. This was then used to predict hatch dates. On nests without cameras, I obtained an egg count during egg laying and during the incubation period. This information was used to predict hatch dates by backdating to when the last egg was laid. I was able to use camera footage to determine exact hatch dates and times for 3 of the 10 nests that had cameras. These were nests that we were able to maintain cameras on throughout incubation. The remaining 7 cameras were removed prior to hatching for use on another project. Hatching dates were determined on these, as well as, the remaining 3 nests without cameras by visual inspection towards the end of incubation.

Statistical Analysis

I determined the nesting rate (proportion of hens attempting to nest) by dividing the number of hens under observation by the number of hens that attempted to nest. I determined nest success by the apparent method (Johnson and Shaffer 1990), which is the percentage of nests that successfully hatched ≥1 chick (i.e., number of nests under observation divided by the number that hatched ≥1 chick). I compared nest success between years, study areas, and age classes using Fisher's Exact Test. I chose this test because of small sample sizes and expected values (Dowdy and Wearden 1985). Age class was defined as adult (entering second or higher breeding season) or juvenile (entering first breeding season). I determined the percentage of re-nests from the proportion of hens that lost their first nest to those that attempted a second nest. Mean clutch size was compared between years, study areas, and age class using 2-sample *t*-tests. I determined hatching success of successful nests in females that successfully hatched ≥1 chick by dividing the number of eggs laid by the number that successfully hatched. Hatching success of successful nests was compared between years, study areas, and age class using Fisher's Exact Test. I compared mean hatch dates of adult and juvenile hens between years and study areas using 2-sample *t*-tests.   Because data were found to be normally distributed, parametric statistics were performed using Statistical Analysis Systems software (SAS Institute, 1996: PROC FREQ, PROC TTEST).

RESULTS

Productivity 1998

I collected data from 18 hens in 1998, 11 on the WERF and 7 on the DRT. One WERF hen was killed before her nest could be found, reducing the total to 17. All hens attempted to nest on the DRT. The proportion of hens attempting to nest was similar between age classes on the WERF (Table 1-1). The proportion of hens attempting to nest was also similar between sites (Table 1-2). The proportion of hens successful in hatching ≥1 chick was similar between age classes, within sites (Table 1-4), and between sites (Table 1-5).

Depredation was the major cause of nest failure in 1998. Predators disturbed or destroyed 29.4% of monitored nests, 2 on the WERF and 3 at the DRT. Four of the nests lost (2 at each site) were completely depredated (all eggs eaten). One nest on the DRT was only partially depredated (some eggs eaten). At the WERF, one hen was killed on her nest by a mammalian predator. Insufficient evidence was available at the nest sites to determine specific predators. There were no re-nests on either site after the depredation events.

I obtained clutch size information from 11 nests, 7 from the WERF and 4 from the DRT. Egg number per nest ranged from 9 to 12 for both areas. Average clutch size was similar between age classes, within sites (Table 1-7) and between sites (Table 1-8). I obtained hatching success from 11 successful nests, 7 from the WERF, and 4 from the DRT. Of 116 eggs laid, 102 (87.9%) hatched. Seventy-two (97.3%) of 74 hatched at the WERF, and 30 (100%) of 42 at the DRT. Two partially depredated nests at the DRT adversely affected this number, however, and if removed from the analysis, 94 (97.9%) of 96 eggs hatched successfully on both sites, and 22 (100%) of 22 at the DRT. Hatching success was similar between age classes, within sites (Table 1-10) and between sites (Table 1-11).

Average hatch dates were similar between age classes, within sites (Table 1-12) and between sites (Table 1-13). The earliest hatching date was 21 May 1998, and the latest was 29 May 1998 on the WERF, and 17 May 1998 and 28 May 1998, respectively, at the DRT.

Productivity 1999

I collected data from 24 hens in 1999, 13 from the WERF, and 11 from the DRT. The proportion of hens that attempted to nest was similar between age classes, within sites (Table 1-1), between sites (Table 1-2), and between years (Table 1-3). The proportion of hens successful in hatching $\geq$1 chick was similar between age classes, within sites (Table 1-4), between sites (Tables 1-5), and between years (Table 1-6).

Depredation was also the major cause of nest failure in 1999. Predators disturbed or destroyed 29.2% of monitored nests, 3 on the WERF, and 4 on the DRT. One DRT hen was killed while incubating. There were no re-nests on either site after the depredation events, however, one WERF hen did re-nest after abandoning her nest. Evidence of nest depredation events was gathered through video surveillance cameras at 2 of the 3 nest depredations at the WERF, one by raccoon (*Procyon lotor*) and one by black rat snake (*Elaphe o. obsoleta*). The snake depredation occurred over a 2-3 day period, with only a few of the eggs removed at a time. Hair analyses from samples gathered at the remaining depredated nest on the WERF suggested black bear (*Ursus americanus*) and/or bobcat (*Lynx rufus*) as possible predators, as both hair types were found at the nest site. A long-tailed weasel (*Mustela frenata*) was also seen on video entering the nest before the video camera was removed from the nest. A lack of disturbance around the nests at the DRT suggests that snakes depredated 2 of the 4 nests. Hair analysis from microscopic viewing (after Adorjan and Kolenosky 1969) from the remaining 2 nest depredations at the DRT was inconclusive. However, other evidence (e.g. physical disturbance and tracks) at one of the DRT nests indicated possible black bear depredation.

I obtained clutch size information from 21 first nest attempts, 12 from the WERF and 9 from the DRT. Clutch size also was obtained from 1 re-nest on the WERF. The number of eggs per nest ranged from 7 to12 on the WERF for first nest attempts (10 for the re-nest), averaging 10.5 ± 0.41. This includes the snake-depredated nest. Excluding this nest from the analysis made sense, as it is possible the number of eggs in the nest (7) may have already been reduced due to depredation before we located the nest. If censored, the number of eggs per nest ranged from 9 to 12 on the WERF, averaging 10.8 ± 0.35. The number of eggs per nest ranged from 7 to 14 on the DRT, averaging 10.4 ± 0.75. The average clutch size was similar for age classes, within sites (Table 1-7), between sites (Table 1-8), and between years (Table 1-9). I determined hatching success from 16 successful nests (including the re-nest); 10 from the WERF and 6 from the DRT. Of 174 eggs laid, 147 (84.5%) hatched, 107 (99.1%) of 108 hatched on the WERF, and 55 (83.3%) of 66 hatched on the DRT. I also observed a DRT nest that seemed to be partially depredated. If censored, overall success would increase to 159 (97.5%) of 163, and 52 (94.5%) of 55 at the DRT. Analysis between age classes was not performed in 1999, because only adult hens were successful in nesting for first nest attempts. Hatching success was similar between sites (Table 1-11), and between years (Table 1-12).

The average hatch date was 23 May 1999 at the WERF with the re-nest hatch included, and 22 May 1999 if the re-nest is not included. The average hatch date at the DRT was 24 May 1999. The earliest hatch date on the WERF for first nest attempts was 18 May 1999, and the latest was 23 May 1999. The re-nest hatched 29 May 1999, making it the latest hatch at the WERF. The earliest hatch date for first nest attempts at the DRT was 20 May 1999, and the latest 26 May 1999, respectively. Analysis between age classes was not performed in 1999, because only adult hens were successful in nesting for first nest attempts. Hatch dates were similar between sites (Table 1-13), and significantly different between years (Table 1-14).

DISCUSSION

Nest depredation was the primary factor influencing grouse nest success. Thirty percent of the nests monitored over 2 years were destroyed, with 91.6% of those attributed to depredation events. Studies have shown that nest depredation can be an important nest loss/nest abandonment mechanism in ruffed grouse (Bergerud 1988, Johnsgard and Maxson 1989). Other studies throughout ruffed grouse range report nest depredation rates from 23% to 41% (Bump et al. 1947, Johnsgard and Maxson 1989, Rusch 1989, Larson 1998, Haulton 1999). Similarly, other gallinaceous species show high incidence of nest depredation leading to lowered nest success (Miller et al. 1998, Paisley et al. 1998, Fies 1999).

Several predators were responsible for the complete or partial nest depredation recorded in this study. Raccoons and rat snakes have been identified as common nest predators (Best and Stauffer 1980, Hernandez et al. 1997, Neal et al. 1998). The raccoon caused substantial disturbance at the nest site, while the snake depredation left no disturbance. Hernandez et al. (1997) suggested that depredation events often are erroneously classified as snake because no evidence was left at the site. Predators such as raccoons also may leave no eggshells or evidence behind.

I also found one instance of nest depredation after a camera was removed from the nest. After reviewing video footage, a weasel was seen repeatedly harassing the ruffed grouse hen on the nest. The hen escaped from the weasel in every instance on videotape, but it is possible that this animal could have finally depredated the nest after I removed the camera. Subsequent hair analysis (after Adorjan and Kolensky 1969) revealed that both bobcat and black bear had also visited this nest site; however, those visits could have been coincidental. Gray fox (*Urocyon cinereoargenteus*), skunk (*Mephitis* spp. or *Spilogale* spp.), red fox (*Vulpes vulpes*), opossum (*Didelphis virginiana*), and coyote (*Canis latrans*) inhabit both study areas and may represent possible nest predators.

Human disturbance may also have an impact on ruffed grouse nest success. Swanson (1993) found that nest abandonment increases if wild turkey hens are disturbed. I recorded only one (2.5%) abandonment out of 40 nest attempts in 2 years. Cause of this abandonment was unknown, though eggs from this nest were viable, and were hatched using artificial incubation. This may have resulted from researcher disturbance, as this was one of the nests that I placed a video camera on in 1999. However, there were no other abandonment events, even though I placed video cameras on 10 nests. These findings suggest that the monitoring of grouse hens via video cameras has minimum effect on nest abandonment.

I observed no re-nest attempts of nests lost to depredation. Haulton (1999) reported a re-nest rate of only 6% over 2 years in the central Appalachians. These values are substantially lower than reported in northern studies. Overall, re-nesting in ruffed grouse has been reported as uncommon (Bump et al. 1947, Johnsgard and Maxson 1989). However, Small et al. (1996) in Wisconsin and Larson (1998) in Michigan observed a >50% re-nesting rate for females that had lost or abandoned their first nest. The stage or time during the nesting period when the nest is destroyed is critical in determining the likelihood of the hen attempting a re-nest (Johnsgard and Maxson 1989). Even though a hen has the biological potential to re-nest the day after a depredation or disturbance, this diminishes rapidly over time. As egg laying ends and incubation begins, the hen's ova begin to be reabsorbed, and additional egg production is difficult (Maxson 1977). Bump et al. (1947) reported that the average clutch size in New York was much lower on re-nesting attempts, averaging 7.5 eggs. In Michigan, the average second nest clutch size was 7.3 (Larson 1998). The one instance of abandonment and re-nest in my study resulted in a clutch of 10 eggs.

I found average clutch sizes for first nest attempts were similar across sites, years, and age classes. Although somewhat lower, my range of clutch sizes is within that of other reported values. Porath and Vohs (1972) and Maxson (1978) found nests with clutch sizes of up to 13 in Iowa and Minnesota, respectively. Bump et al. (1947) noted that clutch sizes range from 9-14 eggs in New York. Larson (1998) reported an average clutch size of 12.7 for first nests in Michigan, and Haulton (1999) found an average clutch size of 9.5, however, these were pooled over the central Appalachian region. Average clutch size for ruffed grouse may be slightly lower in West Virginia and the central Appalachian region, but may be influenced by partial depredation events as reported above. It has also been reported that younger hens had smaller clutch sizes (Bump et al. 1947). My findings, as well as others (Maxson 1978, Larson 1998) do not support this.

Hatching success typically is high in ruffed grouse, usually >90% (Bump et al. 1947 and Rusch and Keith 1971). Hatching success of successful nests in this study was consistent over the 2 years, and comparable to other portions of the grouse range. Larson (1998) reported a first nest hatching success of 95.9%, and a second nest hatching success of 83.3% in Michigan. Bump et al. (1947) suggested that lower second-nest success may result from increased egg infertility.

Grouse hatch dates often depend on the geographical location and prevailing weather conditions (Johnsgard et al. 1989). My findings indicate that West Virginia falls within the range of dates reported for ruffed grouse in all parts of its range. Peak hatch occurred during the last week of May for both years on each site. There was a difference in hatch dates on the WERF between 1998 and 1999, however, and this may represent misclassification of re-nest attempts in 1998. Haulton (1999) also found that peak hatch for ruffed grouse occurred in the last week of May, and reported no differences among sites in the central Appalachians. In Wisconsin, Kubisiak (1978) found that hatching began in the last week of May and continued through July, but that over 74% of the eggs were hatched before 15 June. In Michigan, Larson (1998) found a mean hatch date of 10 June, with approximately 40% of the nests hatching before then. Later hatch dates may result from unseasonable cold, or represent the inclusion of re-nest attempts in first-nest reports.

MANAGEMENT IMPLICATIONS

Depredation may play a key role in limiting ruffed grouse productivity in West Virginia. In the past, potential nest predators such as raccoon, red and gray fox, and bobcat were trapped for their pelts or regularly dog hunted. Along with trapping these “target” species, non-target species such as opossum and skunk were also removed. Fur prices plummeted in the late 1980’s and disinterest in trapping followed (Peoples et al. 1995). This disinterest continues today, with continued furbearer harvest declines (Jim Evans, West Virginia Division of Natural Resources, pers. comm.). Such trends may result in increasing populations of nest predators in many areas of the state.

Changes in forest management practices across West Virginia, which have increased forest fragmentation and edge, may have enhanced predatory efficiency of meso-mammals as well (Heske 1995, Marini et al. 1995). Either an increase in the number of potential predators or their efficiency could have negative impacts on ruffed grouse nesting success.

Increases in predator densities may be represented by higher nest depredation rates, and ground nesting species such as ruffed grouse may be experiencing similar problems as ducks in the Prairie Pothole region. It has been hypothesized that the decline in duck nest success was a result, in part, to increased depredation (Beauchamp et al. 1996a, 1996b). Although Beauchamp et al. (1996b) found that nest success increased when predators were excluded from nesting areas, there was no conclusive evidence that nest depredation by mammalian predators was the cause of long-term decline in duck nest success. Some studies have found positive relationships with predator removal and nesting success and have recommended its use (Balser et al. 1968, Trautman et. al 1974, Duebbert and Lokemon 1980, Livezey 1981, Sargeant and Arnold 1984, Greenwood 1986), while others suggested that predator removal or control was ineffectual, inefficient, and expensive (Chesness et al. 1968, Rusch and Keith 1971). With the varying results, application of predator control on a site-specific basis, with concurrent management and maintenance of nesting habitat may have the most beneficial results (Duebbert and Kantrud 1974).

Increased trapping effort and localized, intensive predator management may compensate for any declines noted in nesting success, but fur prices have still not returned to earlier levels (and may not). Although public support exists for predator management (Messmer et al. 1999), this may not be the most feasible or cost-effective strategy. It may be more cost effective to focus on improving habitat (e.g., breeding, nesting, foraging) for grouse instead of implementing predator control programs. Moreover, concurrent habitat management practices such as creating feathered edges could deter predators from using certain areas (Gates and Geysel 1978, Yahner and Wright 1985, Yahner et al. 1989, Pedlar et al. 1997).

Table 1-1. Within-site comparison of the proportion (*p*) of adult and juvenile ruffed grouse hens that attempted to nest on the Westvaco Ecosystem Research Forest (WERF) in Randolph County, West Virginia and the Westvaco Dutch RunTract (DRT) in Greenbrier County, West Virginia, 1998-99.

	WERF					DRT				
	Adult		Juvenile			Adult		Juvenile		
Year	*n*	*p*	*n*	*p*	P^a	*n*	*p*	*n*	*p*	*P*
1998	7	1.00	3	0.67	0.300	4	1.00	3	1.00	
1999	10	1.00	3	1.00		10	1.00	1	1.00	
Years combined	17	1.00	6	0.83	0.261	14	1.00	4	1.00	

[a] Fisher's Exact Test

Table 1-2. Between-site comparison of the proportion (*p*) of ruffed grouse hens (age classes pooled) that attempted to nest on the Westvaco Ecosystem Research Forest (WERF) in Randolph County, West Virginia and the Westvaco Dutch Run Tract in Greenbrier County, West Virginia, 1998-99.

	WERF		DRT		
Year	*n*	*p*	*n*	*p*	P^a
1998	10	0.90	7	1.00	1.000
1999	13	1.00	11	1.00	
Years combined	23	0.96	18	1.00	1.000

[a] Fisher's Exact Test

Table 1-3. Between-year comparison of the proportion (*p*) of ruffed grouse hens (age classes pooled) that attempted to nest on the Westvaco Ecosystem Research Forest (WERF) in Randolph County, West Virginia and the Westvaco Dutch Run Tract (DRT) in Greenbrier County, West Virginia, 1998-99.

	1998		1999		
Site	*n*	*p*	*n*	*p*	P^a
WERF	10	0.90	13	1.00	0.435
DRT	7	1.00	11	1.00	
Sites combined	17	0.94	24	1.00	0.415

[a] Fisher's Exact Test

Table 1-4. Within-site comparison of the proportion (*p*) of adult and juvenile ruffed grouse hens successful in hatching $\geq$1 chick on the Westvaco Ecosystem Research Forest (WERF) in Randolph County, West Virginia and the Westvaco Dutch Run Tract (DRT) in Greenbrier County, West Virginia, 1998-99.

	WERF					DRT				
	Adult		Juvenile			Adult		Juvenile		
Year	*n*	*p*	*n*	*p*	*P*[a]	*n*	*p*	*n*	*p*	*P*
1998	7	0.71	2	1.00	1.000	4	0.75	3	0.67	1.000
1999	10	0.90	3	0.33	0.108	10	0.60	1	0.00	0.455
Years combined	17	0.82	5	0.60	0.548	14	0.64	4	0.50	1.000

[a] Fisher's Exact Test

Table 1-5. Between-site comparison of the proportion (*p*) of ruffed grouse hens (age classes pooled) successful in hatching $\geq$1 chick on the Westvaco Ecosystem Research Forest (WERF) in Randolph County, West Virginia and the Westvaco Dutch Run Tract (DRT) in Greenbrier County, West Virginia, 1998-99.

	WERF		DRT		
Year	*n*	*p*	*n*	*p*	P^a
1998	9	0.78	7	0.71	1.000
1999	13	0.77	11	0.55	0.390
Years combined	22	0.77	18	0.61	0.315

[a] Fisher's Exact Test

Table 1-6. Between-year comparison of the proportion (*p*) of ruffed grouse hens (age classes pooled) successful in hatching $\geq$1chick on the Westvaco Ecosystem Research Forest (WERF) in Randolph County, West Virginia and the Westvaco Dutch Run Tract (DRT) in Greenbrier County, West Virginia, 1998-99.

	1998		1999		
Site	*n*	*p*	*n*	*p*	P^a
WERF	9	0.78	13	0.77	1.000
DRT	7	0.71	11	0.55	0.637
Sites combined	16	0.75	24	0.67	0.729

[a] Fisher's Exact Test

Table 1-7. Within-site comparison of average clutch size ($\bar{x}$) for adult and juvenile ruffed grouse hens on the Westvaco Ecosystem Research Forest (WERF) in Randolph County, West Virginia and the Westvaco Dutch Run Tract (DRT) in Greenbrier County, West Virginia, 1998-99.

	WERF							DRT						
	Adult			Juvenile				Adult			Juvenile			
Year	$\bar{x}$	SE	*n*	$\bar{x}$	SE	*n*	*P*[a]	$\bar{x}$	SE	*n*	$\bar{x}$	SE	*n*	*P*
1998	10.8	0.37	5	10.0	1.00	2	0.374	9.5	0.50	2	11.5	0.50	2	0.106
1999	11.0	0.33	10	9.0	0.00	1	0.104	10.5	0.85	8	10.0	0.00	1	0.849
Years combined	10.9	0.25	15	9.7	0.67	3	0.060	10.3	0.68	10	11.0	0.58	3	0.606

[a] Two-sample *t*-test

Table 1-8. Between-site comparison of average ($\bar{x}$) clutch size for ruffed grouse hens (age classes pooled) on the Westvaco Ecosystem Research Forest (WERF) in Randolph County, West Virginia and the Westvaco Dutch Run Tract (DRT) in Greenbrier County, West Virginia, 1998-99.

	WERF			DRT			
Year	$\bar{x}$	SE	n	$\bar{x}$	SE	n	P^a
1998	10.6	0.37	7	10.5	0.65	4	0.919
1999	10.8	0.35	11	10.4	0.75	9	0.637
Years combined	10.7	0.25	18	10.5	0.54	13	0.636

[a] Two-sample *t*-test

Table 1-9. Between-year comparison of average clutch size ($\bar{x}$) for ruffed grouse hens (age classes pooled) on the Westvaco Ecosystem Research Forest (WERF) in Randolph county, West Virginia and the Westvaco Dutch Run Tract (DRT) in Greenbrier County, West Virginia, 1998-99.

	1998			1999			
Site	$\bar{x}$	SE	n	$\bar{x}$	SE	n	P[a]
WERF	10.6	0.37	7	10.8	0.35	11	0.649
DRT	10.5	0.65	4	10.4	0.75	9	0.964
Sites pooled	10.5	0.31	11	10.7	0.38	20	0.854

[a] Two-sample *t*-test

Table 1-10. Within-site comparison of the proportion (*p*) of eggs hatched in successful first nest attempts for adult and juvenile ruffed grouse on the Westvaco Ecosystem Research Forest (WERF) in Randolph County, West Virginia and the Westvaco Dutch Run Tract (DRT) in Greenbrier County, West Virginia, 1998-99.

	WERF					DRT				
	Adult		Juvenile			Adult		Juvenile		
Year	*n*	*p*	*n*	*p*	*P*[a]	*n*	*p*	*n*	*p*	P
1998	54	0.96	20	1.00	1.000	10	1.00	12	1.00	
1999[b]	98	0.99				55	0.95			

[a] Fisher's Exact Test

[b] Analysis not performed because only adult hens were successful in first nest attempts

Table 1-11. Between-site comparison of the proportion (*p*) of eggs hatched in successful first nest attempts for ruffed grouse hens on the Westvaco Ecosystem Research Forest (WERF) in Randolph County, West Virginia and the Westvaco Dutch Run Tract (DRT) in Greenbrier County, West Virginia, 1998-99.

	WERF		DRT		
Year	*n*	*p*	*n*	*p*	P^a
1998[b]	74	0.97	22	1.00	1.000
1999[c]	98	0.99	55	0.95	0.133
Years combined	172	0.98	77	0.96	0.377

[a] Fisher’s Exact Test

[b] Adult and juvenile hens

[c] Adult hens only

Table 1-12. Within-site comparison of average hatch dates ($\bar{x}$) of first nests for adult and juvenile ruffed grouse hens on the Westvaco Ecosystem Research Forest (WERF) in Randolph County, West Virginia and the Westvaco Dutch Run Tract (DRT) in Greenbrier County,West Virginia, 1998-99.

	WERF							DRT						
	Adult			Juvenile				Adult			Juvenile			
Year	$\bar{x}^a$	SE	*n*	$\bar{x}$	SE	*n*	P^b	$\bar{x}$	SE	*n*	$\bar{x}$	SE	*n*	*P*
1998	24.6	1.63	5	24.0	2.00	2	0.846	23.5	0.50	2	22.5	5.50	2	0.873
1999[c]	21.8	0.55	9					23.5	1.15	6				

[a] Day in May

[b] Two-sample *t*-test

[c] Analysis not performed because only adult hens were successful in first nests

Table 1-13. Between-site comparison of average hatch dates ($\bar{x}$) of first nests for ruffed grouse hens (age classes pooled) on the Westvaco Ecosystem Research Forest (WERF) in Randolph County, West Virginia and the Westvaco Dutch Run Tract (DRT) in Greenbrier County, West Virginia, 1998-99.

	WERF			DRT			
Year	$\bar{x}$[a]	SE	*n*	$\bar{x}$	SE	*n*	*P*[b]
1998	24.4	1.21	7	23.0	2.27	4	0.554
1999[c]	21.8	0.55	9	23.5	1.15	6	0.156
Years combined	22.9	0.68	16	23.3	1.07	10	0.765

[a] Day in May

[b] Two-sample *t*-test

[c] Only adult hens represented

Table 1-14. Between-year comparison of average hatch dates ($\bar{x}$) for ruffed grouse hens (age classes pooled) on the Westvaco Ecosystem Research Forest (WERF) in Randolph County, West Virginia and the Westvaco Dutch Run Tract in Greenbrier County, West Virginia in 1998 and 1999.

	1998			1999[a]			
Site	$\bar{x}$[b]	SE	*n*	$\bar{x}$	SE	*n*	*P*[c]
WERF	24.4	1.21	7	21.8	0.55	9	0.049
DRT	23.0	2.27	6	23.5	1.15	4	0.833
Sites combined	23.9	1.08	11	22.5	0.58	15	0.221

[a] Only adult hens represented

[b] Day in May

[c] Two-sample *t*-test

CHAPTER 2-DEVELOPING A TRANSMITTER ATTACHMENT METHOD FOR RUFFED GROUSE CHICKS IN WEST VIRGINIA

INTRODUCTION

Radio telemetry can provide information on animal movements, habitat use, and survival (Burger et al. 1991, Bunck et al. 1995). Godfrey (1975), Maxson (1977, 1978), Small et al. (1991) have used radio telemetry techniques to examine these parameters in ruffed grouse (*Bonasa umbellus*). These authors typically have focused on juvenile and adult ecology, however, and examined ruffed grouse chick ecology only cursorily. Investigations of ruffed grouse chick mortality have been lacking.

Rusch et al. (1984) suggested that significant mortality in ruffed grouse occurs within the first few weeks of life, but the factors influencing chick survival have not been well investigated. Although survival estimates and mortality causes of adult ruffed grouse can be obtained via radio telemetry, transmitter size and attachment constraints for chicks have limited the examination of these parameters in broods. Transmitter miniaturization has presented the opportunity for obtaining these parameters (Hubbard et al. 1999). Although radio-telemetry research has been performed on wild turkey (*Meleagris gallopavo*) and ring-necked pheasant (*Phasianus colchicus*) chicks (Speake et al. 1985, Hubbard et al. 1998, 1999), few studies have been conducted on ruffed grouse chicks. Recent work on ruffed grouse chicks in Michigan (Larson 1998), involved removing chicks from the point of capture and taking them out of the field to attach or implant the transmitters. These procedures are time extensive, as well as, highly invasive. Additionally, Larson’s (1998) research typically involved waiting 6-10 days post hatch to attach the transmitters. If the first 2 weeks of life represents a critical chick survival period, waiting 6-10 days significantly limits the information that can be obtained. Consequently, I wanted to develop a field use radio transmitter attachment method for <3-day-old chicks to gain pertinent survivorship and mortality information.

STUDY AREAS

My study was conducted on the Westvaco Wildlife and Ecosystem Research Forest (WERF) located in the Allegheny Mountain Physiographic Province (Fenneman 1938) in Randolph County, West Virginia, and the Westvaco Dutch Run Tract (DRT) located in the Ridge and Valley Physiographic Province (Fenneman 1938) in Greenbrier County, West Virginia.

The WERF is a 3,413 ha area established by Westvaco Corporation in 1994 to use in studying industrial forestry impacts on ecosystems and their processes. Forest management is ongoing, and the oldest forests are second-growth forest stands established after logging events at the turn of the century (Tilghman 1989, Clarkston 1993). The area is managed on a 60-70 year harvest rotation, and harvest methods include diameter-limit, clearcutting, and 2-aged regeneration harvests. Elevations range from 740 to 1200 m. Topography is rugged, with plateau-like ridgetops atop steep slopes and narrow valleys (Fenneman 1938, Ford and Rodrigue 2000)

The WERF is characterized by a cool, moist climate, and average annual precipitation exceeding 198 cm (http://www.nndc.noaa.gov), and contains 3 primary Society of American Foresters (SAF) hardwood forest types (Eyre 1980) typical of the Allegheny Mountains of West Virginia, as well as small areas of non-forested land.

The DRT is a 2,036 ha area is managed strictly for fiber production through clearcutting practices. The area is managed on an even-aged rotation length of 40-70 years, and has a lower site quality, lower site index, and lower average annual precipitation (107 cm; http://www.nndc.noaa.gov) than the WERF. Elevations range from 520 to 1100 m, and the topography is extremely steep and rugged, with ephemeral seeps and streams running throughout.

METHODS

Trapping and Monitoring Females

Female ruffed grouse trapping began in the fall of 1997 and continued until ≥10 hens were captured on both sites. Trapping resumed in the early spring to replace hens lost to mortality and radio-failures from the previous year and continued until the second week of April. Grouse were captured using modified lily-pad traps (Gullion 1965). Ten- to 16-m leads consisting of 46-cm tall poultry wire were used to guide grouse into the funnel and body of the lily-pad trap. There was one trap body at each end of the wire lead (Allen 1996). Once captured, birds were weighed, aged based on feather molt and wear (after Kalla and Dimmick 1995), and leg banded with an aluminum identification tag (# 12, butt-end tags, National Band and Tag, Newport, KY). Each hen was equipped with a necklace-type radio transmitter (Advanced Telemetry Systems, Isanti, MN). Transmitters weighed 10-11 g, had a 2 year life expectancy, operated on the 150-152 mHz frequency range, and were equipped with a mortality sensor.

Transmittered hens were monitored twice weekly in 1998 using a 2-element yagi antennae and portable receiver (Wildlife Materials, Carbondale, IL, and Advanced Telemetry Systems, Isanti, MN). Starting 1 March 1999, hens were monitored 3 times weekly to accurately document nest initiation. I obtained a minimum of 3 azimuths from permanently located Global Positioning System (GPS) stations, and determined locations via triangulation (Mech 1983). I recorded and plotted all locations by hand on topographic maps of the area. As the breeding season progressed, I used these telemetry azimuths to aid in locating nests.

Johnsgard (1983) found that the female's time on the nest increased proportionately to clutch size. Similarly, Maxson (1977, 1978) noted a marked decrease in both activity and movement once hens started nesting, laying eggs, and incubating. These behaviors helped to determine the onset of egg laying and incubation. Once observed, I used telemetry to "home in" and locate nests (Mech 1983).

In 1999, I placed infared cameras (Fuhrman Industries, Seabrook, TX) on 10 nests on the WERF to further aid in the determination of the onset of incubation. The onset of incubation was defined as the first instance where the female remained on her nest the entire day. This was then used to predict hatch dates. On nests without cameras, I obtained an egg count during egg laying and during the incubation period. This information was used to predict hatch dates by backdating to when the last egg was laid. I was able to use camera footage to determine exact hatch dates and times for 3 of the 10 nests that had cameras. These were nests where cameras were maintained throughout incubation. The remaining 7 cameras had to be removed to be used for another project prior to hatching. Hatching dates were determined on these, as well as, the remaining 3 nests without cameras by visually monitoring towards the end of incubation.

Capturing and Radio-marking Chicks

In 1998, I randomly selected broods from collared hens to equip with radio transmitters (Holohil Systems Ltd., Ontario, Canada). I located broods within 24 hr post-hatch by homing in on the female's telemetry signal (Mech 1983). As many of the brood members were caught as possible, and each chick was weighed to the nearest 0.1 g.

Chicks were then randomly selected, from the total captured, to receive transmitters. Transmitters weighed 0.54 g, were approximately 4-5 % of the body weight at time of attachment, and had a 3 week battery life. Transmitters were attached between the scapulas (modified after Johnson et al. 1991; Fig. 2-1) using Skin Bond (Pfizer Hospital Products, Largo, FL).

In 1999, the attachment procedures were similar to 1998 with the following modifications. I located the broods within 48-72 hr post-hatch. Transmitters weighed approximately 0.98 g, were approximately 7-8 % of the body weight at time of attachment, and had a 5 week battery life. Transmitters were attached using a modified necklace method (Fig. 2-2). Necklace loops were 26 mm in circumference (later changed to 32 mm), and made of polyethylene tubing used in arterial surgery (I. D. 0.86mm, O. D. 1.27mm, Intramedic® Clay Adams Brand®, Sparks, MD). Monofilament fishing line (6 lb test; 2.7 kg test) was used to secure the necklace, and all knots were secured with a glue formulated especially for monofilament (Anglin' Glue™, Clemence Inc., Alpharetta, GA).

For both years, field handling time did not exceed 10-15 min after members of the brood were captured. After chicks were equipped with the transmitters, I released chicks captured (radioed and non-radioed) at the capture site, and left the area to allow the hen to quickly gather her brood. Numbers of transmittered chicks per brood ranged from 2-5, depending on chick numbers caught and brood size at time of capture.

Monitoring hens and broods

I monitored female grouse and their radio-equipped broods one or more times per day. Brood locations were determined through triangulation of the hen's telemetry signal. I approached the hen (usually to within 150 m) and took azimuths on each chick. Any instance where one or more of the chicks was not in close proximity to the hen was investigated. All efforts were made to retrieve the lost chick(s), transmitter(s), or both. All aspects of the recovery were noted (e.g. characteristics of the site, type of scat found if applicable, feathers found, transmitter found and no body). All remains were examined for cause of death, and necropsies were performed if the immediate cause of death (e.g. tooth, talon, claw marks, abrasions, hematomas) could not be determined.

Recapturing Chicks

In 1998, my initial protocol was to recapture chicks at 2 weeks of age to replace original transmitters with larger, longer life units. These units weighed approximately 0.85 g and had a 5 week battery life. Efforts were made using mist nets and hand nets to recapture chicks. However, because all transmitters had fallen off by this point it was very difficult to find the chicks, and these efforts were abandoned.

In 1999, my protocol was modified. I recaptured chicks at 2 weeks of age and increased the necklace circumference to 46 mm to allow for growth. I recaptured chicks at 5 weeks, as well, to remove the collars. Because chicks retained their collars, I was able to find chicks using the telemetry signal (similar to “homing in” on nest sites). Once flushed, chicks usually flew only short distances (even up to 5 weeks of age) and hid. Once hidden, the chicks tended not to move. It was then simple to capture the chicks by hand without harm.

RESULTS

In 1998, 9 broods (5 at the WERF, 4 at the DRT), with 45 chicks were captured within 24-48 hr of hatching. I equipped 34 of the 45 chicks (21 at the WERF, 13 at the

DRT) with glue-on transmitters. Average (± SE) retention time for transmitters was estimated to be 5.7 ± 0.69 days ($n = 15$). Twelve (80%) of 15 transmitters fell off at ≤7 days (Table A-1). Transmitter retention ranged from 2 to 12 days. These estimates were based on transmitters recovered at the WERF that had no evidence of predation and/or scavenging. Attachment failure was confirmed when I re-captured brood members that had areas of visible skin between the scapulas where the transmitters had been attached.

In 1999, I captured 55 chicks from 10 broods (6 at the WERF, 4 at the DRT) within 72 hr post-hatch. I equipped 35 of the 55 chicks with transmitters (20 at the WERF, 15 at the DRT). All radio-collared chicks retained their transmitters until death or throughout the sampling period.

DISCUSSION

Transmitter Retention and Effect

I found the glue-on attachment method ineffective for monitoring ruffed grouse chicks, as both average and maximum retention time was poor (e.g., 6 ± 2.1 and 12 days, respectively). I hypothesize that because chicks had undeveloped feathers and retain their down until they are able to thermoregulate (approximately 2 weeks), the glue had no permanent structure other than the skin on which to adhere. Perry and Carpenter (1981) found that when adhesives were attached directly to the skin on the back of captive mourning doves (*Zenaida macroura*), retention time was <5 days. However, when transmitters were glued to the feathers and skin, retention time varied from 21 days to 9 months. Glue-on techniques have been successful on adult passerines where full feather development has occurred, and average retention times were much greater than our 6-day average. Johnson et al. (1991) found that after 7 days, 19% of adult northern cardinals

(*Cardinalis cardinalis*), and over 60% of adult blue jays (*Cyanocitta cristata*), American robins (*Turdus migratorius*), and brown thrashers (*Toxostoma rufum*) retained functional glue-on transmitters. They attributed transmitter losses to animals physically removing them through preening and environmental conditions weakening glue bonds. Wheeler (1991) found that a combination glue and suture method worked well for day-old ducklings, with retention times of 31-78 days. I did not attempt a glue and suture combination. The skin on the back of <3-day-old ruffed grouse chicks was too thin to retain the suture without pulling out. Larson (1998), however, successfully used the glue and suture combination on >6-day-old chicks, though retention time was not reported.

Development of the necklace-type transmitter described here required the refinement of the necklace loop attachment. The rapid growth of ruffed grouse chicks made it difficult to predict what circumference to initially make the necklace loop, as well as what size to enlarge it to at 2 weeks of age. The collar must be tight enough to prevent the chick from getting its beak or feet caught, but must also allow for the passage of food items. Several chicks died after snails they had ingested became lodged in their crop, unable to pass below the collar. I soon rectified this problem by altering the necklace loop size.

Implantable transmitters represent an alternative to external transmitters and have been used with success in day-old ducklings, ring-necked pheasant chicks, and wild turkey poults (Korschgen et al. 1996, Hubbard et al. 1998, Riley et al. 1998). However, problems with this method have been reported in such species as wild turkeys and mourning doves. Hubbard et al. (1998) reported that survival in turkey poults that had implanted transmitters was lower than the control group. They also reported that the anesthesia used during surgery may inhibit motor function upon release. Perry and Carpenter (1981) and Schulz et al. (1998) also reported surgical and behavioral problems with this method in mourning doves. Larson (1998) found survival rates to be lower in ruffed grouse chicks with implanted transmitters (13%) compared to those with the glue-suture attachment (42%). Moreover, the smallest implantable transmitter available with a minimum battery life of >2 weeks weighs ≥1.5 g. This mass would not be an issue for species such as ducks, pheasants, and turkeys, which are 2 or 3 times as large as ruffed grouse chicks at hatch. However, a 1.5 g transmitter would be too heavy for ruffed grouse chicks.

Typically the transmitter mass:body mass ratio “rule of thumb” has been 5%. This has often been associated with birds that have the stress of flight (Caccamise and Hedin 1985, Brigham 1989). The transmitters I placed on 2-3-day-old chicks were approximately 7-8% of their body mass. However, ruffed grouse chicks do not fly until 4-5 days old, and then may fly only short distances. They are physically unable to fly longer distances until their flight feathers have developed. By this time the growth rate of the chicks has quickly decreased the transmitter mass:body mass ratio (Speake et al. 1985). Mauser and Jarvis (1991), Mauser et al. (1994), and Davis et al. (1999) found no effect on survival in ducklings when using transmitters weighing 5-7% of the body mass. Speake et al. (1985) placed transmitter packages on turkey poults weighing approximately 6 % of the body mass, with no impact on survival. To further alleviate any concerns of transmitter mass on survival, I recommend using the smaller 0.54 g radio transmitter for the first 2 weeks, and the 0.98 g transmitter thereafter. Although radio telemetry is the most reliable method for determining timing and extent of mortality and survival (Korschgen et al. 1996) it is important to ensure that transmitters have minimal effects on movements and survival.

Obtaining survival and mortality measures on ruffed grouse chicks has been almost impossible in the past, however, with advances in technology this type of information can now be gathered. Because of its field application, retention time, and minimal effect on chick behavior, the necklace-type transmitter described here may be superior to other available methods.

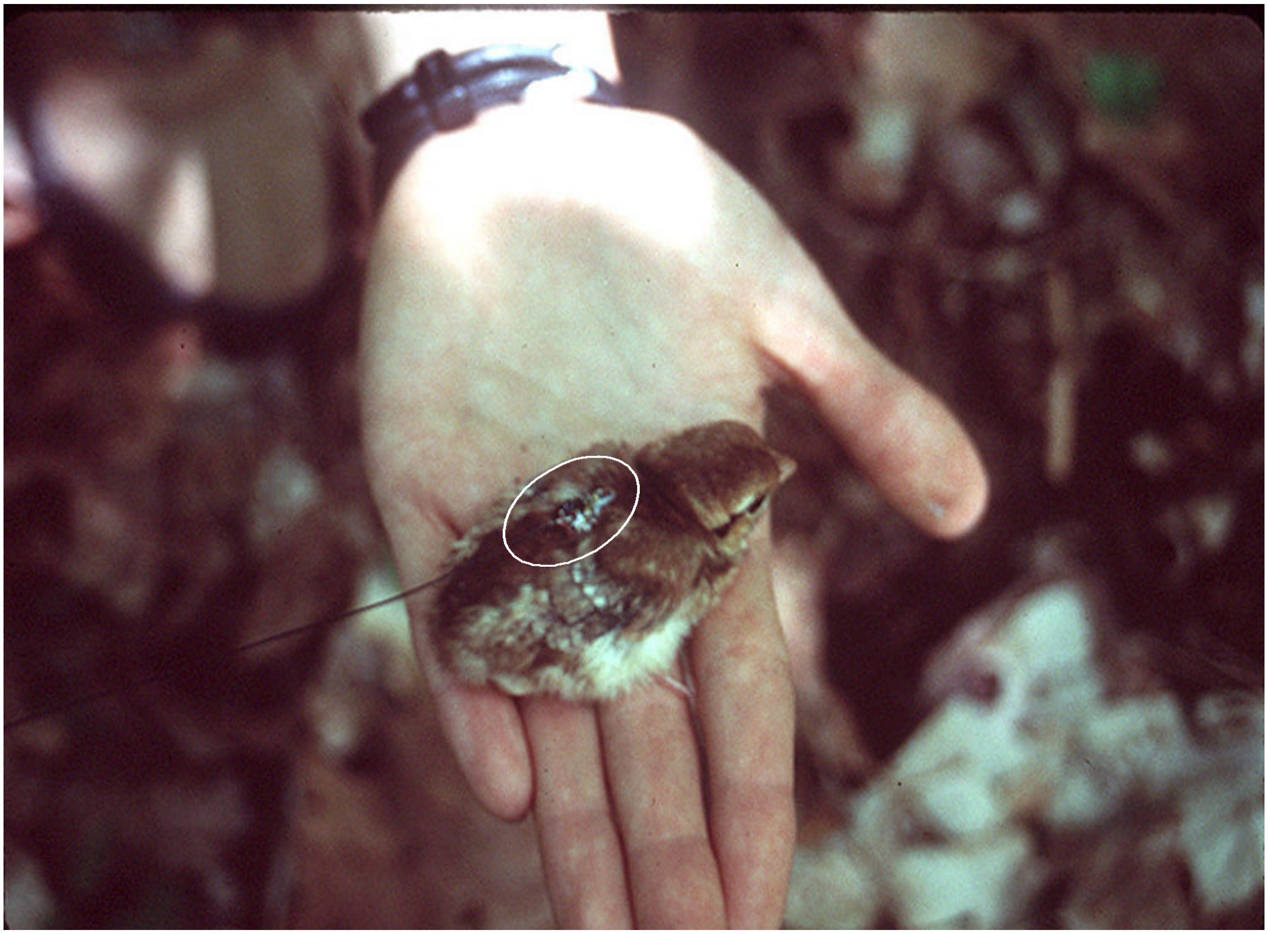

Fig. 2-1. Ruffed grouse chick with glue-on radio transmitter attachment method implemented on the Westvaco Ecosystem Research Forest (WERF) in Randolph County, West Virginia and the Westvaco Dutch Run Tract (DRT) in Greenbrier County, West Virginia in 1998.

Fig. 2-2. Ruffed grouse chick with radio collar transmitter attachment method implemented on the Westvaco Ecosystem Research Forest (WERF) in Randolph County, West Virginia and the Westvaco Dutch Run Tract (DRT) in Greenbrier County, West Virginia in 1999.

CHAPTER 3- FACTORS INFLUENCING CHICK SURVIVAL

INTRODUCTION

Studies of ruffed grouse survivorship have focused on juveniles and adults (Bump et al. 1947, Gullion 1970, Rusch and Keith 1971, Small et al. 1991), and only cursorily examined chick survivorship. Rusch et al. (1984) suggested that significant mortality in ruffed grouse occurs within the first few weeks of life, but factors influencing chick survival have not been well documented. Many authors have suggested that insect abundance and availability is important to gallinaceous chick survival (Southwood and Cross 1969, Nenno and Lindzey 1979, Warner 1984, Johnson and Boyce 1990). Kimmel and Samuel (1978, 1984) found that insects comprised >95% of the diet of ruffed grouse chicks examined, and suggested that arthropod abundance was more important than previously thought.

Ruffed grouse chick survival may also be influenced through the synergistic effect of multiple factors. Southwood and Cross (1969) suggested insect abundance was related to prevailing weather conditions, as inclement weather decreased both insect abundance and search time for food. Bump et al. (1947) concluded that cold, rainy weather adversely affected survival of chicks both directly and indirectly. Extended periods of cold weather may lead to exposure mortality, and may negatively affect arthropod abundance. Larsen and Lahey (1958) concluded that high daily maximum temperatures in late spring and early summer were important during the first few weeks of life as the chick’s ability to thermoregulate and withstand excessive cold is minimal. High maximum temperatures may also enhance insect abundance. Hollifield and Dimmick (1995) suggested grouse survival in Tennessee was impacted by both brood habitat and arthropod availability. Nenno and Lindzey (1979) concluded that a combination of inclement weather conditions and poor brood habitat was responsible for decreased survivorship in turkeys in Pennsylvania.

Predation has long been considered a major cause of mortality in adult ruffed grouse, and may also be an important factor for chicks. Rusch and Keith (1971) found that predation by great horned owls (Bubo virginianus), lynx (Lynx canadensis), and goshawks (Accipiter gentilis) accounted for >50% of brood loss in Alberta, Canada. However, entire brood loss was uncommon, and chick mortality was independent of brood size. Small et al. (1991) reported that avian predation was the greatest cause of juvenile (birds entering their first breeding season) mortality in ruffed grouse in Wisconsin. However, Southwood and Cross (1969) reported that predators and disease appeared to account for only a small proportion of the mortality in juvenile partridge (*Perdix perdix*) in Hampshire, England.

Maxson (1977) suggested hen brooding tendencies were important during the first few days post-hatch, when chicks are least able to thermoregulate. If the hen does not brood her chicks during the early morning hours or in inclement weather, chicks could be exposed to wetting and chilling. Maxson (1977) also suggested juvenile hens were less efficient incubators, that in turn may mean they are less efficient brooders.

Consequently, my objective was to determine cause specific mortality in ruffed grouse broods in West Virginia within the first few weeks of life and to assess which factors may be influencing mortality and survival.

STUDY AREAS

My study was conducted on the Westvaco Wildlife and Ecosystem Research Forest (WERF) located in the Allegheny Mountain Physiographic Province (Fenneman 1938) in Randolph County, West Virginia, and the Westvaco Dutch Run Tract (DRT) located in the Ridge and Valley Physiographic Province (Fenneman 1938) in Greenbrier County, West Virginia.

The WERF is a 3,413 ha area established by Westvaco Corporation in 1994 to study industrial forestry impacts on ecosystems and ecological processes. Forest management is ongoing, and the oldest forests are second-growth forest stands established after turn of the century logging (Tilghman 1989, Clarkston 1993). The area is managed on a 60-70-year harvest rotation. Harvest methods include diameter-limit, clearcutting, and 2-aged regeneration harvests. Elevations range from 740 to 1200 m, and topography is characterized by plateau-like ridgetops with steep slopes and narrow valleys (Fenneman 1938, Ford and Rodrigue 2000).

The WERF is characterized by a cool, moist climate, and average annual rainfall exceeding 198 cm (http://www.nndc.noaa.gov), and contains 3 primary Society of American Foresters (SAF) hardwood forest types (Eyre 1980) typical of the Allegheny Mountain Province of West Virginia, as well as small areas of non-forested land. Sugar maple (*Acer saccharum*), American beech (*Fagus grandifolia*), yellow birch (*Betula allegheniensis*), and black cherry (*Prunus serotina*) comprise the Allegheny hardwood-northern-hardwood type. These stands are typically found on well-drained soils and cover approximately 90% of the site (3,056 ha or 7,548 acres). The second forest type is a mixed mesophytic association of yellow-poplar (*Liriodendron tulipifera*), American basswood (*Tilia americana*), northern red oak (*Quercus rubra*), and white oak (*Q. alba*) or Cove-hardwoods. These associations are typically found at lower elevations and make up about 6% of the hardwood forest cover (195 ha or 483 acres). The remaining hardwood forest cover (21 ha or 53 acres) is classified as the xeric mixed oak type. These stands are found along ridgelines and southwest facing slopes. Primary conifer cover consists of high elevation spruce (*Picea* spp)- hemlock (*Tsuga canadensis*) associations along with patches of riparian hemlock found in sheltered stream drainages. Rhododendron (*Rhododendron maximum*) communities exist throughout upland areas on the site as well (Ford and Rodrigue 2000).

The DRT is a 2,036 ha area is managed strictly for fiber production. The area is managed on an even-aged rotation length of 40-70 years, and has a lower site quality and site index than the WERF. Elevations range from 520 to 1100 m, and the topography is extremely steep and rugged, with ephemeral seeps and streams running throughout. Soils derived mainly from shale parent materials typical of this portion of the Ridge and Valley region give this area the aforementioned low site quality attributes. This well drained soil, combined with a lower annual average rainfall of approximately 107 cm (http://www.nndc.noaa.gov) resulting from a rain shadow from the Allegheny mountains immediately to the west, results in a more xeric climate (Hicks 1998).

Approximately 94% (1,914 ha) of this area is dominated by SAF designated oak-hickory associations typical of the Ridge and Valley Physiographic Province. The remaining 6% consists of cove hardwoods (yellow-poplar and oak mixture - 4%) and pine (*Pinus* spp) stands - 2%. Both sites have well maintained road systems.

METHODS

Trapping and Monitoring Females

Female ruffed grouse trapping began in the fall of 1997 and continued until ≥10 hens were captured on both sites. Trapping resumed in the early spring to replace hens lost to mortality and radio-failures from the previous year and continued until the second week of April. Grouse were captured using modified lily-pad traps (Gullion 1965). Ten- to 16-m leads consisting of 46-cm tall poultry wire were used to guide grouse into the funnel and body of the lily-pad trap. There was one trap body at each end of the wire lead (Allen 1996). Once captured, birds were weighed, aged based on feather molt and wear (after Kalla and Dimmick 1995), and leg banded with an aluminum identification tag (# 12, butt-end tags, National Band and Tag, Newport, KY). Each hen was equipped with a necklace-type radio transmitter (Advanced Telemetry Systems, Isanti, MN). Transmitters weighed 10-11 g, had a 2 year life expectancy, operated on the 150-152 mHz frequency range, and were equipped with a mortality sensor.

Transmittered hens were monitored twice weekly in 1998 using a 2-element yagi antennae and portable receiver (Wildlife Materials, Carbondale, IL, and Advanced Telemetry Systems, Isanti, MN). Starting 1 March 1999, hens were monitored 3 times weekly to accurately document nest initiation. I obtained a minimum of 3 azimuths from permanently located Global Positioning System (GPS) stations, and determined locations via triangulation (Mech 1983). I recorded and plotted all locations by hand on topographic maps of the area. As the breeding season progressed, I used these telemetry azimuths to aid in locating nests.

Johnsgard (1983) found that the female’s time on the nest increased proportionately to clutch size. Similarly, Maxson (1977, 1978) noted a marked decrease in both activity and movement once hens started nesting, laying eggs, and incubating. These behaviors helped to determine the onset of egg laying and incubation. Once observed, I used telemetry to “home in” and locate nests (Mech 1983).

In 1999, I placed infrared cameras (Fuhrman Industries, Seabrook, TX) on 10 nests on the WERF. When possible, cameras were placed on nests when hens were absent. However, 6 of 10 hens were flushed to allow for camera placement. I only placed the actual camera lens and attachment arm near the nest. A cable ran from the camera lens to the video recording unit and power source 20 m away from the nest. Therefore, subsequent daily visits to the VCR unit of the camera to change tapes and batteries did not disturb the grouse.

I used camera footage to determine the onset of incubation. The onset of incubation was defined as the first instance where the female remained on her nest the entire day. This was then used to predict hatch dates. On nests without cameras, I obtained an egg count during egg laying and during the incubation period. This information was used to predict hatch dates by backdating to when the last egg was laid. I was able to use camera footage to determine exact hatch dates and times for 3 of the 10 nests that had cameras. These were nests that we were able to maintain cameras on throughout incubation. The remaining 7 cameras were removed prior to hatching for use on another project. Hatching dates were determined on these, as well as, the remaining 3 nests without cameras by visual inspection towards the end of incubation.

Capturing and Radio-marking Chicks

In 1998, I randomly selected broods from collared hens to equip with radio transmitters (Holohil Systems Ltd., Ontario, Canada). I located broods within 24 hr post-hatch by homing in on the female's telemetry signal (Mech 1983). As many of the brood members were caught as possible, and each chick was weighed to the nearest 0.1 g. Chicks were then randomly selected, from the total captured, to receive transmitters. Transmitters weighed 0.54 g, were approximately 4-5 % of the body weight at time of attachment, and had a 3 week battery life. Transmitters were attached between the scapulas (modified after Johnson et al. 1991; Fig. 2-1) using Skin Bond (Pfizer Hospital Products, Largo, FL).

In 1999, the attachment procedures were similar to 1998 with the following modifications. I located the broods within 48-72 hr post-hatch. Transmitters weighed approximately 0.98 g, were approximately 7-8 % of the body weight at time of attachment, and had a 5 week battery life. Transmitters were attached using a modified necklace method (Fig. 2-2). Necklace loops were 26 mm in circumference (later changed to 32 mm), and made of polyethylene tubing used in arterial surgery (I. D. 0.86mm, O. D. 1.27mm, Intramedic® Clay Adams Brand®, Sparks, MD). Monofilament fishing line (6 lb test; 2.7 kg test) was used to secure the necklace, and all knots were secured with a glue formulated especially for monofilament (Anglin' Glue^{TM}, Clemence Inc., Alpharetta, GA).

For both years, field handling time did not exceed 10-15 min after members of the brood were captured. After chicks were equipped with the transmitters, I released chicks captured (radioed and non-radioed) at the capture site, and left the area to allow the hen to quickly gather her brood. Numbers of transmittered chicks per brood ranged from 2-5, depending on chick numbers caught and brood size at time of capture.

Monitoring hens and broods

I monitored female grouse and their radio-equipped broods one or more times per day. Brood locations were determined through triangulation of the hen's telemetry signal. I approached the hen (usually to within 150 m) and took azimuths on each chick. Any instance where one or more of the chicks was not in close proximity to the hen was investigated. All efforts were made to retrieve the lost chick(s), transmitter(s), or both. All aspects of the recovery were noted (e.g. characteristics of the site, type of scat found if applicable, feathers found, transmitter found and no body). All remains were examined for cause of death, and necropsies were performed if the immediate cause of death (e.g. tooth, talon, claw marks, abrasions, hematomas) could not be determined.

Recapturing Chicks

In 1998, my initial protocol was to recapture chicks at 2 weeks of age to replace original transmitters with larger, longer life units. These units weighed approximately 0.85 g and had a 5 week battery life. Efforts were made using mist nets and hand nets to recapture chicks. However, because all transmitters had fallen off by this point it was very difficult to find the chicks, and these efforts were abandoned.

In 1999, my protocol was modified. I recaptured chicks at 2 weeks of age and increased the necklace circumference to 46 mm to allow for growth. I recaptured chicks at 5 weeks, as well, to remove the collars. Because chicks retained their collars, I was able to find chicks using the telemetry signal (similar to "homing in" on nest sites). Once flushed, chicks usually flew only short distances (even up to 5 weeks of age) and hid.

Once hidden, the chicks tended not to move. It was then simple to capture the chicks by hand without harm.

Arthropod Sampling

I sampled arthropods from the “zone of availability” to grouse (Stiven 1961). This is an area encompassing the ground, ground vegetation (e.g. understory vegetation, grasses, and ferns), and extremely low-hanging vegetation. Bump et al. (1947) noted that ruffed grouse chicks are apparently attracted to arthropods by movement, and only rarely turn up leaves or litter or scratch for insects and larvae. Accordingly, only the insects on the ground, ground vegetation, and low-hanging vegetation were sampled.

Arthropod abundance and biomass can be measured or sampled by many different methods. Because grouse chick’s diets include terrestrial and flying insects (Kimmel and Samuel 1984), I choose a combination of 2 sampling techniques: pitfall trapping and flight interception trapping to estimate insect abundance, biomass, and family richness. Pitfall traps gave an accurate account of the insects available to the ruffed grouse chicks on the ground; flight interception traps gave an accurate account of the insects available in the low strata of vegetation. When properly installed, pitfall traps and flight interception traps were affected only by extreme environmental conditions (e.g. infrequent flooding with extreme amounts of rainfall and high winds, respectively).

I sampled arthropods 5 times weekly from 25 May-5 July 1998 in each representative cover type to obtain estimates of abundance and biomass. Six main cover types were delineated from Westvaco FRIS™ stand maps for both study areas: 1) Open cutovers < 2 years old; 2) Mesic-Alleghany hardwood regeneration 2-5 years old; 3) Mesic-Alleghany hardwood regeneration 6-15 years; 4) Mesic-Alleghany hardwoods 55-

85 years old; 5) Upland Hardwoods 55–85 years, and 6) Non-forested Roads. Trapping transects and point locations were determined as follows: (1) I randomly selected stand numbers that corresponded to respective cover types, and these stands then became the areas in which transects were established to sample; (2) Established GPS telemetry stations along roads that ran through the respective cover types were randomly selected to use as starting points; and (3) I randomly chose the initial distance from starting points to be 25 m, and that distance was kept constant between sampling points. In each cover type, 3 replicate transects were established, and in each transect, there were 3 trapping stations. At each trapping station, I placed a pitfall near a cover object, a pitfall in the open, and a flight trap near low-hanging vegetation. Traps were placed within 1 m of each other and typically were positioned to form a triangle. In total there were 18 sampling transects (3 replicates within each cover type), 9 trapping stations within each cover type, and a total of 108 pitfalls and 54 flight traps, resulting in 162 total traps.

Pitfall methodology followed Morrill (1975) as modified by McCay et al. (1998). Pitfalls were sunk into the soil so the opening was level with the soil surface. Flight traps (modified after Nijholt and Chapman 1968, Masner and Goulet 1981) were constructed of plexi-glass and composed of 2 intersecting panes (31 x 31 cm) supported by a 7.7 x 31 cm catch basin (Fig. 3-1). I used a 5% formalin solution in pitfalls and in the catch basin of the flight-interception traps to fix and preserve specimens (Southwood 1978, Handley and Kalko 1993, Ford et al. 1994, Handley and Varn 1994). I checked each trap (pitfall and flight) daily to note any differences in insect numbers associated with changing environmental conditions. Insects were removed by filtering them through a sieve made out of standard window screening material. I placed new formalin solution in traps when needed, and when traps were replaced. Samples were then frozen until they could be processed. I identified all arthropods to the lowest taxonomic classification possible (i.e., class, order or family). All samples were dried in a drying oven for 24 hr at 80º C and weighed to the nearest 0.0001 g. Samples were pooled within cover types, and differences in abundance, biomass, and family richness were determined among types. A sample was defined as the total number of traps within a cover type.

Data were separated among sampling transects and trapping stations within cover types to provide information on differences in abundance and biomass among the different trap types (cover-based pitfall vs. open-based pitfall vs. flight trap), as well as information on combined trapping effort of all traps within and among cover types. Data were also pooled within each cover type and among sampling transects and trapping stations to provide gross estimates of abundance within and among cover types.

Environmental Monitoring

I monitored the temperature in each cover type (excluding non-forested roads) on the study areas using portable data loggers (Hobo, StowAway Temperature, Onset Computer Corporation, Bourne, MA). One data logger was placed in each cover type (6 total) approximately 25 cm above the ground. Data loggers were programmed to collect data hourly, and at the end of the season, data were downloaded using BoxCar software (Onset Computer Corporation, Bourne, MA). I measured daily precipitation reaching the forest floor using rain gauges (Tru-Chek Rain Guages, Albert Lea, MN). Two rain gauges were placed in each cover type (12 total) approximately 30 cm above the ground. In forested areas, one rain gauge was placed under canopy, and one was placed in the open.

STATISTICAL ANALYSIS

Estimating Chick Survival Rates

Ruffed grouse chick survival rates were modeled using a modified version of the Kaplan-Meier survival estimator (Flint et al. 1995) in Krebs Software (Program Survival, 1998: Ecological Methodology). I determined survival for 1998 and 1999 at both sites based on flush counts at 7, 21, and 35 days post-hatch, and for 1999 for both sites based on radiotelemetry data. The original version of the Kaplan-Meier model (Kaplan and Meier 1958) assumes that survival of individual chicks within a brood is independent of their brood mates. Pollock et al. (1989) and Flint et al. (1995) believe that this assumption is unrealistic and often violated. Flint et al. (1995) suggested that violation of this assumption does not bias the survival estimates, but causes variance underestimation. The modified version of the estimator is not biased by a lack of intrabrood independence, and eliminated bias in the variance. For this estimator, chicks (*N*) were the sampling unit for calculating survival estimates.

Because of transmitter attachment problems in 1998, which resulted in small samples, no statistical comparisons of survival between years, sites, or methods were performed. Survival estimates were combined for both years and sites and reported strictly to ascertain when the majority of mortality was occurring. I assumed that all chicks in the brood had independent survival rates. When new radio-equipped chicks were added, they had the same survival function as those tagged previously (Pollock et al. 1989). Although radio-tagging may have some influence on chick survival (Chapter 2), I assumed this influence was minimal.

Arthropod Abundance and Biomass and Environmental Conditions

I used 1-way analysis of variance (ANOVA) to determine differences in arthropod abundance, biomass, and family richness among cover types (Dowdy and Wearden 1985). Arthropod abundance was defined as the number of arthropods/sample. Biomass was defined as grams of arthropods/sample. Abundance, biomass and family richness measures were natural log-transformed to more closely approximate a normal distribution (Sokal and Rohlf 1981). After transformation, data were not significantly skewed from normal (PROC UNIVARIATE). Untransformed means and standard errors are reported. ANOVA was also used to determine differences in precipitation and temperature among cover types. I examined the relation between arthropod abundance and biomass and precipitation and temperature using regression analysis. All analysis was completed using Statistical Analysis Systems (SAS; SAS Institute, 1996: PROC FREQ, PROC REG, PROC UNIVARIATE).

RESULTS

Chick Survival

Ruffed grouse chick survival was <30% for both methods (flush counts and telemetry) on the WERF and <40% on the DRT within the first 5 weeks post-hatch (Table 3-1). The majority of mortality occurred within the first week post-hatch (Table 3-1), and decreased over subsequent weeks (Fig. 3-2). Nine entire brood losses were recorded over 2 years (sites combined). Five entire brood losses were recorded within the first 2 weeks post-hatch (sites combined). Of these, 80% occurred within 48 hours post-hatch. Both flush counts and radio-telemetry estimates revealed that after the first 1–2 weeks, survival increased (Table 3-1). Although flush counts showed a slight decrease from week1-3 to 3–5, the trend towards higher survival remained stable.

Mortality Causes

In 1998, 5 (15.2%) of 33 radio-equipped chicks were killed by predators, 2 (6.0%) died of exposure, and the fates of 26 (78.8%) were unknown (Table 3-3, A-1). Six (23.1%) of 26 transmitters could not be located, either by ground search or by aircraft. It is not known if this was due to transmitter failure, predators removing the chicks and transmitters from the study areas, or problems with terrain blocking the signals from the transmitters. The remaining 20 (76.9%) transmitters were recovered, but there was no evidence of mortality at any of the recovery sites, and it was later determined that these transmitters had fallen off the chicks (Chapter 2). Three (60%) of 5 chicks were killed by unknown avian predators, 2 at the WERF, and 1 at the DRT. The remaining 2 (40%) were killed by mammalian predators, one unknown mammal at the WERF, and one weasel (*Mustela* sp) at the DRT. Of the 2 exposure deaths, one occurred at the WERF, and one occurred at the DRT.

In 1999, I determined that 16 (45.7%) of 35 radio-equipped chicks were killed by predators. Eleven (31.4%) died as a result of problems with the transmitter necklace, 3 (8.6%) failed to leave the point of release and died of exposure, 3 (8.6%) were alive at the end of the study, and 2 (5.7%) transmitters could not be found (Table 3-3). Eight (50%) of 16 chicks were killed by unknown avian predators, 5 at the WERF, and 3 at the DRT. The remaining 8 (50%) of the 16 chicks were killed by mammalian predators, 4 were by unknown mammals on the WERF, one by a canid, one by a weasel, and 2 by unknown mammals on the DRT. Seven (63.6%) of the 11 transmitter-induced deaths occurred at the WERF, 4 (36.3%) at the DRT. All 3 exposure deaths were at the WERF. Two transmitters could not be found, one at the WERF, and 1 at the DRT .

Arthropod Abundance, Biomass, and Family Richness

Non-forested roads produced higher numbers of arthropods than any other cover type except mesic-Allegheny hardwood regeneration 6-15 years ($F_{5, 150}$ = 15.15, P = 0.0001; Table 3-2). Biomass was similar in all cover types, except Allegheny hardwood regeneration 6-15 years which produced significantly more biomass than open-cutovers <2 years old ($F_{5, 150}$ = 3.45, P = 0.006; Table 3-2). Non-forested roads also produced higher family richness of arthropods than any other cover types except mesic-Allegheny hardwood regeneration 6-15 years and mesic-Allegheny hardwood regeneration 2-5 years ($F_{5, 150}$ = 8.65, P = 0.0001; Table 3-2).

Trap Type

I captured 4 classes, 25 orders, and 203 families of arthropods containing >20,000 individuals on the WERF in 1998 (Table A-2). Flight traps caught significantly more insects in open-cutovers <2 years old than both types of pitfalls ($F_{2, 20}$ = 6.84, P = 0.005; Table 3-2). Number of insects caught in either trap type (flight or pitfall) among cover types ($F_{2, 20}$ = 0.14-1.89, $P > 0.05$; Table 3-2) did not differ significantly. There were no significant differences ($F_{2, 20}$ = 0.14-6.84, $P > 0.05$) in mean catch between pitfalls (open vs. cover based) within cover types (Table 3-2). There were also no significant differences ($F_{2, 20}$ = 2.26-47.33, $P > 0.05$) in the amount of biomass caught in pitfalls (open vs. cover based) within cover types (Table 3-2). Flight traps, however, caught significantly less ($F_{2, 20}$ = 12.78-41.48, $P < 0.05$) biomass than the pitfalls in all cover types (Table 3-2) except open-cutovers <2 years old, where there were no differences in biomass caught ($F_{2, 20}$ = 2.26, $P > 0.05$; Table 3-2). Flight traps caught significantly higher numbers of arthropod families in all cover types ($F_{2, 20}$ = 31.59-55.24, $P < 0.05$; Table 3-2).

Temperature and Rainfall

Mean daily temperature for 25 May-5 July 1998 was similar to the 30-year average. Total daily rainfall for the same period was approximately twice as high as the 30-year average (~ 290 mm vs. 138 mm, respectively; http://www.nndc.noaa.gov). Open-cutovers <2 years old had significantly higher mean temperatures than all other cover types, ($\bar{x}$ = 18.3 C , $F_{4, 5,343}$ = 50.28, P = 0.0001; Table 3-4). Mesic-Allegheny regeneration > 2-5 years received the highest amount of average daily rainfall at the forest floor (except for non-forested roads), while upland and mesic-Allegheny hardwoods $\geq$55-85 years received the lowest average daily amounts ($\bar{x}$ = 4.90 mm, 4.71 mm, 3.53 mm, and 3.45 mm, respectively, $F_{4, 14,257}$ = 16.95, P = 0.0001; Table 3-4).

Temperature and Rainfall as Predictors of Arthropod Abundance and Biomass

I found a positive relation between temperature and biomass ($Y = 0.377 + 0.059x$, $F_{1, 143}$ = 7.30, P = 0.008, r^2 = 0.05; Fig. 3-3). I found no significant relation between temperature and arthropod abundance (P = 0.122). Rainfall had a negative impact on both arthropod abundance and biomass ($Y = 109.82 – 57.08x$, $F_{1, 143}$ = 27.58, P = 0.0001, r^2 = 0.16, and $Y = 1.54 - 0.788x$, $F_{1, 143}$ = 12.32, P = 0.0006, r^2 = 0.11; Fig. 3-4, 3-5, respectively).

DISCUSSION

Chick Survival

Grouse chick mortality was highest within 1–2 weeks post-hatch. Similarly, this pattern has been found in other portions of the species’ range (Bump et al. 1947, Rusch et al. 1984). However, the relatively high incidence of entire brood loss within 2-3 days post-hatch found in West Virginia has not been reported in other studies. Moreover, entire brood loss within 2 weeks post-hatch has been reported as uncommon in Alberta (Rusch and Keith 1971). However, Haulton (1999), found a similar survival trend in the central Appalachian region, suggesting that entire brood loss may be a phenomenon particular to this area.

Differences in survival also become evident when comparing survival estimates found in West Virginia to other portions of the grouse range. Survival estimates in West Virginia of 0.17 and 0.35 (WERF and DRT, respectively) 5 weeks post-hatch are higher than reported in Virginia (Haulton 1999). Survival estimates >0.30, however, have been reported from Great Lakes region for ruffed grouse chicks up to 12 weeks post-hatch (Bump et al. 1947, Rusch and Keith 1971, Larson 1998). Reports of higher survival from past studies may be an artifact of the sampling methods. Typically, survival has been estimated from brood observations or flushes of hens. If hens that have experienced complete brood loss are not included in the study because the observer mistakenly believes that those hens never had a brood, survival estimates will be inflated. This may not account for all disparity in survival estimates in different regions of the grouse range, however.

Similar trends between radiotelemetry and flush count estimates suggests that transmitters are having little effect on survival. Hubbard et al. (1999) also reported no differences in survival estimates from flush counts and radiotelemetry for wild turkey poults.

Mortality Causes

The major cause of ruffed grouse chick mortality in West Virginia in 1998 and 1999 was avian and mammalian predation, and incidence of multiple mortality events within the same brood by the same predator (or type of predator) was noted repeatedly. Unfortunately, I was unable to ascertain specific predator identities (beyond avian or mammalian) for most predation events. Larson (1998) experienced similar difficulties in Michigan, as visible signs and remains left by predators are quickly removed through scavenging and insect activity.

The occurrence of a predator taking individuals from a brood, along with the subsequent scattering of the brood, may result in a combination of direct mortality coupled with exposure risk for the rest of the chicks. If the predator stays in the area long enough to keep the hen from brooding her chicks, conditions may result where all chicks die from exposure. I noted relatively few exposure deaths, and this may not be a concern during warm weather, or after an age when chicks can thermoregulate. However, if predation events occur within the first few days post-hatch (as noted above) the result may be entire brood loss. Studies looking at cause specific mortality in other species of precocial or gallinaceous gamebirds have also noted that predation accounts for the majority of mortality (Speake et al. 1985, Peoples et al. 1995, Riley et al. 1998, Hubbard et al. 1999).

Arthropod Abundance, Biomass, and Family Richness

Roads and regeneration areas supported greater arthropod abundance than other cover types, except upland hardwoods $\geq$55-85 years. Although not quantitatively measured, roads and regeneration areas supported a better developed ground cover layer of herbaceous and woody vegetation than other cover types. In contrast, upland hardwoods ≥55-85 years old were less structurally complex, but supported a similar number of arthropods. However, logging roads and skidder trails criss-cross the upland hardwood cover types from prior logging events, and these trails remain in early succession because of heavy deer browsing. This may increase the heterogeneity of upland hardwood stands, and it is likely that the interspersed roads supported enough vegetation and structural diversity to maintain an abundance of insects. Increased structural diversity has been found to correspond with increased numbers of arthropods (Hurst 1972, Nenno and Lindzey 1979, Kimmel and Samuel 1984, Thompson et al. 1987). Arthropods were least abundant in open cutovers <2 years old. Because of their age and browsing pressure, these stands may not have developed the necessary vegetative structure to support high arthropod numbers.

My findings suggest that early successional vegetation found on logging roads and trails within the forest interior are providing the majority of arthropod habitat on the WERF. Similarily, Hollifield and Dimmick (1995) found that non-forested roads in Tennessee produced the highest numbers of arthropods, and recent clearcuts produced lowest numbers. They also found high arthropod numbers in mature forests, and suggested that this results from herbaceous ground cover producing good arthropod habitat. It may be more beneficial for the grouse chicks to forage in these types of areas (e.g. mature forests with herbaceous cover) as opposed to roads, openings, and edges, for these open areas may expose the chicks to higher predation risks. Unfortunately, due to deer browsing, herbaceous cover is virtually non-existent in many areas of the WERF, and the broods are forced to forage in less than ideal conditions.

Biomass was similar in all cover types, except regeneration areas supported more biomass than the most recent cuts. This would tend to reinforce the above finding of reduced arthropod numbers in this cover type. Hollifield and Dimmick (1995) suggested that biomass may actually be more important to ruffed grouse chicks than abundance measures. Although it may be easier for chicks to catch more abundant insects it may not be cost-efficient if those insects are small flies or terrestrial insects that contain little energy or nutrition. This suggests that since biomass did not differ among cover types (except open-cutovers), sufficient biomass may be available in all cover types on the WERF to support grouse chicks. This may be due to non-forested areas outside and within mature forests providing adequate habitat to support higher arthropod numbers and thus higher biomass (Healy 1985, Stauffer and Peterson 1985, Thompson et al. 1987). It may represent the different arthropod communities that inhabit different cover types, and heavier insects may inhabit these areas (non-forested or early successional areas) compared to the forest interior, providing increased biomass (Hollifield and Dimmick 1995).

Family richness was greatest in roads and mesic-Allegheny regeneration 2-15 years old. Ruffed grouse chicks feed on certain taxa of arthropods over others (Kimmel and Samuel 1978, 1984). However, it is not known whether increases in family richness would result in a shift in brood foraging. Possible benefits of increased richness may include a greater opportunity to feed on higher quality forage (e.g., insects with higher protein, calcium, and nutrient content). If little variety in families is available to grouse chicks they would be forced to forage on what is available, possibly uptaking less nutrition, or be forced to move to other areas to forage, and possibly subjecting them to higher predation risks and energy expenditures.

Trap Type

There were no differences in abundance, biomass or family richness between open-and cover-based pitfalls among cover types, suggesting that perhaps only one pitfall is needed at each trapping station. Additionally, this suggests that acceptable efficacy can be obtained without the use of drift fences or the need to place pitfalls near cover. This decreases the amount of time and effort spent collecting data, while still providing an accurate assessment of relative arthropod abundance, biomass, and family richness in each cover type. Flight traps also caught similar numbers of insects as the pitfalls, however, flight traps caught more insects in open-cutovers <2 years old. Flight traps also caught significantly less biomass than pitfalls in all cover types except open-cutovers <2 years old. In contrast to pitfalls, flight traps captured the flying component of the insect population, specifically small flying insects (e.g. dipterans). These flying insects usually weigh less than terrestrial ones (e.g. carabids) because they are typically smaller and have a much lower content of chitin in their exoskeleton (Stiven 1961). Flight traps also caught higher numbers of families than pitfalls in all cover types. This may be a reflection of the great diversity in flying insects on the study site (Tom Allen, West Virginia Division of Natural Resources, pers. comm.). These results suggest that, in order to adequately sample the insect population that is available for ruffed grouse chicks, it is important to sample with both pitfalls and flight traps. Cooper and Whitmore (1990) also suggested that it was important to use multiple collection methods in order to adequately sample insect populations to assess arthropod availability.

Temperature and Rainfall

Open-cutovers maintained the highest average temperature among cover types. This cover type has limited vegetation during the first year to provide grouse chicks cover or relief from high temperatures. Combined with lower arthropod availability, this would suggest that these areas are poor grouse brood habitat. Moreover, this type provides little protection from predators. Although there was not a significant relation found between temperature and abundance, Taylor (1963) noted that there may be a maximum temperature at which flight and activity is inhibited in arthropods. Factors such as vegetative species and structure, which were not quantitatively measured, may account for more variation, and may in fact be a better predictor than rainfall and temperature of arthropod abundance and biomass (Hurst 1972, Porath and Vohs 1972, Thompson et al. 1987, Scott et al. 1998).

Mesic-Allegheny regeneration 2-5 years old and non-forested roads received the highest amount of average rainfall reaching the forest floor, while mature hardwoods received the lowest. This rainfall encourages vegetative growth, and subsequent increases in the structural diversity of herbaceous and woody plants increases arthropod numbers (Grace 1942, Hurst 1972, Kimmel and Samuel 1984, Thompson et al. 1987). Although roads and young regeneration areas also had the highest numbers of arthropods, I found a negative relation with arthropod abundance and rainfall. However, since ground level evapo-transpiration is also higher in these areas, rainfall effects may be minimized, and increased light penetration may compensate. Additionally, there was a negative relationship between increasing rainfall and abundance and biomass in all cover types, however, due to the inherent variability in the arthropod measures, these environmental measures provided poor predictive value. Some rainfall is needed to provide vegetative growth and structure for increased arthropod abundance and biomass, however, too much rainfall may have a negative impact on arthropod measures by killing them or keeping them in hiding (Bump et al. 1947, Southwood and Cross 1969).

MANAGEMENT IMPLICATIONS

My findings suggest that predation may be the most important factor influencing ruffed grouse chick survival in West Virginia on the WERF and DRT. Both mammalian and avian predators accounted for an approximately equal amount of this predation. It would be very difficult to manage to decrease avian predators, however, efforts could be made to decrease efficiency of these species. Increases in stem densities through advanced regeneration (clearcutting practices in concurrence with deer herd decreases) can increase cover for grouse chicks and make it more difficult for predators to fly through the understory. Efforts could also be made to decrease mammalian risks. Meso-mammal population levels may be reduced through such habitat manipulation as creating feathered instead of hard edges and removing den trees (Pedlar et al. 1997). Fragmentation brought about by clearcut plots of different ages can provide this habitat and edge.

Trapping furbearers has provided an excellent management method to help complement habitat management in the past, however, as I mentioned in Chapter 1, trapping has decreased dramatically over the past decade (Peoples et al. 1995). Fies (1999) reported that removing predators has been successful in a bobwhite quail nest depredation experiment, and it may be feasible to extend this type of removal to predators of grouse chicks on a small scale.

Differences in the abundance of arthropods, the biomass, and the family richness in each cover type would suggest that management for roads and openings would enhance arthropod availability. Hollifield and Dimmick (1995) suggested that arthropod measures can be further improved by planting roads and openings to clover (*Trifolium* spp.) and orchardgrass (*Dactylis glomerata*). The most successful management plan for ruffed grouse broods on the WERF would be to provide openings and daylight exsisting roads near areas of cover, such as regeneration and some mature forests. This would provide a combination of increased forage and cover. Gullion (1977) recommended providing an interspersion of young, dense stands of <10-year-old saplings for brood use, combined with 10-25-year-old stands for breeding cover, and areas containing 25-40-year-old areas for foraging. He believed if these areas were provided in ≤4 ha plots interspersed among the aforementioned cover types, grouse could be maintained. Under similar management practices in Pennsylvania, Scott et al. (1998) suggested that increased use of these areas by grouse broods was due to increased vegetative diversity. On the WERF, management practices of this type would have to be implemented in concurrence with a decrease in the deer herd. Overbrowsing by deer has decreased vegetative structure for arthropods, and decreased escape cover for grouse (Tilghman 1989). The effects of browsing may decrease habitat quality for grouse, increase brood movements to find adequate resources, and result in increased predation risks for adults and young.

Table 3-1. Survival (*S*) of ruffed grouse chicks calculated from flush counts and radiotelemetry data on the Westvaco Ecosystem Research Forest (WERF) in Randolph County, West Virginia and the Westvaco Dutch Run Tract (DRT) in Greenbrier County, West Virginia in 1998 and 1999.

	Flush count									Radiotelemetry								
		WERF				DRT					WERF				DRT			
Year	Interval[a]	*S*	SE	*N*[b]	*n*[c]	*S*	SE	*N*[b]	*n*[c]	Interval[d]	*S*	SE	*N*[b]	*n*[c]	*S*	SE	*N*[b]	*n*[c]
1998[d]	H[e] - 1	0.433	0.064	60	5	0.633	0.088	30	4	H - 1								
	1 - 3	0.615	0.095	26	5	0.789	0.094	19	4	1 - 2								
	3 - 5	0.438	0.124	16	5	0.800	0.103	15	4	2 - 3								
	H - 5	0.117	0.041	60	5	0.400	0.089	30	4	H - 3								
1999[f]	H - 1	0.216	0.048	74	7					H - 1	0.500	0.158	10	6	0.546	0.150	11	4
	1 - 3	0.813	0.098	16	5					1 - 2	0.600	0.219	5	5	0.667	0.192	6	3
	3 - 5	0.692	0.128	13	4					2 - 3	0.667	0.272	3	4	1.000	0.000	4	2
	H - 5	0.168	0.095	107	7	0.349	0.073	43	5	H - 3	0.100	0.095	10	6	0.364	0.145	11	4
Years pooled	H - 1	0.313	0.040	134	12	0.633	0.088	30	4	H - 1	0.500	0.158	10	6	0.546	0.150	11	4
	1 - 3	0.690	0.071	42	10	0.789	0.094	19	4	1 - 2	0.600	0.219	5	5	0.667	0.192	6	3
	3 - 5	0.552	0.092	29	9	0.800	0.103	15	4	2 - 3	0.667	0.272	3	4	1.000	0.000	4	2
	H - 5	0.150	0.028	167	12	0.370	0.057	73	9	H - 3	0.100	0.095	10	6	0.364	0.145	11	4

[a] Interval in weeks

[b] Total number of ruffed grouse chicks used for survival analysis

[c] Total number of ruffed grouse broods

[d] Survival estimates not recorded in 1998 due to radio-transmitter retention problems

[e] Hatch

[f] Flush counts not performed for 7 and 21 days post-hatch on the DRT

Table 3-2. Comparison of mean ($\bar{x}$) arthropod abundance, biomass, and family richness among 6 cover types and 3 trap types at the Westvaco Ecosystem Research Forest (WERF) in Randolph County, West Virginia, 1998.

			Cover type[a]											
			AR25		MA5585		MAR615		NFR		OC2		UH5585	
Measure	Trap[b] type	**n**	$\bar{x}$ [cde]	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE
Arthropod abundance	F	9	122.22Aa	12.56	119.33Aa	10.30	180.78Aa	22.61	197.22Aa	67.57	102.67Aa	9.62	158.56Aa	12.58
	C	9	105.00Aa	12.56	106.67Aa	10.30	157.44Aa	22.61	259.89Aa	67.57	60.78Bb	9.62	118.67Aa	12.58
	O	9	94.00Aa	12.56	109.22Aa	10.30	137.78Aa	22.61	165.89Aa	67.57	52.56Bb	9.62	128.44Aa	12.58
	COM	27	107.07C	18.10	111.74C	18.1	158.67AB	18.10	207.67A	18.10	72.00D	18.10	135.22BC	18.10
Arthropod biomass	F	9	0.59Aa	0.28	0.40Aa	0.27	0.71Aa	0.35	0.69Aa	0.27	0.59Aa	0.21	0.48Aa	0.43
	C	9	1.89ABb	0.28	1.79ABb	0.27	2.78Ab	0.35	2.16ABb	0.27	1.06Ba	0.21	2.71ABb	0.43
	O	9	1.98Ab	0.28	2.44Ab	0.27	2.83Ab	0.35	2.29Ab	0.27	1.17Ba	0.21	3.31Ab	0.43
	COM	27	1.49AB	0.23	1.54AB	0.23	2.11A	0.23	1.71AB	0.23	0.97B	0.23	2.16AB	0.23
Family richness	F	9	39.00Aa	2.02	29.89Aa	1.57	40.33Aa	2.44	43.00Aa	2.01	34.00Aa	2.02	37.67Aa	1.83
	C	9	14.67ABb	2.02	12.33ABb	1.57	16.44ABb	2.44	17.67Ab	2.01	11.56Bb	2.02	14.56ABb	1.83
	O	9	15.67ABb	2.02	10.89Bb	1.57	15.56ABb	2.44	18.78Ab	2.01	10.89Bb	2.02	12.56Bb	1.83
	COM	27	23.11AB	1.25	17.70C	1.25	24.11AB	1.25	26.48A	1.25	18.81C	1.25	21.59BC	1.25

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[a] OC2 = Open cutovers <2 years old; AR25 = Mesic-Alleghany hardwood regeneration 2-5 years old; MAR615 = Mesic-Alleghany hardwood regeneration 6-15 years old; MA5585 = Mesic-Alleghany hardwoods 55-85 years old; UH5585 = Upland hardwoods 55-85 years old; NFR = Non-forested roads

[b] F = flight-interception trap; C = pitfall trap near some cover object (e.g., stump, log); O = pitfall trap in the open (not near cover object); COM = traps combined

[c] Means reported untransformed.

[d] Means with different capital letters across rows differ as determined through Student-Newman-Keuls' Test ($P < 0.05$).

[e] Means with different lower case letters within columns and within abundance, biomass, and family richness measures differ among separated trap types (F, C, O) as determined through Student-Newman-Keuls' Test ($P < 0.05$)

Table 3-3. Fates of transmittered ruffed grouse chicks on the Westvaco Ecosystem Research Forest (WERF) in Randolph County, West Virginia and the Westvaco Dutch Run Tract (DRT) in Greenbrier County, West Virginia, 1998 and 1999, sites and years combined.

	n	% of chicks marked	% of known death
Total chicks radioed	68		
Total known lost	37	54.4	
Cause of death			
Predation	21	30.8	56.7
Avian predation	11	16.2	29.7
Unknown avian	10	14.7	27
Unknown owl	1	1.5	2.7
Mammalian predation	10	14.7	27.0
Weasel	2	2.9	5.4
Unknown canid sp	1	1.5	2.7
Unknown mammal	7	10.3	18.9
Transmitter induced	11	16.2	29.7
Other*	5	7.3	13.5
Censored	28	41.2	
Known to have survived 35 days post hatch	3	4.4	

* Exposure, starvation, disease, etc.

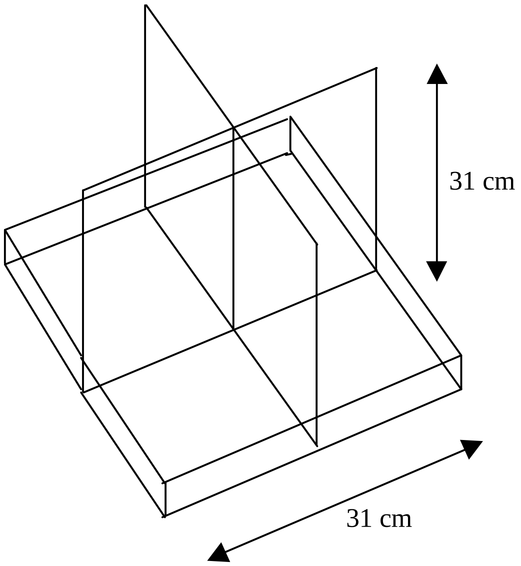
Table 3-4. Mean ($\bar{x}$) daily temperature and rainfall (mm) among cover types from 25 May to 5 July 1998 on the Westvaco Ecosystem Research Forest (WERF) in Randolph County, West Virginia.

	Temperature			Rainfall		
Cover type[a]	$\bar{x}$ [b]	SE	*n*	$\bar{x}$	SE	*n*
OC2	18.3a	0.163	1072	4.24b	0.18	1546
AR25	16.2cd	0.163	1080	4.90a	0.15	2184
MAR615	17.3b	0.163	1080	4.40b	0.13	3111
MA5585	16.1d	0.163	1080	3.45c	0.15	2158
UH5585	16.6c	0.163	1080	3.53c	0.14	2613
NFR				4.71ab	0.13	2919

[a] OC2 = Open cutovers <2 years old; AR25 = Mesic-Alleghany hardwood regeneration 2-5 years old; MAR615 = Mesic-Alleghany hardwood regeneration 6-15 years old; MA5585 = Mesic-Alleghany hardwoods 55-85 years old; UH5585 = Upland hardwoods 55-85 years old; NFR = Non-forested roads

[b] Means with different letters in columns differ as determined through Student-Newman-Keuls' Test ($P < 0.05$).

Flight-interception trap with no rain-guard



Flight-interception trap with rain-guard top

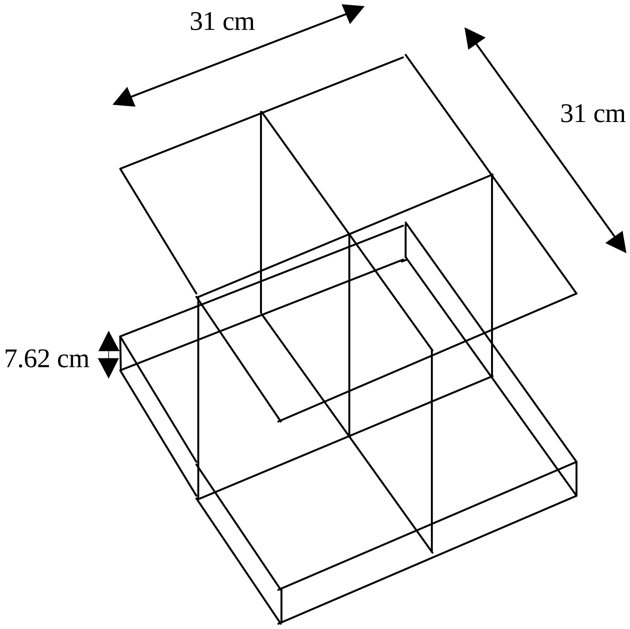


Fig. 3-1. Flight-interception trap used in arthropod sampling on the Westvaco Ecosystem Research Forest (WERF) in Randolph County, West Virginia in 1998.

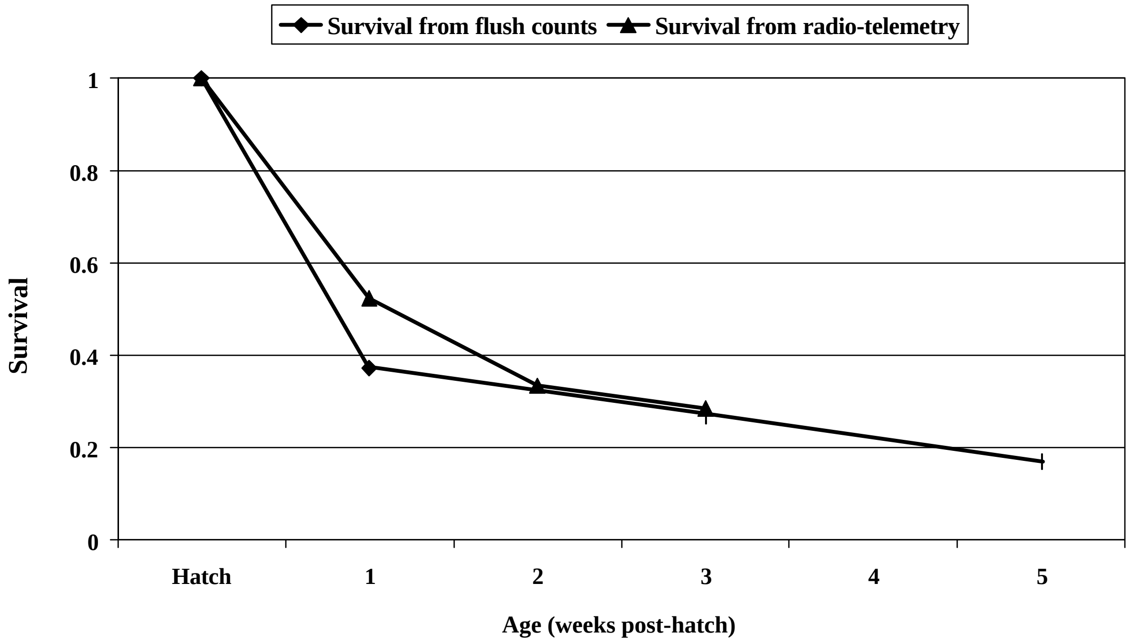


Fig. 3-2. Survival of ruffed grouse chicks in West Virginia, 1998-99, years and sites pooled.

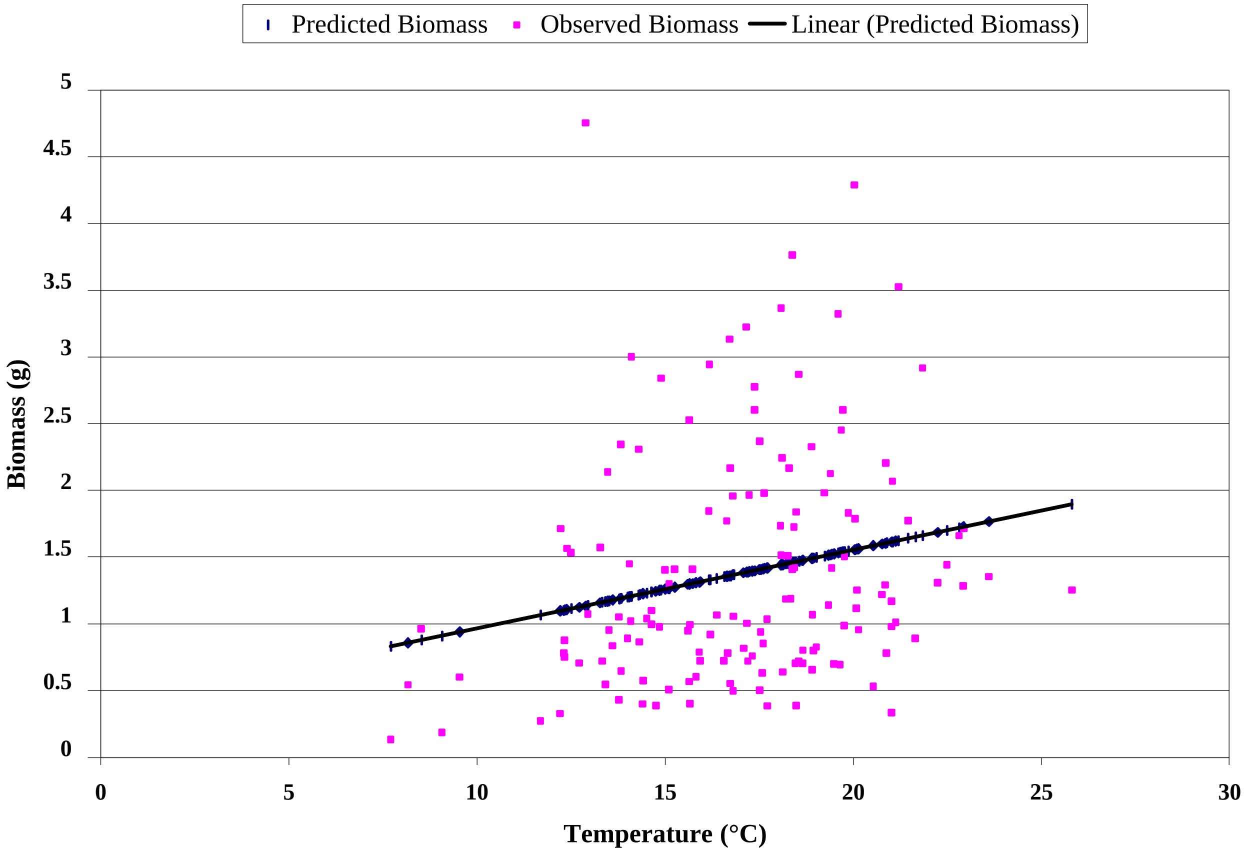


Fig. 3-3. Relation of temperature (°C) and arthropod biomass at the Westvaco Ecosystem Research Forest (WERF) in Randolph County, West Virginia, 1998.

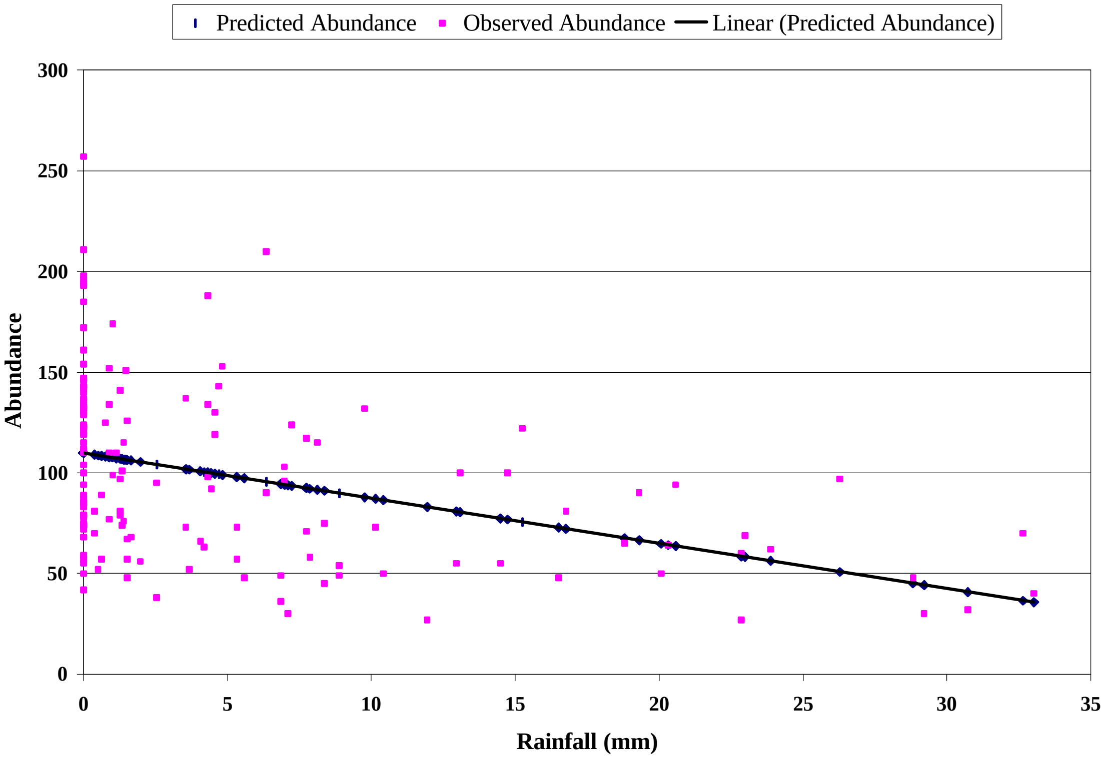


Fig. 3-4. Relation of rainfall (mm) and arthropod abundance at the Westvaco Ecosystem Research Forest (WERF) in Randolph County, West Virginia, 1998.

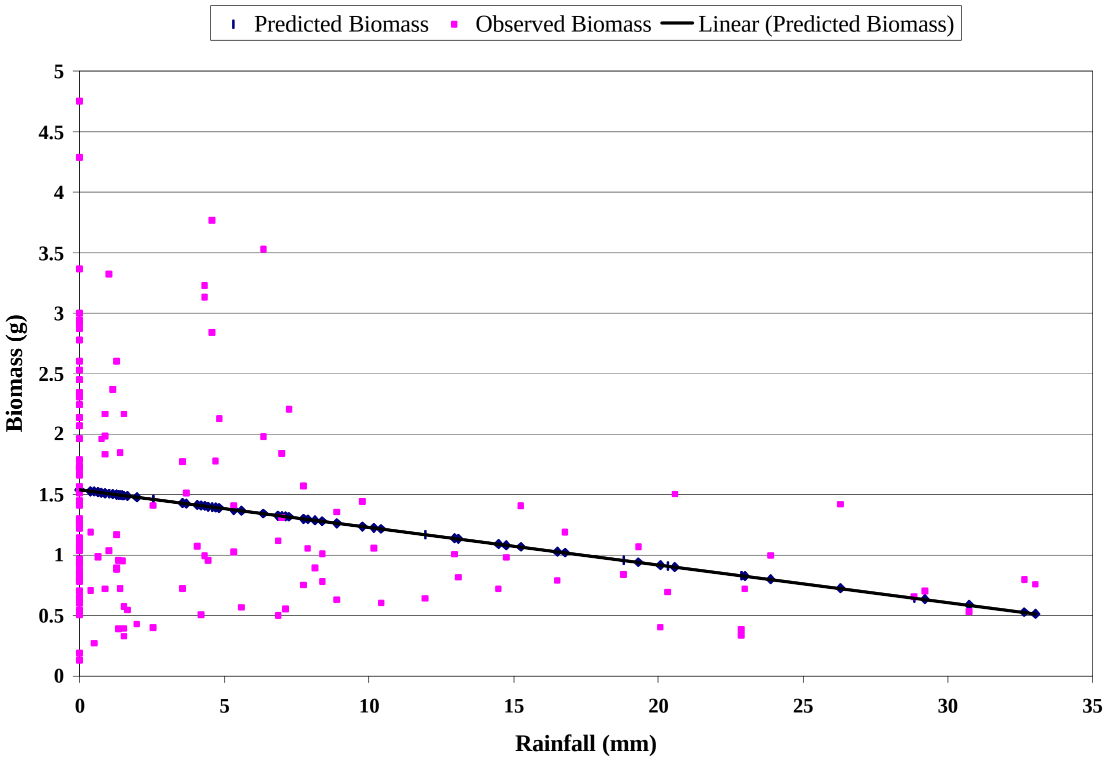


Fig. 3-5. Relation of rainfall (mm) and arthropod biomass at the Westvaco Ecosystem Research Forest (WERF) in Randolph County, West Virginia, 1998.

APPENDIX

Table A-1. General information gathered for ruffed grouse chicks and radio transmitter attachment methods on the Westvaco Ecosystem Research Forest (WERF), Randolph County, West Virginia and the Westvaco Dutch Run Tract (DRT), Greenbrier County, West Virginia in 1998 and 1999.

Year	Id	Mass[a]	Age[b]	Attachment Method	Retention Time[c]	Fate
1998	WERF1	13.6	36-48	Glue-on	9	UNK
1998	WERF2	13.4	36-48	Glue-on		Exposure
1998	WERF3	14.2	36-48	Glue-on	7	UNK
1998	WERF4	13.4	36-48	Glue-on		Lost Contact
1998	WERF5	12.6	24-36	Glue-on	5	UNK
1998	WERF6	11.8	24-36	Glue-on		Avian
1998	WERF7	11.5	24-36	Glue-on	6	UNK
1998	WERF8	12.2	24-36	Glue-on	4	UNK
1998	WERF9	12.8	24-36	Glue-on		Mammalian
1998	WERF10	11.4	24-36	Glue-on		Avian
1998	WERF11	11.7	24-36	Glue-on	7	UNK
1998	WERF12	11.7	24-36	Glue-on	5	UNK
1998	WERF13	11.8	24-36	Glue-on	2	UNK
1998	WERF14	12.5	24-36	Glue-on	12	UNK
1998	WERF15	9.9	24-36	Glue-on	5	UNK
1998	WERF16	12.2	24-36	Glue-on	5	UNK
1998	WERF17	12.6	24-36	Glue-on	3	UNK
1998	WERF18	13.0	24-36	Glue-on		Lost Contact
1998	WERF19	11.5	24-36	Glue-on	5	UNK
1998	WERF20	11.9	24-36	Glue-on	8	UNK
1998	DRT1	11.8	24-36	Glue-on		Exposure
1998	DRT2	11.6	24-36	Glue-on		UNK
1998	DRT3	11.4	24-36	Glue-on		Lost Contact
1998	DRT4	11.3	24-36	Glue-on		Lost Contact
1998	DRT5	14.2	36-48	Glue-on		UNK
1998	DRT6	13.3	36-48	Glue-on		UNK
1998	DRT7	13.8	36-48	Glue-on		Mammalian
1998	DRT8	13.6	36-48	Glue-on		Lost Contact
1998	DRT9	14.0	36-48	Glue-on		UNK
1998	DRT10	12.4	24-36	Glue-on		Avian
1998	DRT11	11.3	24-36	Glue-on		UNK
1998	DRT12	10.2	24-36	Glue-on		Lost Contact
1998	DRT13	12.4	24-36	Glue-on		UNK
1999	WERF1	12.6	48-60	Collar		Exposure
1999	WERF2	12.8	48-60	Collar		Mammalian
1999	WERF3	12.3	48-60	Collar		Mammalian
1999	WERF4	12.1	48-60	Collar		Transmitter
1999	WERF5	13.5	48-60	Collar		Avian
1999	WERF6	12.3	48-60	Collar		Avian

Table A-1. (continued)

Year	Id	Mass[a]	Age[b]	Attachment Method	Retention Time[c]	Fate
1999	WERF7	13.0	48-60	Collar		Transmitter
1999	WERF8	15.1	60-72	Collar		Avian
1999	WERF9	14.5	60-72	Collar		Avian
1999	WERF10	15.7	60-72	Collar		Transmitter
1999	WERF11	12.1	48-60	Collar		Exposure
1999	WERF12	12.4	48-60	Collar		Mammalian
1999	WERF13	13.5	48-60	Collar		Lost Contact
1999	WERF14	12.5	48-60	Collar		Transmitter
1999	WERF15	14.3	48-60	Collar		Exposure
1999	WERF16	13.1	48-60	Collar		Transmitter
1999	WERF17	12.8	60-72	Collar		Avian
1999	WERF18	12.4	60-72	Collar		Mammalian
1999	WERF19	13.0	60-72	Collar		Transmitter
1999	WERF20	14.9	60-72	Collar		Transmitter
1999	DRT1	11.8	48-60	Collar		Mammalian
1999	DRT2	11.8	48-60	Collar		Mammalian
1999	DRT3	11.7	48-60	Collar		Avian
1999	DRT4	11.4	48-60	Collar		Avian
1999	DRT5	14.2	48-60	Collar		Avian
1999	DRT6	13.7	48-60	Collar		Transmitter
1999	DRT7	12.3	48-60	Collar		Alive
1999	DRT8	12.6	48-60	Collar		Alive
1999	DRT9	12.9	48-60	Collar		Transmitter
1999	DRT10	12.8	48-60	Collar		Transmitter
1999	DRT11	12.4	48-60	Collar		Alive
1999	DRT12	12.2	48-60	Collar		Mammalian
1999	DRT13	12.8	48-60	Collar		Lost Contact
1999	DRT14	12.7	48-60	Collar		Mammalian
1999	DRT15	13.0	48-60	Collar		Transmitter

[a] Weight in grams

[b] Age in hours

[c] Retention in days; missing values in 1998 indicate either death or unknown fate and missing values 1999 reflect that transmitters stayed on until death of the individual or the end of the study

[d] Age in days

Table A-2. Results of arthropod sampling on the Westvaco Ecosystem Research Forest (WERF) in Randolph County, West Virginia in 1998.

Class	Order	Family
Chilopoda		
Diplopoda		
Isopoda		
Insecta		
	Acari	
	Araneae	
	Blattaria	Blattellidae
		Cryptocercidae
	Chalcidoidea	
	Coccoidea	
	Coleoptera	Alleculidae
		Anobiidae
		Anthicidae
		Anthribidae
		Artematopidae
		Buprestidae
		Byrrhidae
		Byturidae
		Cantharidae
		Carabidae
		Cephaloidae
		Cerambycidae
		Chrysomelidae
		Cicindelidae
		Cleridae
		Coccinellidae
		Colydiidae
		Corylophidae
		Cryptophagidae
		Cucujidae
		Curculionidae
		Dascillidae
		Dytiscidae
		Elateridae
		Endomychidae
		Erotylidae
		Eucinetidae
		Eucnemidae
		Euglenidae
		Helodidae
		Heteroceridae
		Histeridae
		Hyrophilidae
		Lagriidae

Table A-2. (continued)

Class	Order	Family
Insecta	Coleoptera	Lampyridae
		Lathridiidae
		Leiodidae
		Lucanidae
		Lycidae
		Melandryiidae
		Meloidae
		Mordellidae
		Mycetophagidae
		Nitidulidae
		Oedemeridae
		Phalacridae
		Pselaphidae
		Ptilidae
		Ptilodactylidae
		Pyrochoridae
		Rhipiphoridae
		Salpingidae
		Scarabaeidae
		Scolytidae
		Scydmaenidae
		Silphidae
		Staphylinidae
		Tenebrionidae
		Throscidae
	Collembola	Hypogastruridae
		Isotomidae
		Poduridae
		Sminthuridae
	Dermaptera	Forficulidae
	Diptera	Agromyzidae
		Anthomyiidae
		Asilidae
		Athericidae
		Bibionidae
		Calliphoridae
		Cecidomyiidae
		Certopogonidae
		Chaoboridae
		Chironomidae
		Chloropidae
		Clusiidae
		Conopidae
		Dolichopodidae
		Drosophilidae

Table A-2. (continued)

Class	Order	Family
Insecta	Diptera	Empididae
		Ephydridae
		Heleomyzidae
		Lauxaniidae
		Lonchopteridae
		Milichiidae
		Muscidae
		Mycetophilidae
		Otididae
		Periscelididae
		Phoridae
		Piophilidae
		Pipunculidae
		Platypezidae
		Psychodidae
		Rhagionidae
		Sarcophagidae
		Scatophagidae
		Scatopsidae
		Sciaridae
		Sciomyzidae
		Sepsidae
		Sphaeroceridae
		Straiomyidae
		Syrphidae
		Tabanidae
		Tachinidae
		Tephritidae
		Tipulidae
		Xylomyidae
		Xylophagidae
	Hemiptera	Anthocoridae
		Berytidae
		Coreidae
		Cydnidae
		Dipsocoridae
		Lygaeidae
		Miridae
		Nabidae
		Pentatomidae
		Reduviidae
		Rhopalidae
		Saldidae
		Thyreocoridae
		Tingidae

Table A-2. (continued)

Class	Order	Family
Insecta	Homoptera	Adelgidae
		Aphididae
		Cercopidae
		Cicadellidae
		Cixiidae
		Delphacidae
		Derbidae
		Diaspididae
		Eriosomatidae
		Membracidae
		Phylloxeridae
		Psyllidae
		Andrenidae
		Anthophoridae
		Apidae
		Aulacidae
		Bethylidae
		Braconidae
		Ceraphronidae
		Chalcididae
		Colletidae
		Cynipidae
		Diapriidae
		Dryinidae
		Encyrtidae
		Eulophidae
		Eumenidae
		Eupelmidae
		Formicidae
		Halictidae
		Ichneumonidae
		Megachilidae
		Megaspilidae
		Mutillidae
		Mymaridae
		Platygasteridae
		Pompilidae
		Proctotrupidae
		Pteromalidae
		Roproniidae
		Scelionidae
		Sphecidae
		Tenthredinidae
		Tiphiidae
		Trigonalidae

Table A-2. (continued)

Class	Order	Family
	Hymenoptera	Vespidae
	Lepidoptera	Gelechidae
		Geometridae
		Hesperiidae
		Noctuiidae
		Notodontidae
		Pyralidae
		Totricidae
	Mecoptera	Bittacidae
		Panorpidae
		Panorpodidae
	Microcoryphia	Machilidae
	Neuroptera	Chrysopidae
		Coniopterygidae
	Odonata	Agriidae
	Orthoptera	Acrididae
		Gryllacrididae
		Gryllidae
		Tetrigidae
		Tettigoniidae
	Phalangida	Phalangidae
	Plecoptera	Leuctridae
		Nemouridae
		Peltoperlidae
		Perlodidae
	Pseudoscorpiones	
	Psocoptera	Liposcelidae
		Mesopsocidae
		Psocidae
	Siphonaptera	Ceratophyllidae
		Pulicidae
	Thysanoptera	Aeolothripidae
	Trichoptera	Hydropsychidae

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